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APPLICATION NO.	ISSUE DATE	PATENT NO.	ATTORNEY DOCKET NO.	CONFIRMATION NO.
12/910,779	02/12/2013	8373591		8875

23497 7590 01/23/2013

JED MARGOLIN
1981 EMPIRE ROAD
RENO, NV 89521-7430

ISSUE NOTIFICATION

The projected patent number and issue date are specified above.

Determination of Patent Term Adjustment under 35 U.S.C. 154 (b)
(application filed on or after May 29, 2000)

The Patent Term Adjustment is 243 day(s). Any patent to issue from the above-identified application will include an indication of the adjustment on the front page.

If a Continued Prosecution Application (CPA) was filed in the above-identified application, the filing date that determines Patent Term Adjustment is the filing date of the most recent CPA.

Applicant will be able to obtain more detailed information by accessing the Patent Application Information Retrieval (PAIR) WEB site (http://pair.uspto.gov).

Any questions regarding the Patent Term Extension or Adjustment determination should be directed to the Office of Patent Legal Administration at (571)-272-7702. Questions relating to issue and publication fee payments should be directed to the Application Assistance Unit (AAU) of the Office of Data Management (ODM) at (571)-272-4200.

APPLICANT(s) (Please see PAIR WEB site http://pair.uspto.gov for additional applicants):

Jed Margolin, VC Highlands, NV;

Substitute for form 1449/PTO

INFORMATION DISCLOSURE STATEMENT BY APPLICANT

(Use as many sheets as necessary)

Sheet 1 of 4

Complete if Known	
Application Number	
Filing Date	
First Named Inventor	Jed Margolin
Art Unit	
Examiner Name	
Attorney Docket Number	

Change(s) applied to document, /G.R.P./ 1/5/2013

U. S. PATENT DOCUMENTS

Examiner Initials*	Cite No.[1]	Document Number Number-Kind Code[2] (if known)	Publication Date MM-DD-YYYY	Name of Patentee or Applicant of Cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear
	3	US- 4,782,450	11-01-1998	Flax	Abstract
	5	US- 5,153,836	10-06-1992	Fraughton, et al.	Abstract
	7	US- 5,187,485	02-16-1993	Tsui, et al.	
	9	US- 5,724,041	03-03-1998	Inoue, et al.	Abstract
	11	US- 4,195,293	03-25-1980	Margolin	
	12	US- 3,986,168	10 ~~12~~-12-1976	Anderson	
	13	US- 3,515,805	06-02-1970	Fracassi et al.	
	25	US- 6,377,436 B1	05-23-2002	Margolin	
		US- 7,737,878	06-15-2008	va Tooren, et al.	
		US- 5,036,330	07-30-1991	Imae, et al.	
		US- 5,955,993	09-21-1999	Houghton, et al.	
		US- 6,031,485	02-29-2000	Cellai, et al.	
		US-			
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		US-			
		US-			
		US-			
		US-			

FOREIGN PATENT DOCUMENTS

Examiner Initials*	Cite No.[1]	Foreign Patent Document Country Code[3]-Number[4]-Kind Code[5] (if known)	Publication Date MM-DD-YYYY	Name of Patentee or Applicant of Cited Document	Pages, Columns, Lines, Where Relevant Passages Or Relevant Figures Appear	T[6]

Examiner Signature		Date Considered	

*EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP 609. Draw line through citation if not in conformance and not considered. Include copy of this form with next communication to applicant. [1] Applicant's unique citation designation number (optional). [2] See Kinds Codes of USPTO Patent Documents at www.uspto.gov or MPEP 901.04. [3] Enter Office that issued the document, by the two-letter code (WIPO Standard ST.3). [4] For Japanese patent documents, the indication of the year of the reign of the Emperor must precede the serial number of the patent document. [5] Kind of document by the appropriate symbols as indicated on the document under WIPO Standard ST.16 if possible. [6] Applicant is to place a check mark here if English language Translation is attached.

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /M.B./

PART B - FEE(S) TRANSMITTAL

Complete and send this form, together with applicable fee(s), to: Mail **Mail Stop ISSUE FEE**
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Alexandria, Virginia 22313-1450
or Fax (571)-273-2885

INSTRUCTIONS: This form should be used for transmitting the ISSUE FEE and PUBLICATION FEE (if required). Blocks 1 through 5 should be completed where appropriate. All further correspondence including the Patent, advance orders and notification of maintenance fees will be mailed to the current correspondence address as indicated unless corrected below or directed otherwise in Block 1, by (a) specifying a new correspondence address; and/or (b) indicating a separate "FEE ADDRESS" for maintenance fee notifications.

CURRENT CORRESPONDENCE ADDRESS (Note: Use Block 1 for any change of address)

23497 7590 12/21/2012

JED MARGOLIN
1981 EMPIRE ROAD
RENO, NV 89521-7430

Note: A certificate of mailing can only be used for domestic mailings of the Fee(s) Transmittal. This certificate cannot be used for any other accompanying papers. Each additional paper, such as an assignment or formal drawing, must have its own certificate of mailing or transmission.

Certificate of Mailing or Transmission

I hereby certify that this Fee(s) Transmittal is being deposited with the United States Postal Service with sufficient postage for first class mail in an envelope addressed to the Mail Stop ISSUE FEE address above, or being facsimile transmitted to the USPTO (571) 273-2885, on the date indicated below.

(Depositor's name)
(Signature)
(Date)

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
12/910,779	10/22/2010	Jed Margolin		8875

TITLE OF INVENTION: SYSTEM FOR SENSING AIRCRAFT AND OTHER OBJECTS

APPLN. TYPE	SMALL ENTITY	ISSUE FEE DUE	PUBLICATION FEE DUE	PREV. PAID ISSUE FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	YES	$885	$300	$0	$1185	03/21/2013

EXAMINER	ART UNIT	CLASS-SUBCLASS
BARKER, MATTHEW M	3646	342-030000

1. Change of correspondence address or indication of "Fee Address" (37 CFR 1.363).

☐ Change of correspondence address (or Change of Correspondence Address form PTO/SB/122) attached.

☐ "Fee Address" indication (or "Fee Address" Indication form PTO/SB/47; Rev 03-02 or more recent) attached. **Use of a Customer Number is required.**

2. For printing on the patent front page, list

(1) the names of up to 3 registered patent attorneys or agents OR, alternatively, 1

(2) the name of a single firm (having as a member a registered attorney or agent) and the names of up to 2 registered patent attorneys or agents. If no name is listed, no name will be printed. 2 ______ 3 ______

3. ASSIGNEE NAME AND RESIDENCE DATA TO BE PRINTED ON THE PATENT (print or type)

PLEASE NOTE: Unless an assignee is identified below, no assignee data will appear on the patent. If an assignee is identified below, the document has been filed for recordation as set forth in 37 CFR 3.11. Completion of this form is NOT a substitute for filing an assignment.

(A) NAME OF ASSIGNEE

(B) RESIDENCE: (CITY and STATE OR COUNTRY)

Please check the appropriate assignee category or categories (will not be printed on the patent) : ☐ Individual ☐ Corporation or other private group entity ☐ Government

4a. The following fee(s) are submitted:

☒ Issue Fee

☒ Publication Fee (No small entity discount permitted)

☒ Advance Order - # of Copies 10

4b. Payment of Fee(s): **(Please first reapply any previously paid issue fee shown above)**

☐ A check is enclosed.

☒ Payment by credit card. ~~Form PTO-2038 is attached~~. Paid through EFS

☐ The Director is hereby authorized to charge the required fee(s), any deficiency, or credit any overpayment, to Deposit Account Number ______ (enclose an extra copy of this form).

5. **Change in Entity Status** (from status indicated above)

☐ a. Applicant claims SMALL ENTITY status. See 37 CFR 1.27.

☐ b. Applicant is no longer claiming SMALL ENTITY status. See 37 CFR 1.27(g)(2).

NOTE: The Issue Fee and Publication Fee (if required) will not be accepted from anyone other than the applicant; a registered attorney or agent; or the assignee or other party in interest as shown by the records of the United States Patent and Trademark Office.

Authorized Signature *Jed Margolin* Date 1/2/2013

Typed or printed name Jed Margolin Registration No.

This collection of information is required by 37 CFR 1.311. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, Virginia 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, Virginia 22313-1450.

Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

Electronic Patent Application Fee Transmittal

Application Number:	12910779
Filing Date:	22-Oct-2010
Title of Invention:	SYSTEM FOR SENSING AIRCRAFT AND OTHER OBJECTS
First Named Inventor/Applicant Name:	Jed Margolin
Filer:	Jed Margolin
Attorney Docket Number:	

Filed as Small Entity

Utility under 35 USC 111(a) Filing Fees

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Basic Filing:				
Pages:				
Claims:				
Miscellaneous-Filing:				
Petition:				
Patent-Appeals-and-Interference:				
Post-Allowance-and-Post-Issuance:				
Utility Appl issue fee	2501	1	885	885
Publ. Fee- early, voluntary, or normal	1504	1	300	300

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Extension-of-Time:				
Miscellaneous:				
Printed copy of patent - no color	8001	10	3	30
		Total in USD ($)		**1215**

Electronic Acknowledgement Receipt

EFS ID:	14594076
Application Number:	12910779
International Application Number:	
Confirmation Number:	8875
Title of Invention:	SYSTEM FOR SENSING AIRCRAFT AND OTHER OBJECTS
First Named Inventor/Applicant Name:	Jed Margolin
Customer Number:	23497
Filer:	Jed Margolin
Filer Authorized By:	
Attorney Docket Number:	
Receipt Date:	02-JAN-2013
Filing Date:	22-OCT-2010
Time Stamp:	12:08:49
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	yes
Payment Type	Credit Card
Payment was successfully received in RAM	$1215
RAM confirmation Number	7307
Deposit Account	
Authorized User	

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)

1	Issue Fee Payment (PTO-85B)	noa_PartB_signed.pdf	88734 f8b48af1cf2130ebe5b19b7b640ed6d2c015c2dd	no	1
Warnings:					
Information:					
2	Fee Worksheet (SB06)	fee-info.pdf	33258 b7e785955449a0fd8044944bdc4e11084b501448	no	2
Warnings:					
Information:					
			Total Files Size (in bytes):	121992	

This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.

<u>New Applications Under 35 U.S.C. 111</u>
If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

<u>National Stage of an International Application under 35 U.S.C. 371</u>
If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

<u>New International Application Filed with the USPTO as a Receiving Office</u>
If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

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NOTICE OF ALLOWANCE AND FEE(S) DUE

23497 7590 12/21/2012

JED MARGOLIN
1981 EMPIRE ROAD
RENO, NV 89521-7430

EXAMINER	
BARKER, MATTHEW M	
ART UNIT	PAPER NUMBER
3646	

DATE MAILED: 12/21/2012

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
12/910,779	10/22/2010	Jed Margolin		8875

TITLE OF INVENTION: SYSTEM FOR SENSING AIRCRAFT AND OTHER OBJECTS

APPLN. TYPE	SMALL ENTITY	ISSUE FEE DUE	PUBLICATION FEE DUE	PREV. PAID ISSUE FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	YES	$885	$300	$0	$1185	03/21/2013

THE APPLICATION IDENTIFIED ABOVE HAS BEEN EXAMINED AND IS ALLOWED FOR ISSUANCE AS A PATENT. PROSECUTION ON THE MERITS IS CLOSED. THIS NOTICE OF ALLOWANCE IS NOT A GRANT OF PATENT RIGHTS. THIS APPLICATION IS SUBJECT TO WITHDRAWAL FROM ISSUE AT THE INITIATIVE OF THE OFFICE OR UPON PETITION BY THE APPLICANT. SEE 37 CFR 1.313 AND MPEP 1308.

THE ISSUE FEE AND PUBLICATION FEE (IF REQUIRED) MUST BE PAID WITHIN THREE MONTHS FROM THE MAILING DATE OF THIS NOTICE OR THIS APPLICATION SHALL BE REGARDED AS ABANDONED. THIS STATUTORY PERIOD CANNOT BE EXTENDED. SEE 35 U.S.C. 151. THE ISSUE FEE DUE INDICATED ABOVE DOES NOT REFLECT A CREDIT FOR ANY PREVIOUSLY PAID ISSUE FEE IN THIS APPLICATION. IF AN ISSUE FEE HAS PREVIOUSLY BEEN PAID IN THIS APPLICATION (AS SHOWN ABOVE), THE RETURN OF PART B OF THIS FORM WILL BE CONSIDERED A REQUEST TO REAPPLY THE PREVIOUSLY PAID ISSUE FEE TOWARD THE ISSUE FEE NOW DUE.

HOW TO REPLY TO THIS NOTICE:

I. Review the SMALL ENTITY status shown above.

If the SMALL ENTITY is shown as YES, verify your current SMALL ENTITY status:

A. If the status is the same, pay the TOTAL FEE(S) DUE shown above.

B. If the status above is to be removed, check box 5b on Part B - Fee(s) Transmittal and pay the PUBLICATION FEE (if required) and twice the amount of the ISSUE FEE shown above, or

If the SMALL ENTITY is shown as NO:

A. Pay TOTAL FEE(S) DUE shown above, or

B. If applicant claimed SMALL ENTITY status before, or is now claiming SMALL ENTITY status, check box 5a on Part B - Fee(s) Transmittal and pay the PUBLICATION FEE (if required) and 1/2 the ISSUE FEE shown above.

II. PART B - FEE(S) TRANSMITTAL, or its equivalent, must be completed and returned to the United States Patent and Trademark Office (USPTO) with your ISSUE FEE and PUBLICATION FEE (if required). If you are charging the fee(s) to your deposit account, section "4b" of Part B - Fee(s) Transmittal should be completed and an extra copy of the form should be submitted. If an equivalent of Part B is filed, a request to reapply a previously paid issue fee must be clearly made, and delays in processing may occur due to the difficulty in recognizing the paper as an equivalent of Part B.

III. All communications regarding this application must give the application number. Please direct all communications prior to issuance to Mail Stop ISSUE FEE unless advised to the contrary.

IMPORTANT REMINDER: Utility patents issuing on applications filed on or after Dec. 12, 1980 may require payment of maintenance fees. It is patentee's responsibility to ensure timely payment of maintenance fees when due.

PART B - FEE(S) TRANSMITTAL

Complete and send this form, together with applicable fee(s), to: Mail **Mail Stop ISSUE FEE**
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CURRENT CORRESPONDENCE ADDRESS (Note: Use Block 1 for any change of address)

23497 7590 12/21/2012

JED MARGOLIN
1981 EMPIRE ROAD
RENO, NV 89521-7430

Note: A certificate of mailing can only be used for domestic mailings of the Fee(s) Transmittal. This certificate cannot be used for any other accompanying papers. Each additional paper, such as an assignment or formal drawing, must have its own certificate of mailing or transmission.

Certificate of Mailing or Transmission

I hereby certify that this Fee(s) Transmittal is being deposited with the United States Postal Service with sufficient postage for first class mail in an envelope addressed to the Mail Stop ISSUE FEE address above, or being facsimile transmitted to the USPTO (571) 273-2885, on the date indicated below.

(Depositor's name)
(Signature)
(Date)

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
12/910,779	10/22/2010	Jed Margolin		8875

TITLE OF INVENTION: SYSTEM FOR SENSING AIRCRAFT AND OTHER OBJECTS

APPLN. TYPE	SMALL ENTITY	ISSUE FEE DUE	PUBLICATION FEE DUE	PREV. PAID ISSUE FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	YES	$885	$300	$0	$1185	03/21/2013

EXAMINER	ART UNIT	CLASS-SUBCLASS
BARKER, MATTHEW M	3646	342-030000

1. Change of correspondence address or indication of "Fee Address" (37 CFR 1.363).

❑ Change of correspondence address (or Change of Correspondence Address form PTO/SB/122) attached.

❑ "Fee Address" indication (or "Fee Address" Indication form PTO/SB/47; Rev 03-02 or more recent) attached. **Use of a Customer Number is required.**

2. For printing on the patent front page, list

(1) the names of up to 3 registered patent attorneys or agents OR, alternatively,

(2) the name of a single firm (having as a member a registered attorney or agent) and the names of up to 2 registered patent attorneys or agents. If no name is listed, no name will be printed.

1 ____________________

2 ____________________

3 ____________________

3. ASSIGNEE NAME AND RESIDENCE DATA TO BE PRINTED ON THE PATENT (print or type)

PLEASE NOTE: Unless an assignee is identified below, no assignee data will appear on the patent. If an assignee is identified below, the document has been filed for recordation as set forth in 37 CFR 3.11. Completion of this form is NOT a substitute for filing an assignment.

(A) NAME OF ASSIGNEE

(B) RESIDENCE: (CITY and STATE OR COUNTRY)

Please check the appropriate assignee category or categories (will not be printed on the patent) : ❑ Individual ❑ Corporation or other private group entity ❑ Government

4a. The following fee(s) are submitted:

❑ Issue Fee

❑ Publication Fee (No small entity discount permitted)

❑ Advance Order - # of Copies ____________

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❑ A check is enclosed.

❑ Payment by credit card. Form PTO-2038 is attached.

❑ The Director is hereby authorized to charge the required fee(s), any deficiency, or credit any overpayment, to Deposit Account Number __________ (enclose an extra copy of this form).

5. **Change in Entity Status** (from status indicated above)

❑ a. Applicant claims SMALL ENTITY status. See 37 CFR 1.27.

❑ b. Applicant is no longer claiming SMALL ENTITY status. See 37 CFR 1.27(g)(2).

NOTE: The Issue Fee and Publication Fee (if required) will not be accepted from anyone other than the applicant; a registered attorney or agent; or the assignee or other party in interest as shown by the records of the United States Patent and Trademark Office.

Authorized Signature ______________________ Date ______________________

Typed or printed name ______________________ Registration No. ______________________

This collection of information is required by 37 CFR 1.311. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, Virginia 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, Virginia 22313-1450.

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APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
12/910,779	10/22/2010	Jed Margolin		8875

23497 7590 12/21/2012

JED MARGOLIN
1981 EMPIRE ROAD
RENO, NV 89521-7430

EXAMINER	
BARKER, MATTHEW M	
ART UNIT	PAPER NUMBER
3646	

DATE MAILED: 12/21/2012

Determination of Patent Term Adjustment under 35 U.S.C. 154 (b)

(application filed on or after May 29, 2000)

The Patent Term Adjustment to date is 243 day(s). If the issue fee is paid on the date that is three months after the mailing date of this notice and the patent issues on the Tuesday before the date that is 28 weeks (six and a half months) after the mailing date of this notice, the Patent Term Adjustment will be 243 day(s).

If a Continued Prosecution Application (CPA) was filed in the above-identified application, the filing date that determines Patent Term Adjustment is the filing date of the most recent CPA.

Applicant will be able to obtain more detailed information by accessing the Patent Application Information Retrieval (PAIR) WEB site (http://pair.uspto.gov).

Any questions regarding the Patent Term Extension or Adjustment determination should be directed to the Office of Patent Legal Administration at (571)-272-7702. Questions relating to issue and publication fee payments should be directed to the Customer Service Center of the Office of Patent Publication at 1-(888)-786-0101 or (571)-272-4200.

Privacy Act Statement

The Privacy Act of 1974 (P.L. 93-579) requires that you be given certain information in connection with your submission of the attached form related to a patent application or patent. Accordingly, pursuant to the requirements of the Act, please be advised that: (1) the general authority for the collection of this information is 35 U.S.C. 2(b)(2); (2) furnishing of the information solicited is voluntary; and (3) the principal purpose for which the information is used by the U.S. Patent and Trademark Office is to process and/or examine your submission related to a patent application or patent. If you do not furnish the requested information, the U.S. Patent and Trademark Office may not be able to process and/or examine your submission, which may result in termination of proceedings or abandonment of the application or expiration of the patent.

The information provided by you in this form will be subject to the following routine uses:

1. The information on this form will be treated confidentially to the extent allowed under the Freedom of Information Act (5 U.S.C. 552) and the Privacy Act (5 U.S.C 552a). Records from this system of records may be disclosed to the Department of Justice to determine whether disclosure of these records is required by the Freedom of Information Act.
2. A record from this system of records may be disclosed, as a routine use, in the course of presenting evidence to a court, magistrate, or administrative tribunal, including disclosures to opposing counsel in the course of settlement negotiations.
3. A record in this system of records may be disclosed, as a routine use, to a Member of Congress submitting a request involving an individual, to whom the record pertains, when the individual has requested assistance from the Member with respect to the subject matter of the record.
4. A record in this system of records may be disclosed, as a routine use, to a contractor of the Agency having need for the information in order to perform a contract. Recipients of information shall be required to comply with the requirements of the Privacy Act of 1974, as amended, pursuant to 5 U.S.C. 552a(m).
5. A record related to an International Application filed under the Patent Cooperation Treaty in this system of records may be disclosed, as a routine use, to the International Bureau of the World Intellectual Property Organization, pursuant to the Patent Cooperation Treaty.
6. A record in this system of records may be disclosed, as a routine use, to another federal agency for purposes of National Security review (35 U.S.C. 181) and for review pursuant to the Atomic Energy Act (42 U.S.C. 218(c)).
7. A record from this system of records may be disclosed, as a routine use, to the Administrator, General Services, or his/her designee, during an inspection of records conducted by GSA as part of that agency's responsibility to recommend improvements in records management practices and programs, under authority of 44 U.S.C. 2904 and 2906. Such disclosure shall be made in accordance with the GSA regulations governing inspection of records for this purpose, and any other relevant (i.e., GSA or Commerce) directive. Such disclosure shall not be used to make determinations about individuals.
8. A record from this system of records may be disclosed, as a routine use, to the public after either publication of the application pursuant to 35 U.S.C. 122(b) or issuance of a patent pursuant to 35 U.S.C. 151. Further, a record may be disclosed, subject to the limitations of 37 CFR 1.14, as a routine use, to the public if the record was filed in an application which became abandoned or in which the proceedings were terminated and which application is referenced by either a published application, an application open to public inspection or an issued patent.
9. A record from this system of records may be disclosed, as a routine use, to a Federal, State, or local law enforcement agency, if the USPTO becomes aware of a violation or potential violation of law or regulation.

Notice of Allowability	**Application No.** 12/910,779	**Applicant(s)** MARGOLIN, JED	
	Examiner MATTHEW M. BARKER	**Art Unit** 3646	

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address--

All claims being allowable, PROSECUTION ON THE MERITS IS (OR REMAINS) CLOSED in this application. If not included herewith (or previously mailed), a Notice of Allowance (PTOL-85) or other appropriate communication will be mailed in due course. **THIS NOTICE OF ALLOWABILITY IS NOT A GRANT OF PATENT RIGHTS.** This application is subject to withdrawal from issue at the initiative of the Office or upon petition by the applicant. See 37 CFR 1.313 and MPEP 1308.

1. ☒ This communication is responsive to *the supplemental amendment filed 12/3/2012*.
2. ☐ An election was made by the applicant in response to a restriction requirement set forth during the interview on _____; the restriction requirement and election have been incorporated into this action.
3. ☒ The allowed claim(s) is/are *10-16*. As a result of the allowed claim(s), you may be eligible to benefit from the **Patent Prosecution Highway** program at a participating intellectual property office for the corresponding application. For more information, please see http://www.uspto.gov/patents/init_events/pph/index.jsp or send an inquiry to PPHfeedback@uspto.gov .
4. ☐ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).

   a) ☐ All b) ☐ Some* c) ☐ None of the:

   1. ☐ Certified copies of the priority documents have been received.
   2. ☐ Certified copies of the priority documents have been received in Application No. _____ .
   3. ☐ Copies of the certified copies of the priority documents have been received in this national stage application from the International Bureau (PCT Rule 17.2(a)).

   * Certified copies not received: _____.

Applicant has THREE MONTHS FROM THE "MAILING DATE" of this communication to file a reply complying with the requirements noted below. Failure to timely comply will result in ABANDONMENT of this application.
THIS THREE-MONTH PERIOD IS NOT EXTENDABLE.

5. ☐ CORRECTED DRAWINGS (as "replacement sheets") must be submitted.

   ☐ including changes required by the attached Examiner's Amendment / Comment or in the Office action of Paper No./Mail Date _____.

   Identifying indicia such as the application number (see 37 CFR 1.84(c)) should be written on the drawings in the front (not the back) of each sheet. Replacement sheet(s) should be labeled as such in the header according to 37 CFR 1.121(d).

6. ☐ DEPOSIT OF and/or INFORMATION about the deposit of BIOLOGICAL MATERIAL must be submitted. Note the attached Examiner's comment regarding REQUIREMENT FOR THE DEPOSIT OF BIOLOGICAL MATERIAL.

Attachment(s)

1. ☒ Notice of References Cited (PTO-892)
2. ☐ Information Disclosure Statements (PTO/SB/08), Paper No./Mail Date _____
3. ☐ Examiner's Comment Regarding Requirement for Deposit of Biological Material
4. ☐ Interview Summary (PTO-413), Paper No./Mail Date _____ .
5. ☐ Examiner's Amendment/Comment
6. ☒ Examiner's Statement of Reasons for Allowance
7. ☐ Other _____.

DETAILED ACTION

Response to Amendment

1. The supplemental amendment filed 12/3/2012 is accepted.

Drawings

2. The replacement drawings received 12/3/2012 are acceptable.

Allowable Subject Matter

3. Claims 10-16 are allowed.

4. The following is an examiner's statement of reasons for allowance: The prior art does not disclose or render obvious a system for sensing aircraft and other objects where the claimed hardware determines and displays the range and bearing to the target, wherein the claimed ellipsoids are produced.

Any comments considered necessary by applicant must be submitted no later than the payment of the issue fee and, to avoid processing delays, should preferably accompany the issue fee. Such submissions should be clearly labeled "Comments on Statement of Reasons for Allowance."

Conclusion

5. Any inquiry concerning this communication or earlier communications from the examiner should be directed to MATTHEW M. BARKER whose telephone number is (571)272-3103. The examiner can normally be reached on M-F, 8:30 AM-5:00 PM.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Jack Keith can be reached on (571)272-6878. The fax phone number for the organization where this application or proceeding is assigned is 571-273-8300.

Information regarding the status of an application may be obtained from the Patent Application Information Retrieval (PAIR) system. Status information for published applications may be obtained from either Private PAIR or Public PAIR. Status information for unpublished applications is available through Private PAIR only. For more information about the PAIR system, see http://pair-direct.uspto.gov. Should you have questions on access to the Private PAIR system, contact the Electronic Business Center (EBC) at 866-217-9197 (toll-free). If you would like assistance from a USPTO Customer Service Representative or access to the automated information system, call 800-786-9199 (IN USA OR CANADA) or 571-272-1000.

/M. M. B./
Examiner, Art Unit 3646

/JOHN B. SOTOMAYOR/

Primary Examiner, Art Unit 3646

Notice of References Cited	Application/Control No. 12/910,779	Applicant(s)/Patent Under Reexamination MARGOLIN, JED	
	Examiner MATTHEW M. BARKER	Art Unit 3646	Page 1 of 1

U.S. PATENT DOCUMENTS

*		Document Number Country Code-Number-Kind Code	Date MM-YYYY	Name	Classification
*	A	US-4,746,924 A	05-1988	Lightfoot, Fred M.	342/453
	B	US-			
	C	US-			
	D	US-			
	E	US-			
	F	US-			
	G	US-			
	H	US-			
	I	US-			
	J	US-			
	K	US-			
	L	US-			
	M	US-			

FOREIGN PATENT DOCUMENTS

*		Document Number Country Code-Number-Kind Code	Date MM-YYYY	Country	Name	Classification
	N					
	O					
	P					
	Q					
	R					
	S					
	T					

NON-PATENT DOCUMENTS

*		Include as applicable: Author, Title Date, Publisher, Edition or Volume, Pertinent Pages)
	U	
	V	
	W	
	X	

*A copy of this reference is not being furnished with this Office action. (See MPEP § 707.05(a).)
Dates in MM-YYYY format are publication dates. Classifications may be US or foreign.

Search Notes	Application/Control No.	Applicant(s)/Patent Under Reexamination
	12910779	MARGOLIN, JED
	Examiner	**Art Unit**
	MATTHEW M BARKER	3646

SEARCHED

Class	Subclass	Date	Examiner
342	147	11/8/2012	MMB
	updated	12/6/2012	MMB

SEARCH NOTES

Search Notes	Date	Examiner
342/74-81, 146, 147, 353, 453 text search - see printout	11/8/2012	MMB
EAST text search - see printout	10/29/2012	MMB
INSPEC NPL search - see printout	11/29/2012	MMB
PALM inventor name search	11/8/2012	MMB
Consult JB Sotomayor	11/7/2012	MMB
updated text, inventor search - see printout	12/6/2012	MMB

INTERFERENCE SEARCH

Class	Subclass	Date	Examiner
	EAST interference text search - see interference search printout	12/6/2012	MMB

EAST Search History

EAST Search History (Prior Art)

Ref #	Hits	Search Query	DBs	Default Operator	Plurals	Time Stamp
L8	2154	(342/74-81,146,147).CCLS.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2012/12/06 18:05
L9	36330	cross adj correlat$3	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2012/12/06 18:05
L10	60916	spread adj spectrum	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2012/12/06 18:05
L11	10	L8 and L9 and L10	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2012/12/06 18:05
L12	248	(342/453).CCLS.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2012/12/06 18:05
L13	109060	ellipse or ellipsiod	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2012/12/06 18:05
L14	18	L12 and L13	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2012/12/06 18:05
L15	49330	triangulat$3	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2012/12/06 18:05
L16	29404	directional near2 antenna	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2012/12/06 18:05
L17	60916	spread adj spectrum	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2012/12/06 18:05
L18	114	L15 with L16	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2012/12/06 18:05
L19	33	L17 and L18	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2012/12/06 18:05
L20	940796	correlat$3	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2012/12/06 18:05
L21	32	L20 and L19	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2012/12/06 18:05
L22	397708	satellite	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2012/12/06 18:05
L23	43238	L20 with code	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO;	OR	ON	2012/12/06 18:05

			DERWENT; IBM_TDB			
L24	173	L23 and L22 and L13	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2012/12/06 18:05
L25	2471590	reflect$3	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2012/12/06 18:05
L26	107	L24 and L25	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2012/12/06 18:05
L28	6132	16 and 20	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2012/12/06 18:17
L29	571421	sun	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2012/12/06 18:18
L30	524	28 and 29	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2012/12/06 18:18
L31	1239752	(distance or range) with (angle or bearing or direction)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2012/12/06 18:19
L32	348	30 and 31	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2012/12/06 18:19
L33	136598	ellipse or ellipsoid	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2012/12/06 18:19
L34	28	32 and 33	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2012/12/06 18:20
L35	98114	(two or second) near2 buffer	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2012/12/06 18:23
L36	89959	(two or second) near2 antenna	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2012/12/06 18:23
L37	101045	(two or second) near2 receiver	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2012/12/06 18:24
L39	1	35 and 36 and 37 and 20 and 33	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2012/12/06 18:24
L41	102029	(multiplex$3 or switch$3) with antenna	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2012/12/06 18:27
L44	106518	code with key	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2012/12/06 18:28
L45	82	41 and 33 and 20 and 22 and 13 and 44	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2012/12/06 18:30
L47	31	41 and 33 and 20 and 22 and 13 and 31 not breed.in.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2012/12/06 18:36

12/6/2012 7:08:28 PM

C:\ Users\ mbarker2\ Documents\ EAST\ Workspaces\ 12910779.wsp

EAST Search History

EAST Search History (Interference)

Ref #	Hits	Search Query	DBs	Default Operator	Plurals	Time Stamp
L27	60448	correlat$3.clm.	US-PGPUB; UPAD	OR	ON	2012/12/06 18:07
L49	18836	satellite.clm.	US-PGPUB; UPAD	OR	ON	2012/12/06 19:01
L50	6817	code with key.clm.	US-PGPUB; UPAD	OR	ON	2012/12/06 19:02
L51	29240	(target or object) with (distance or range) with (angle or bearing or direction)	US-PGPUB; UPAD	OR	ON	2012/12/06 19:03
L52	1	27 same 49 same 50 same 51	US-PGPUB; UPAD	OR	ON	2012/12/06 19:04
L54	1808	ellipsoid.clm.	US-PGPUB; UPAD	OR	ON	2012/12/06 19:05
L55	1	27 same 49 same 54 same 51	US-PGPUB; UPAD	OR	ON	2012/12/06 19:05
L57	59774	antenna.clm.	US-PGPUB; UPAD	OR	ON	2012/12/06 19:06
L58	8508	sun.clm.	US-PGPUB; UPAD	OR	ON	2012/12/06 19:06
L60	1	27 same 51 same 57 same 58	US-PGPUB; UPAD	OR	ON	2012/12/06 19:07

12/6/2012 7:07:54 PM
C:\Users\mbarker2\Documents\EAST\Workspaces\12910779.wsp

Issue Classification

Application/Control No.	Applicant(s)/Patent Under Reexamination
12910779	MARGOLIN, JED
Examiner	**Art Unit**
MATTHEW M BARKER	3646

ORIGINAL

CLASS	SUBCLASS
342	146

INTERNATIONAL CLASSIFICATION

CLAIMED					NON-CLAIMED				
G	0	1	S	13 / 48 (2006.0)	G	0	1	S	13 / 93 ()

CROSS REFERENCE(S)

CLASS	SUBCLASS (ONE SUBCLASS PER BLOCK)				
342	30	453			

☐ Claims renumbered in the same order as presented by applicant ☐ CPA ☐ T.D. ☐ R.1.47

Final	Original	Final	Original	Final	Original	Final	Original	Final	Original	Final	Original	Final	Original	Final	Original
1	10														
2	11														
4	12														
5	13														
3	14														
6	15														
7	16														

/MATTHEW M BARKER/ Examiner.Art Unit 3646 (Assistant Examiner)	12/6/2012 (Date)	**Total Claims Allowed:** 7
/JOHN B SOTOMAYOR/ Primary Examiner.Art Unit 3646 (Primary Examiner)	12/07/2012 (Date)	O.G. Print Claim(s): 10 O.G. Print Figure: 13

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application of Jed Margolin

Serial No.: 12/910,779

Filed: 10/22/2010

For: SYSTEM FOR SENSING AIRCRAFT AND OTHER OBJECTS

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

SUPPLEMENTAL AMENDMENT

Dear Sir:

This supplemental amendment is filed per an interview with the Examiner in order to correct informalities in the previous response and to place the claims in condition for allowance.

An Amendment to the Specification begins on page 2 of this paper.

Amendments to the Claims are reflected in the listing of claims which begins on page 3 of this paper.

Remarks begin on page 11 of this paper.

Replacement drawings begin on page 12 of this paper.

<u>Amendment to the Specification</u>

Please replace numbered paragraph [086] beginning on page 22, line 20 with the following paragraph (the single correction is on line 20 of this page):

[086] Figure 1 is a general illustration showing a TCAS system used as a radar, using standard TCAS antennas. TCAS Interrogation Receiver 106 listens for Interrogation signals from other aircraft. When it receives one, TCAS Transponder Transmitter 107 sends out a signal containing the unique ID number of the aircraft and its altitude. TCAS Interrogation Transmitter 105 periodically (and randomly) sends out an Interrogation signal that other TCAS-equipped aircraft respond to. These transponder responses are received by TCAS Transponder Receiver 108. There are at least two antennas: Omni-Directional Antenna 101 and Directional Antenna 102 which is under the control of Antenna Controller 103. Directional Antenna 102 and Antenna Controller 103 may be in the form of several directional antennas which may be selected in turn or used simultaneously. Antenna Diplexer 104 is used to select and/or combine Omni-Directional Antenna 101 and Directional Antenna 102 and route the signals (receiving and transmitting) to the appropriate piece of equipment. The preceding operations are under the control of TCAS Processor 109. The time delay between when the TCAS Interrogation signal is sent out by TCAS Interrogation Transmitter 105 and when a transponder signal from other aircraft is received by TCA<u>S</u> Transponder Receiver 108 is used to determine the range to the responding aircraft.

TCAS operation is improved by using the signal produced by TCAS Interrogation Transmitter 105 as a radar with reflected signals received by TCAS Interrogation Receiver 106 under the control of TCAS Processor 109 and Radar Processor 110. The results are displayed on Display 111.

If the number and range of targets reported by radar do not match the number and range of aircraft reported by TCAS then there is an aircraft out there that does not have TCAS or it is broken or has been disabled.

Amendments to the Claims

This listing of claims will replace all prior versions, and listings, of claims in the application:

Claims 1-9 (canceled)

Claim 10. (Currently amended) A system for sensing aircraft and other objects comprising:

(a) four or more orbiting satellites;

(b) an antenna;

(c) a receiver;

(d) a data buffer;

(e) a cross-correlator with two or more inputs and one or more outputs;

(f) a system controller;

(g) a list of code keys;

(h) a display;

wherein

(a) each of said four or more orbiting satellites ~~transmits~~ is configured to transmit a signal encoded by a unique code key selected from said list of code keys,

(b) said antenna is connected to said receiver,

(c) the output of said receiver is connected to the input of said data buffer,

(d) the output of said data buffer is connected to a first of said two or more inputs of said cross-correlator,

(e) said system controller ~~provides~~ is configured to provide a second of said two or more inputs of said cross-correlator,

(f) said system controller ~~receives~~ is configured to receive an output of said one or more outputs of said cross-correleator,

and whereby

(a) said system controller ~~uses~~ is configured to use said signal transmitted by each of said four or more orbiting satellites, said list of code keys, and said cross-correlator to uniquely identify each of said four or more orbiting satellites,

(b) said system controller ~~determines~~ is configured to determine a distance and a direction to each uniquely identified satellite,

(c) said signal from said each uniquely identified satellite is reflected by a target producing a uniquely identifiable reflected signal,

(d) each said uniquely identifiable reflected signal is received by said antenna, which is connected to said receiver, which is connected to said data buffer, which is connected to said first of said two or more inputs of said cross-correlator,

(e) said system controller ~~uses~~ is configured to use said list of code keys and said cross-correlator to identify each said uniquely identifiable reflected signal,

(f) said system controller ~~uses~~ is configured to use each said uniquely identifiable reflected signal and said range and said direction to said each uniquely identified satellite to determine a range and a bearing to said target, and

(g) said system controller is configured to display ~~displays~~ said range and said bearing on said display,

and wherein

(a) the range and direction to a first of said four or more orbiting satellites and the signal from said first of said four or more orbiting satellites reflected from said target produce a first ellipsoid with said first of said four or more orbiting satellites at one focal point of said first ellipsoid, said antenna at the other focal point of said first ellipsoid, and said target on the surface of said first ellipsoid,

(b) the range and direction to a second of said four or more orbiting satellites and the signal from said second of said four or more orbiting satellites reflected from said target produce a second ellipsoid with said second of said four or more orbiting satellites at one focal point of said second ellipsoid, said antenna at the other focal point of said second ellipsoid, and said target on the surface of said second ellipsoid,

(c) the range and direction to a third of said four or more orbiting satellites and the signal from said third of said four or more orbiting satellites reflected from said target produce a third ellipsoid with said third of said four or more orbiting satellites at one focal point of said third ellipsoid, said antenna at the other focal point of said third ellipsoid, and said target on the surface of said third ellipsoid,

(d) the range and direction to a fourth of said four or more orbiting satellites and the signal from said fourth of said four or more orbiting satellites reflected from said target produce a fourth ellipsoid with said fourth of said four or more orbiting satellites at one focal point of said fourth ellipsoid, said antenna at the other focal point of said fourth ellipsoid, and said target on the surface of said fourth ellipsoid,

(e) said first ellipsoid and said second ellipsoid intersect in an ellipse with said target located on said ellipse,

(f) said third ellipsoid and said ellipse intersect at two points with said target located at one of said two points,

(g) said fourth ellipsoid intersects with only one of said two points with said target located at said only one of said two points.

11. (Original) The system of claim 10 further comprising communications links between each of said four or more orbiting satellites.

12. (Original) The system of claim 10 wherein at least one of said four or more orbiting satellites is located in low earth orbit.

13. (Currently amended) The system of claim 10 further comprising:

(a) a receiver in each of said four or more orbiting satellites;

(b) a transmitter;

whereby said receiver in each of said four or more orbiting satellites and said transmitter are ~~used~~ configured for said transmitter to send transmissions to at least one of said four or more orbiting satellites in order to provide two-way communications through said at least one of said four or more orbiting satellites.

14. (Currently amended) The system of claim 11 further comprising a satellite receiver in at least two or more of said four or more orbiting satellites whereby a signal transmitted by said at least two or more of said four or more orbiting satellites and said satellite receiver are ~~used~~ configured to perform long baseline radar interferometric measurements of terrain elevations.

15. (Currently amended) A system for sensing aircraft and other objects comprising:

(a) one or more orbiting satellites;

(b) a first antenna;

(c) a second antenna;

(d) a controller for said second antenna;

(e) an antenna multiplexer;

(f) a receiver;

(g) a data buffer;

(h) a cross-correlator with two or more inputs and one or more outputs;

(i) a system controller;

(j) a list of code keys;

(k) a display;

wherein

(a) said antenna multiplexer ~~selects~~ is configured to select between said first antenna and said second antenna under control of said system controller,

(b) the output of said antenna multiplexer is connected to the input of said receiver,

(c) said second antenna is directional and is controlled by said antenna controller under control of said system controller,

(d) the output of said receiver is connected to the input of said data buffer,

(e) the output of said data buffer is connected to a first of said two or more inputs of said cross-correlator,

(f) said system controller ~~provides~~ is configured to provide a second of said two or more inputs of said cross-correlator,

(g) said system controller ~~receives~~ is configured to receive an output of said one or more outputs of said cross-correleator,

and whereby

(a) said first antenna is selected by said system controller,

(b) said one or more orbiting satellites ~~transmits~~ is configured to transmit a signal encoded by a unique code key selected from said list of code keys,

(c) said system controller ~~uses~~ is configured to use said signal transmitted by said one or more orbiting satellites, said list of code keys, and said cross-correlator to uniquely identify said one or more orbiting satellites,

(d) said system controller ~~determines~~ is configured to determine a distance to a uniquely identified satellite,

(e) said signal from said uniquely identified satellite is reflected by a target producing a uniquely identifiable reflected signal,

(f) said uniquely identifiable reflected signal is received by said second antenna, which is connected to said receiver, which is connected to said data buffer, which is connected to said first of said two or more inputs of said cross-correlator,

(g) said system controller ~~uses~~ is configured to use said list of code keys and said cross-correlator to identify said uniquely identifiable reflected signal,

(h) said system controller ~~uses~~ is configured to use said antenna controller to direct said second antenna at the source of said uniquely identifiable reflected signal to produce a bearing to said uniquely identifiable reflected signal,

(i) said system controller ~~uses~~ is configured to use said uniquely identifiable reflected signal and said range to said uniquely identified satellite to determine a range and a bearing to said target, and

(j) said system controller is configured to display ~~displays~~ said range and said bearing on said display,

and wherein

(a) the range and direction to said one or more orbiting satellites and the signal from said one or more orbiting satellites reflected from said target produces an ellipsoid with said one or more orbiting satellites at one focal point of said ellipsoid, said antenna at the other focal point of said ellipsoid, and said target on the surface of said ellipsoid,

(b) said second antenna is aimed to receive said signal from said one or more orbiting satellites reflected from said target, and

(c) the direction of said second antenna is used to determine the location of said target on said ellipsoid.

16. (Currently amended) A system for sensing aircraft and other objects during daytime comprising:

(a) a first directional antenna;

(b) a first antenna controller;

(c) a first receiver;

(d) a first data buffer;

(e) a second directional antenna;

(f) a second antenna controller;

(g) a second receiver;

(h) a second data buffer;

(i) a cross-correlator;

(j) a system controller;

(k) a display;

whereby

(a) the position of said first directional antenna is controlled by said first antenna controller under the control of said system controller,

(b) the position of said second directional antenna is controlled by said second antenna controller under the control of said system controller,

(c) said cross-correlator has two inputs and one output,

(d) said first directional antenna is connected to the input of said first receiver,

(e) the output of said first receiver is connected to the input of said first data buffer,

(f) the output of said first data buffer is connected to a first input of said cross-correlator under control of said system controller,

(g) said second directional antenna is connected to the input of said second receiver,

(h) the output of said second receiver is connected to the input of said second data buffer,

(i) the output of said second data buffer is connected to a second input of said cross-correlator under control of said system controller,

(j) said system controller ~~directs~~ is configured to direct said first antenna controller to point said first directional antenna at the Sun to produce a first signal,

(k) said system controller ~~directs~~ is configured to direct said cross-correlator to perform a cross-correlation between said first signal received from said first directional antenna which is stored in said first data buffer and a second signal received from said second directional antenna which is stored in said second data buffer,

(l) said system controller ~~directs~~ is configured to direct said second antenna controller to point said second directional antenna to produce said second signal to maximize said output of said cross-correlator where said second directional antenna is not pointed at said Sun,

whereas

(a) said second signal is a reflection of said first signal produced by said Sun, said reflection being produced by a target,

(b) a time delay between said first signal and said second signal is used to determine an ellipsoid with said first directional antenna located at one focal point of said ellipsoid, said Sun located at the other focal point of said ellipsoid and said target on the surface of said ellipsoid,

(c) the direction of said second directional antenna is used to determine the location of said target on said ellipsoid,

(d) said system controller ~~uses~~ is configured to use said location of said target on said ellipsoid to produce a range and a bearing to said target, and

(e) said system controller is configured to display ~~displays~~ said range and said bearing on said display.

REMARKS

This supplemental amendment is filed per an interview with the Examiner in order to correct informalities in the previous response and to place the claims in condition for allowance.

In the specification, the paragraph [086] has been amended to correct a minor error.

Replacement drawings are being filed because, while Applicant originally submitted his drawings in landscape mode, the Patent Office software treated them as being in portrait mode. (See Patent Publication US 2011/0169684.) This resulted in the figures being smaller than Applicant intended and difficult to read. Applicant has redone the drawings so that, while the PDF files are in portrait mode, the figures are in landscape orientation. Replacement drawings are being submitted here to correct informalities in replacement drawings filed 11/27/2012. The replacement drawings contain no new matter.

Claims 1-9 have been canceled. Claims 1-6 have been canceled as a result of a restriction requirement by the Examiner. The subject matter claimed in Claims 1-4 is the subject of a co-pending divisional application. Applicant reserves the right to file a divisional application for the subject matter claimed in Claims 5-6. Claims 7-9 have been canceled to facilitate prosecution of the current case. Applicant reserves the right to file an RCE for the subject matter claimed in Claims 7-9.

The Examiner has acknowledged that Claims 10-16 are allowable. Claims 10-16 have been amended at Examiner's request to bring the claims in compliance with Patent Office practice.

Applicant respectfully requests that a timely Notice of Allowance be issued in this case.

Applicant requests that Figure 13 be used on the front page of the issued patent.

Respectfully submitted,

/Jed Margolin/ Date: December 3, 2012

Jed Margolin
1981 Empire Rd.
Reno, NV 89521-7430
775-847-7845

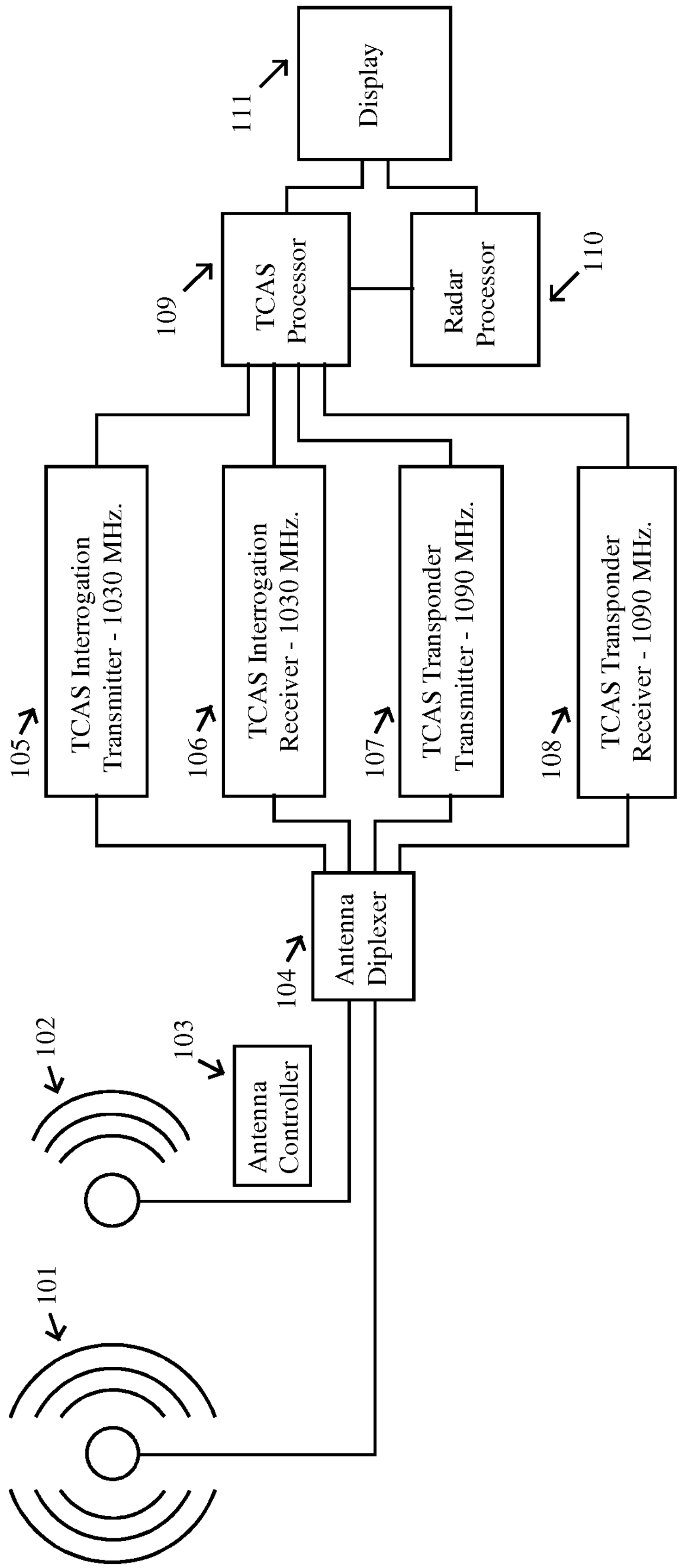

101
102
103
Antenna Controller
104
Antenna Diplexer
105
TCAS Interrogation Transmitter - 1030 MHz.
106
TCAS Interrogation Receiver - 1030 MHz.
107
TCAS Transponder Transmitter - 1090 MHz.
108
TCAS Transponder Receiver - 1090 MHz.
109
TCAS Processor
110
Radar Processor
111
Display

Fig. 1

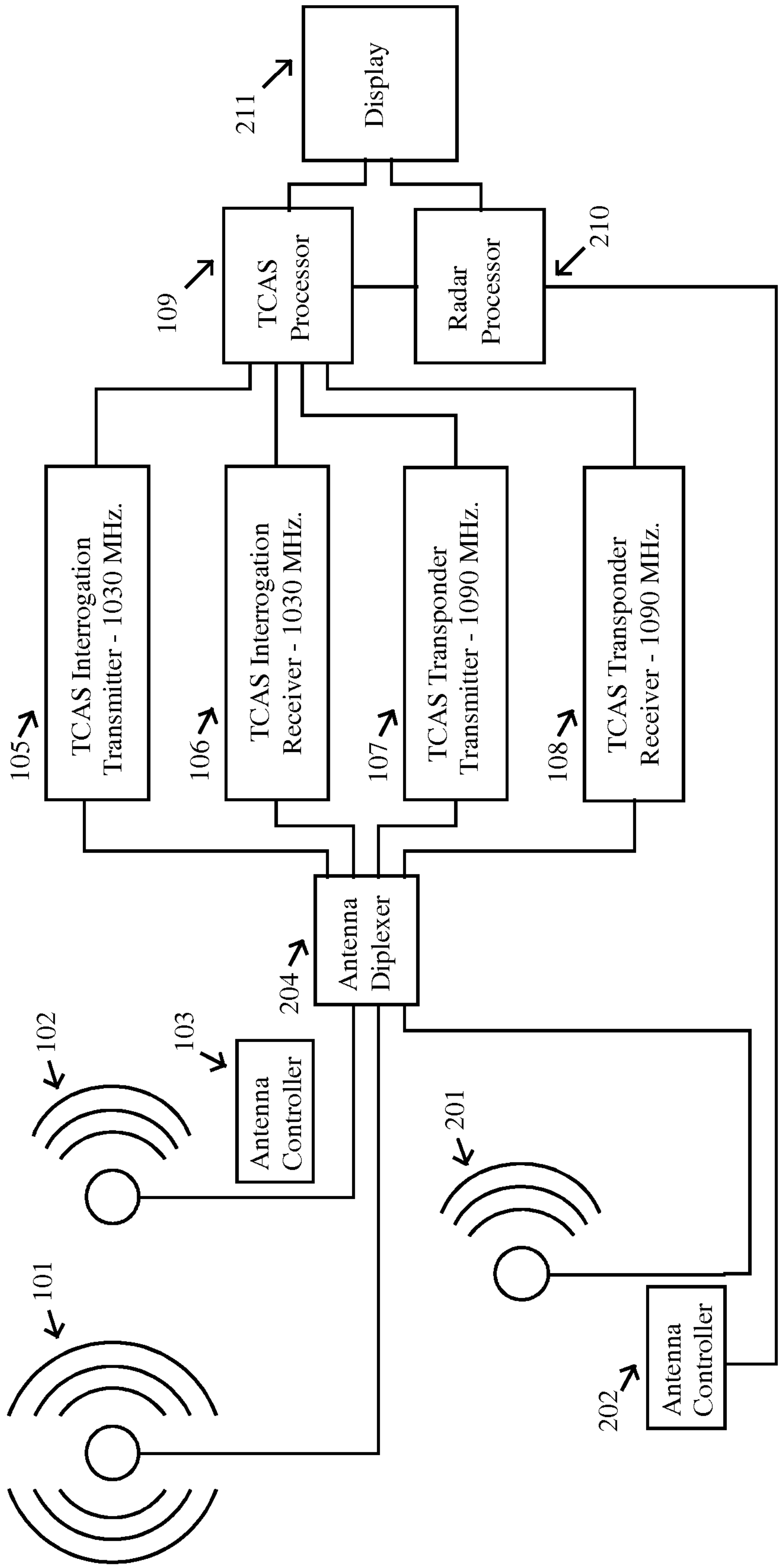

211
Display
109
TCAS Processor
Radar Processor
210
105
TCAS Interrogation Transmitter - 1030 MHz.
106
TCAS Interrogation Receiver - 1030 MHz.
107
TCAS Transponder Transmitter - 1090 MHz.
108
TCAS Transponder Receiver - 1090 MHz.
204
Antenna Diplexer
102
103
Antenna Controller
101
201
202
Antenna Controller

Fig. 2

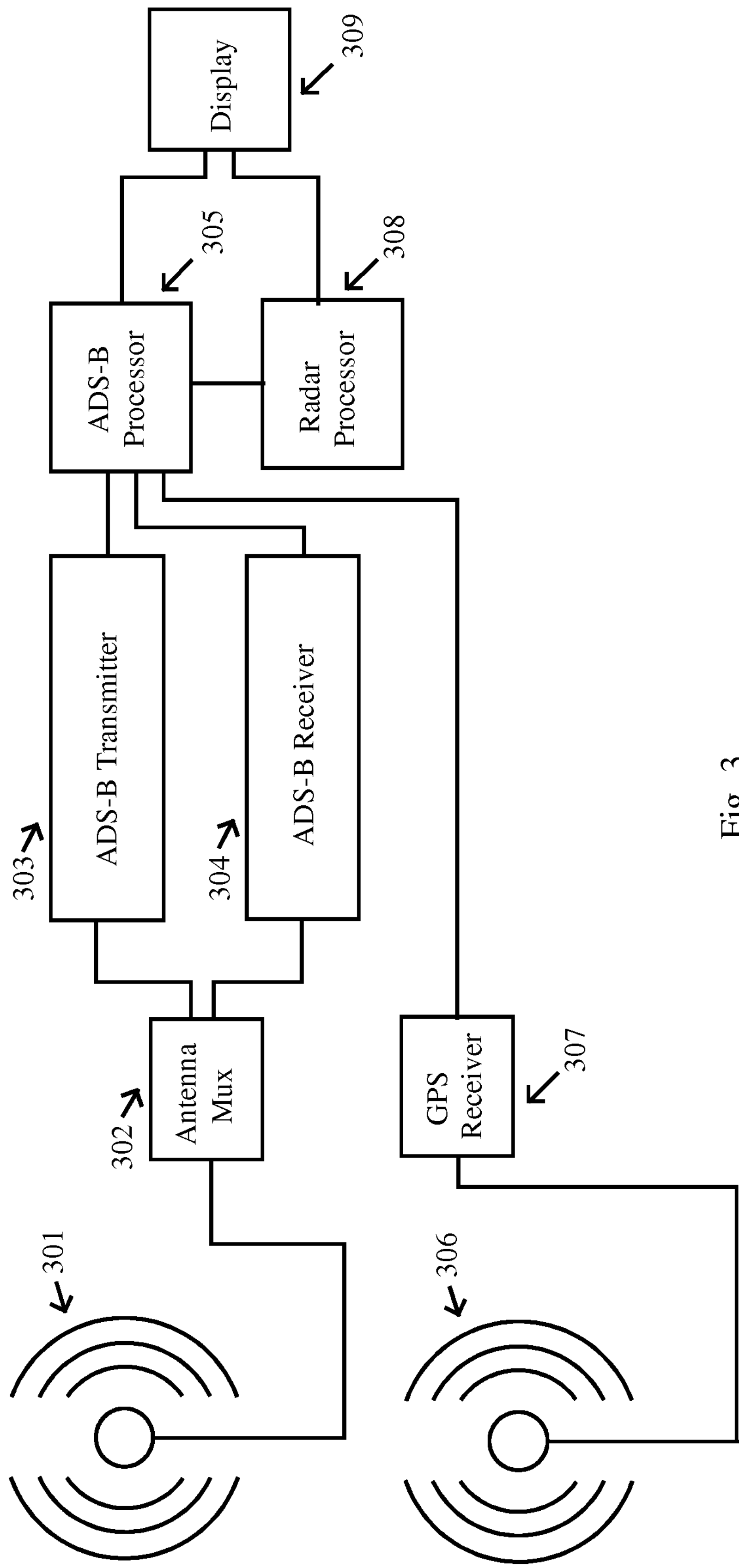

Display
309
305
308
ADS-B Processor
Radar Processor
ADS-B Transmitter
ADS-B Receiver
303
304
Antenna Mux
302
GPS Receiver
307
301
306

Fig. 3

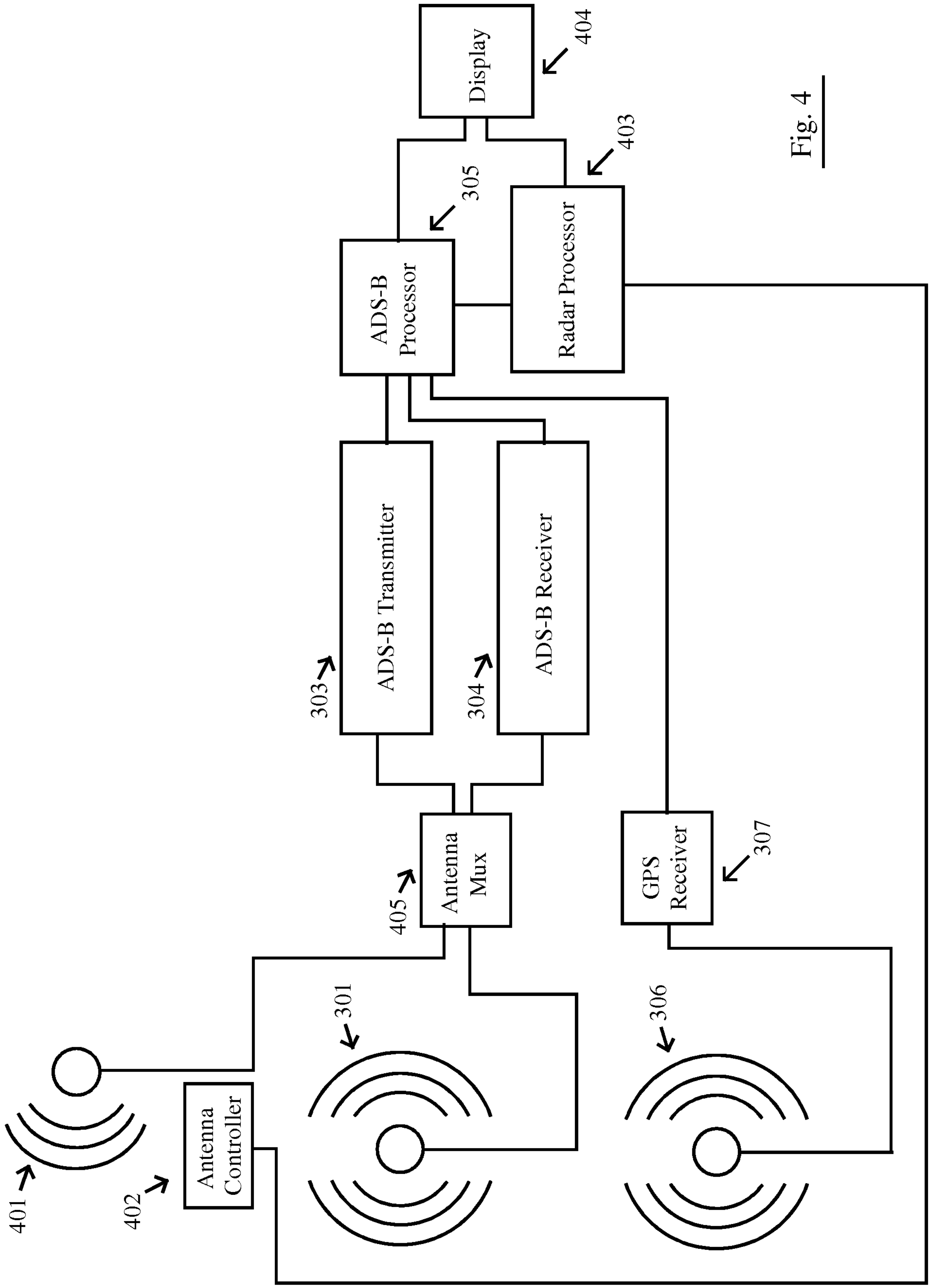

Display
404
403
305
ADS-B Processor
Radar Processor
ADS-B Transmitter
ADS-B Receiver
303
304
Antenna Mux
405
GPS Receiver
307
301
306
401
402
Antenna Controller

Fig. 4

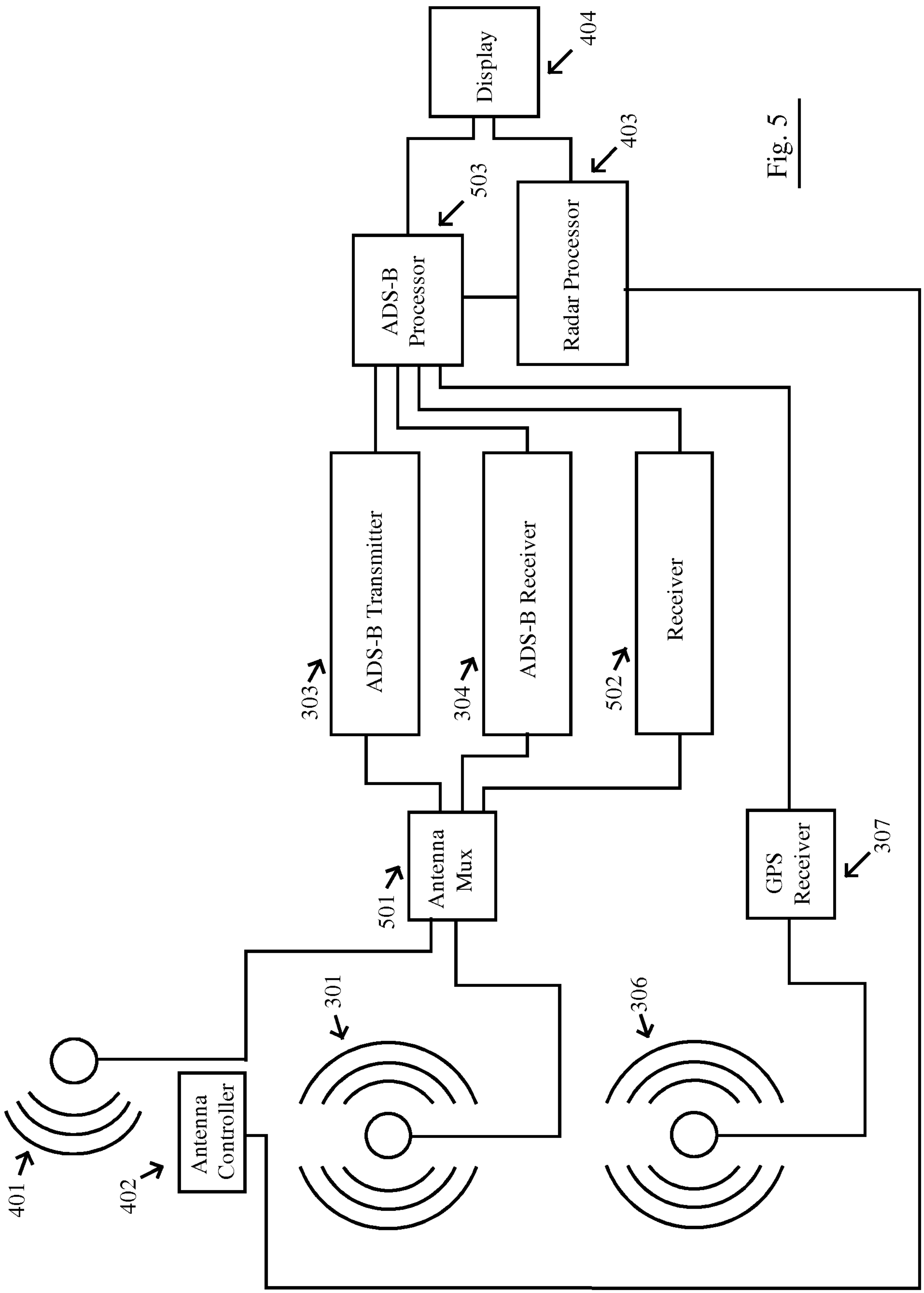

Display
404
403
503
ADS-B Processor
Radar Processor
ADS-B Transmitter
303
ADS-B Receiver
304
Receiver
502
Antenna Mux
501
GPS Receiver
307
301
306
401
Antenna Controller
402

Fig. 5

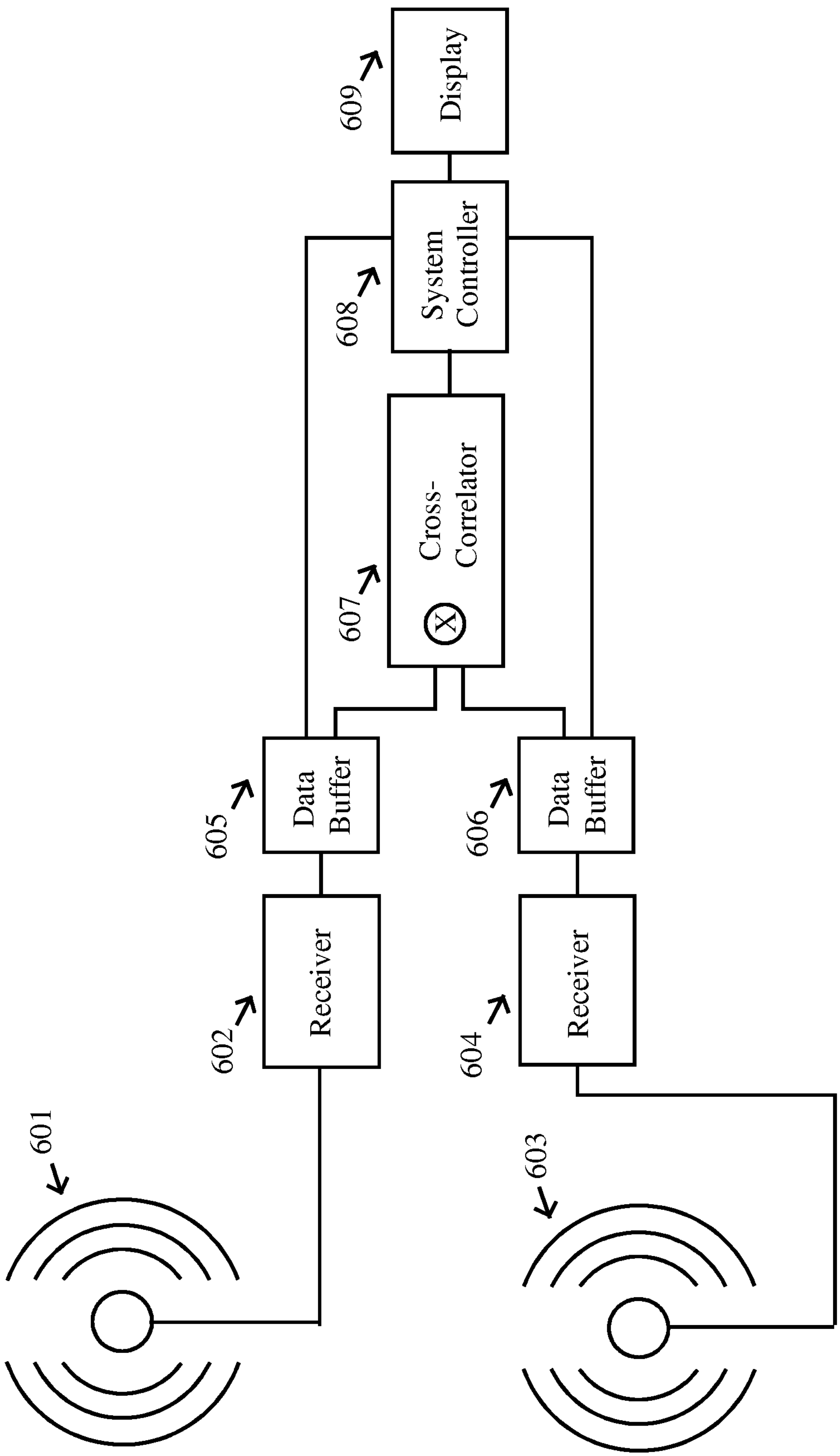

609
Display
608
System Controller
607
Cross-Correlator
X
605
Data Buffer
606
Data Buffer
602
Receiver
604
Receiver
601
603

Fig. 6

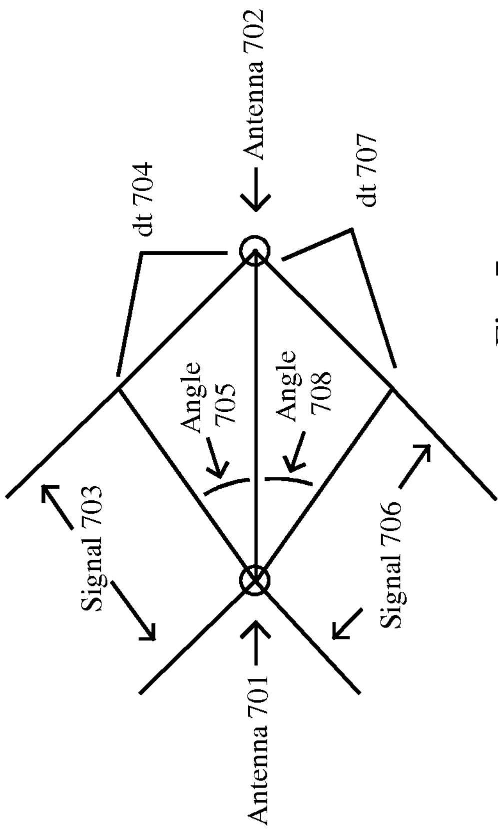

Antenna 702
dt 704
dt 707
Angle 705
Angle 708
Signal 703
Signal 706
Antenna 701

Fig. 7

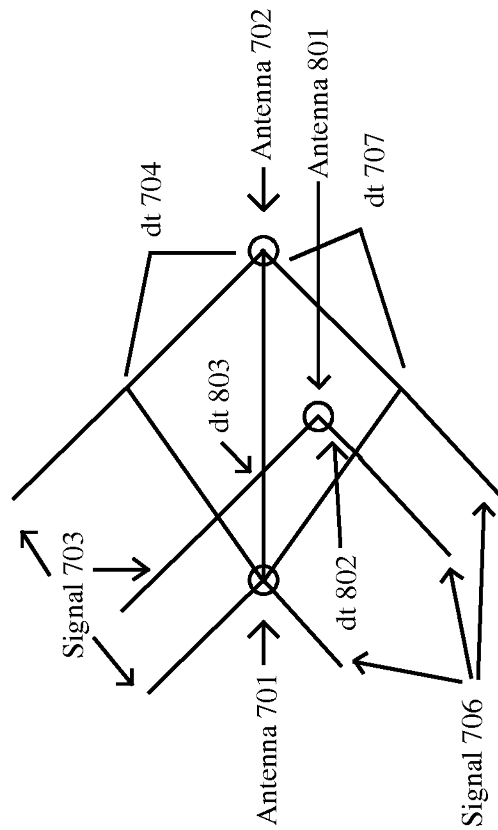

Antenna 702
Antenna 801
dt 704
dt 707
dt 803
dt 802
Signal 703
Signal 706
Antenna 701

Fig. 8

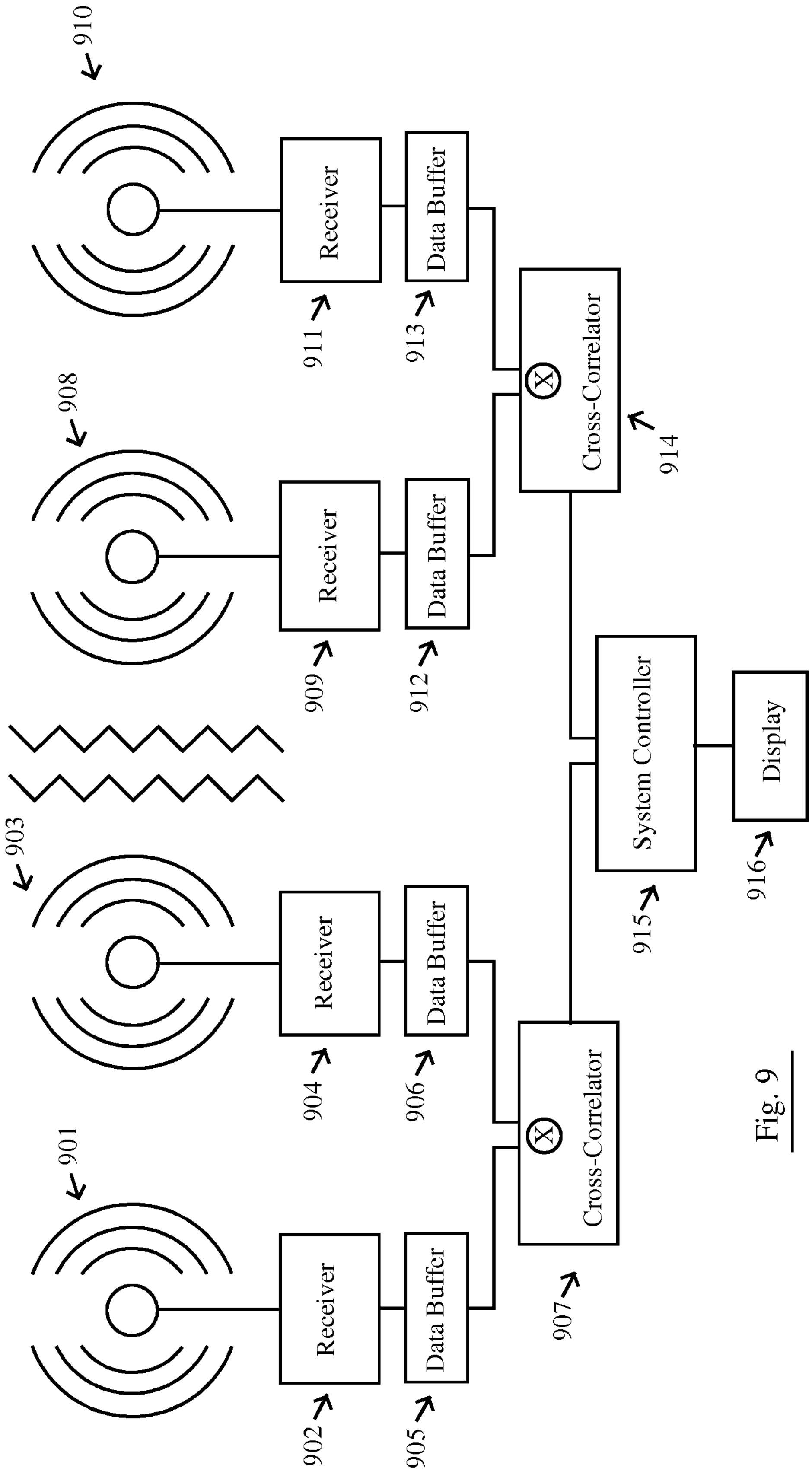

901
902
Receiver
905
Data Buffer
903
904
Receiver
906
Data Buffer
907
Cross-Correlator
908
909
Receiver
912
Data Buffer
910
911
Receiver
913
Data Buffer
914
Cross-Correlator
915
System Controller
916
Display

Fig. 9

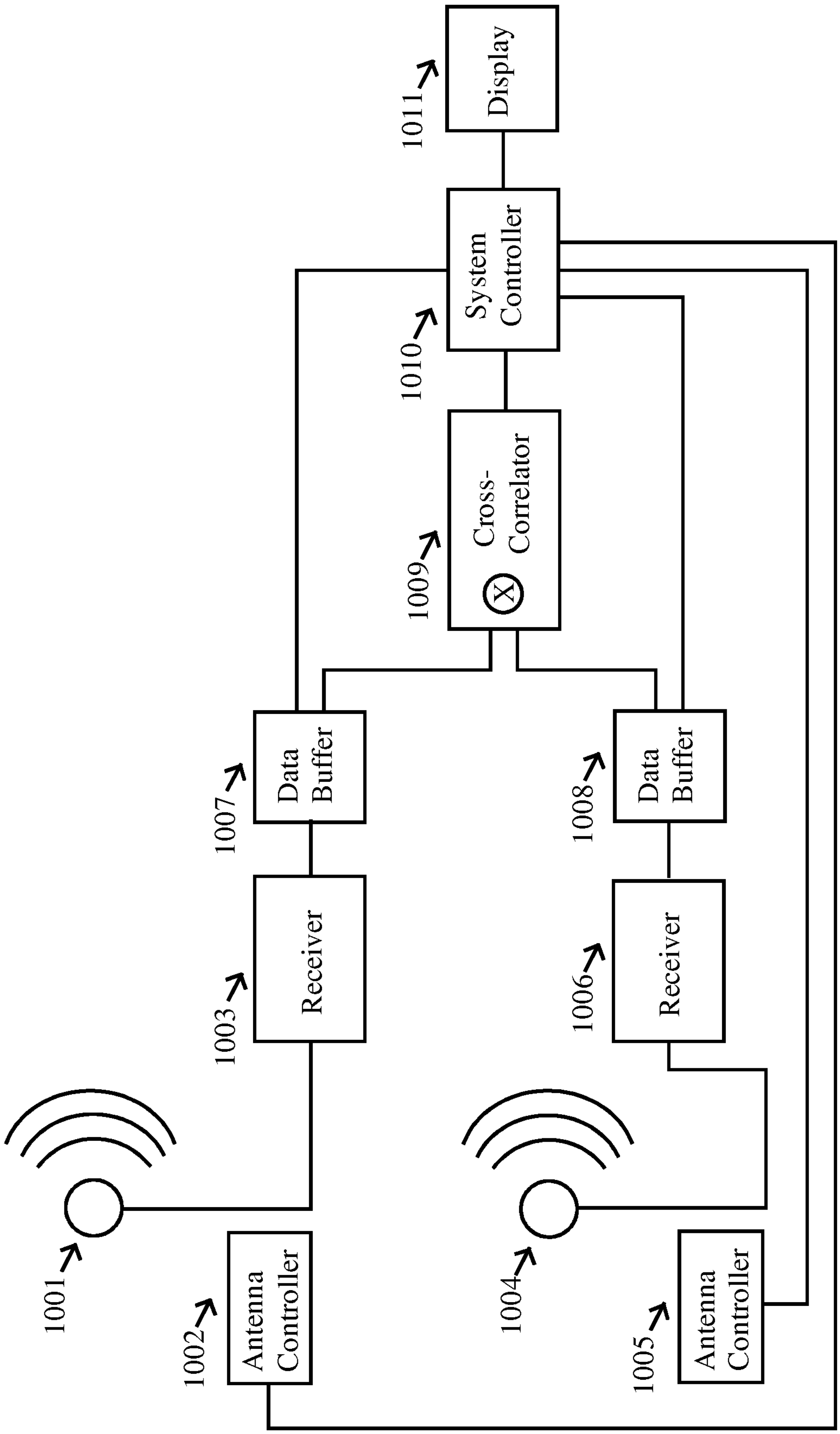

1011
Display
1010
System Controller
1009
Cross-Correlator
X
1007
Data Buffer
1008
Data Buffer
1003
Receiver
1006
Receiver
1001
1004
1002
Antenna Controller
1005
Antenna Controller

Fig. 10

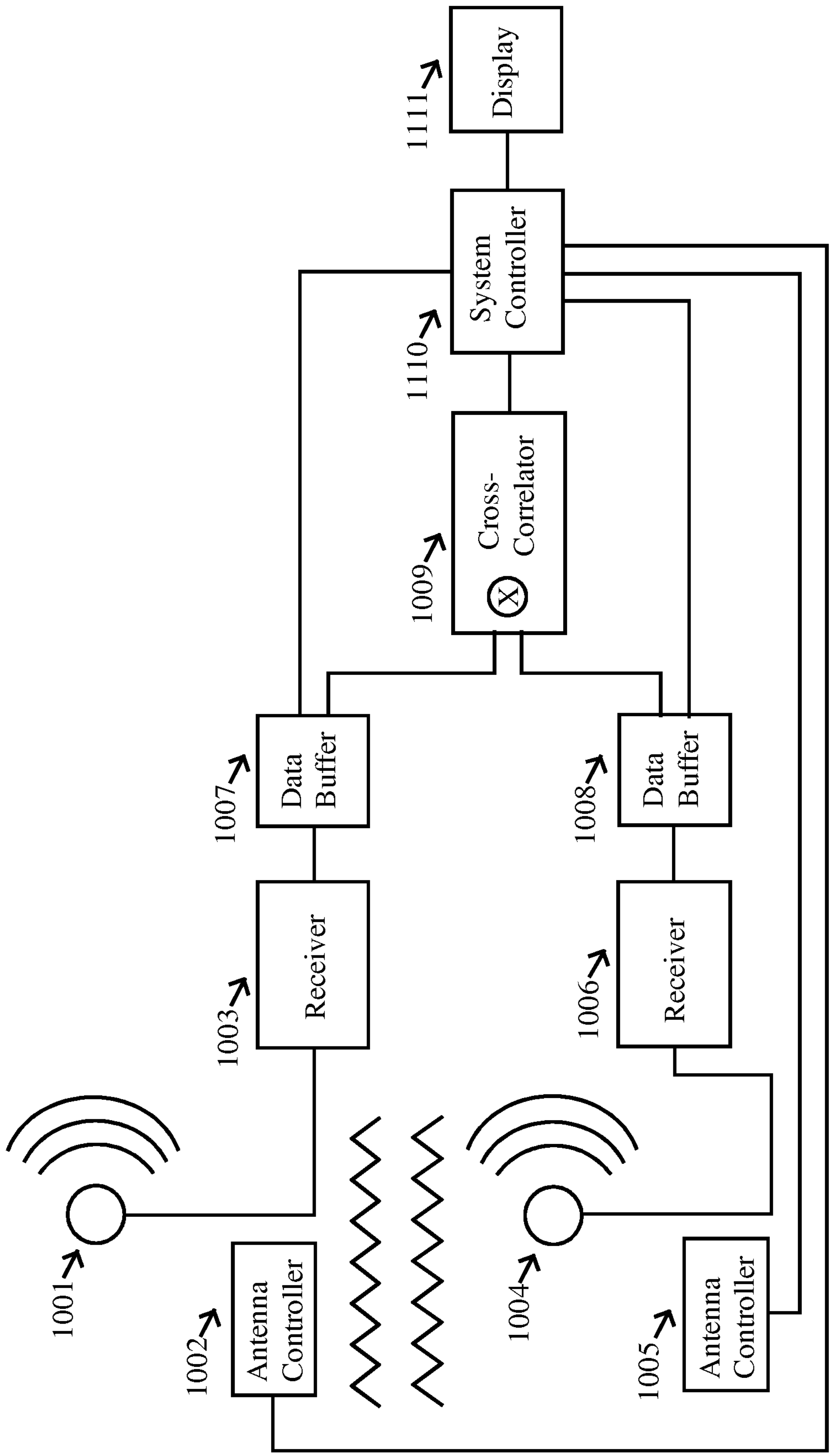

1111
Display
1110
System Controller
1009
Cross-Correlator
X
1007
Data Buffer
1008
Data Buffer
1003
Receiver
1006
Receiver
1001
1002
Antenna Controller
1004
1005
Antenna Controller

Fig. 11

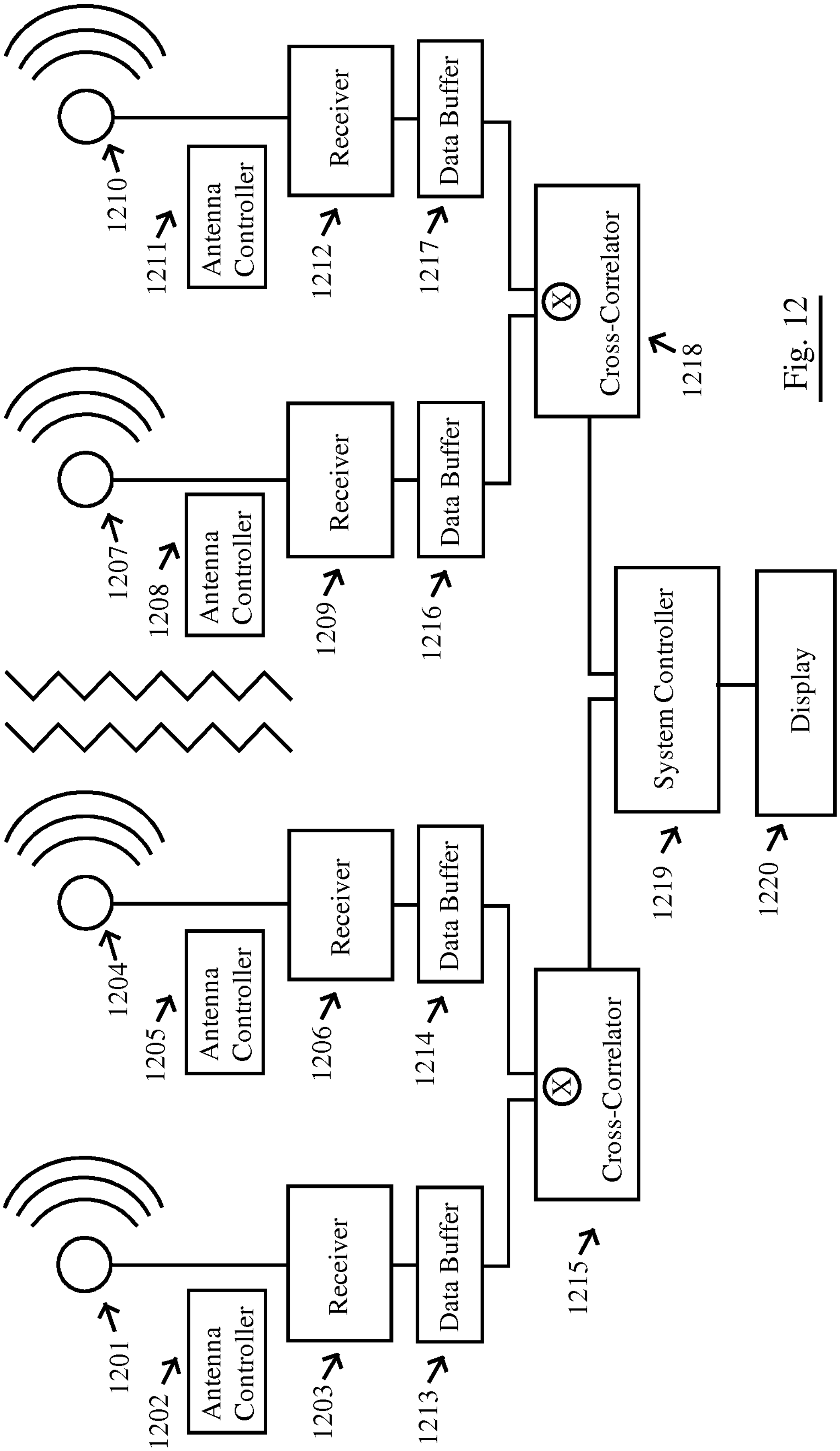

Antenna Controller
Receiver
Data Buffer
Cross-Correlator
System Controller
Display
X
1201
1202
1203
1204
1205
1206
1207
1208
1209
1210
1211
1212
1213
1214
1215
1216
1217
1218
1219
1220

Fig. 12

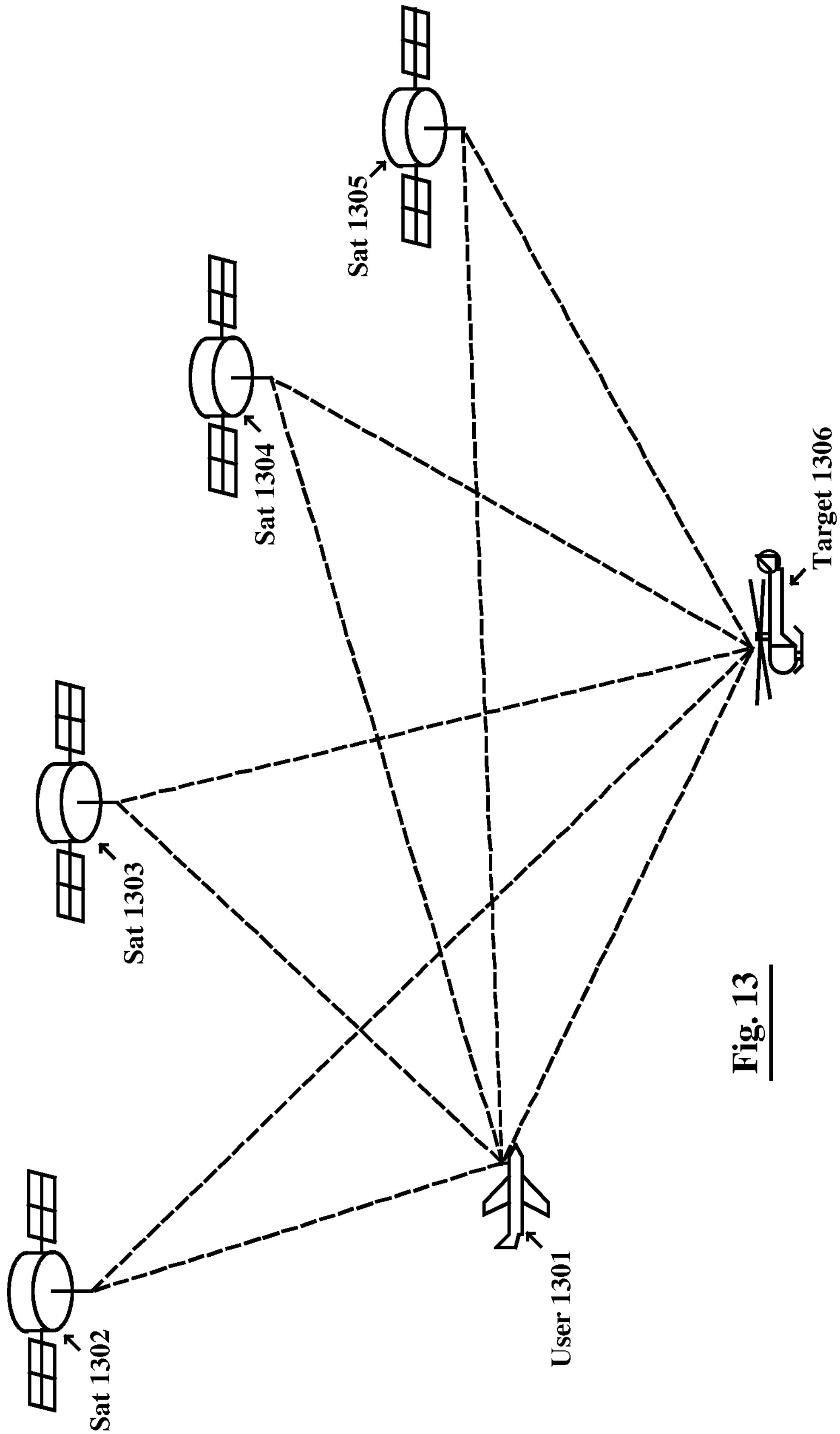


Fig. 13

Fig. 14

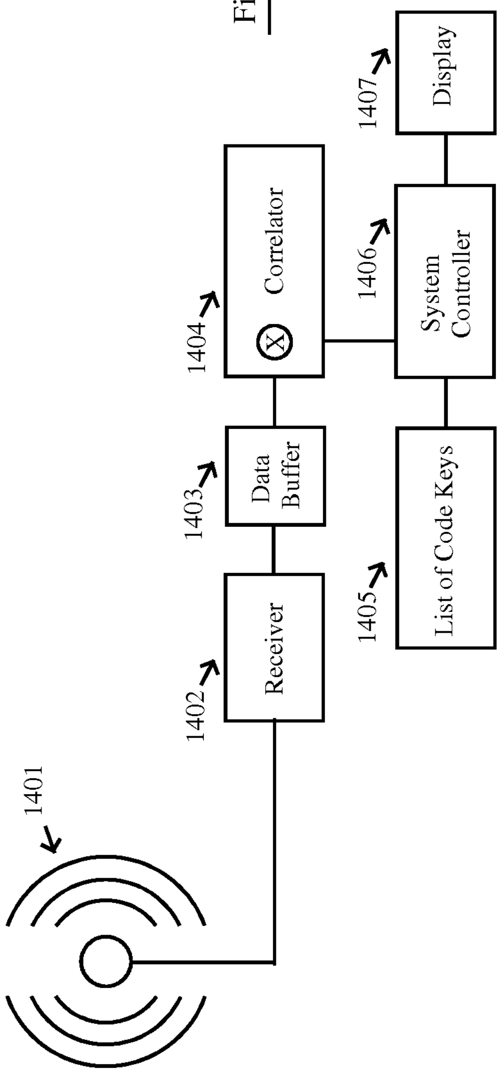
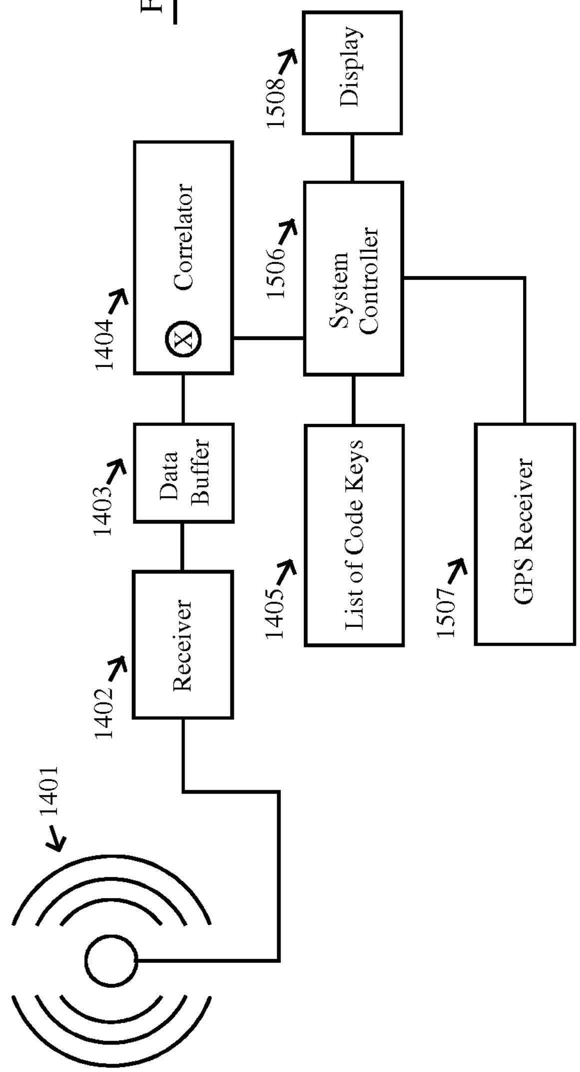
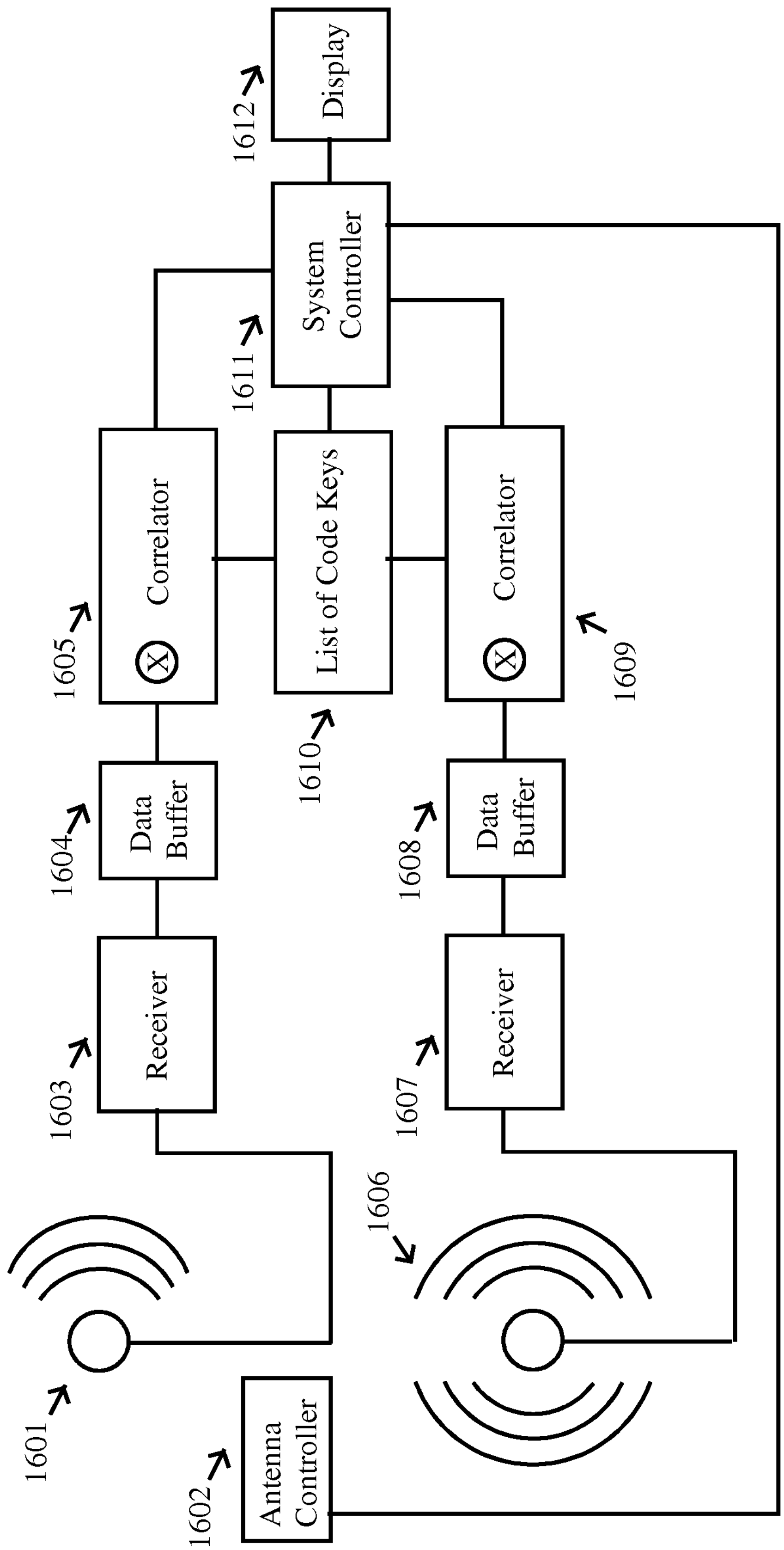

1401
1402
Receiver
1403
Data
Buffer
1404
Correlator
1405
List of Code Keys
1406
System
Controller
1407
Display

Fig. 15


1401
1402
Receiver
1403
Data
Buffer
1404
Correlator
1405
List of Code Keys
1506
System
Controller
1507
GPS Receiver
1508
Display


1612
Display
1611
System Controller
1605
Correlator
X
List of Code Keys
1610
Correlator
X
1609
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Data Buffer
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Receiver
1607
Receiver
1606
1601
1602
Antenna Controller

Fig. 16

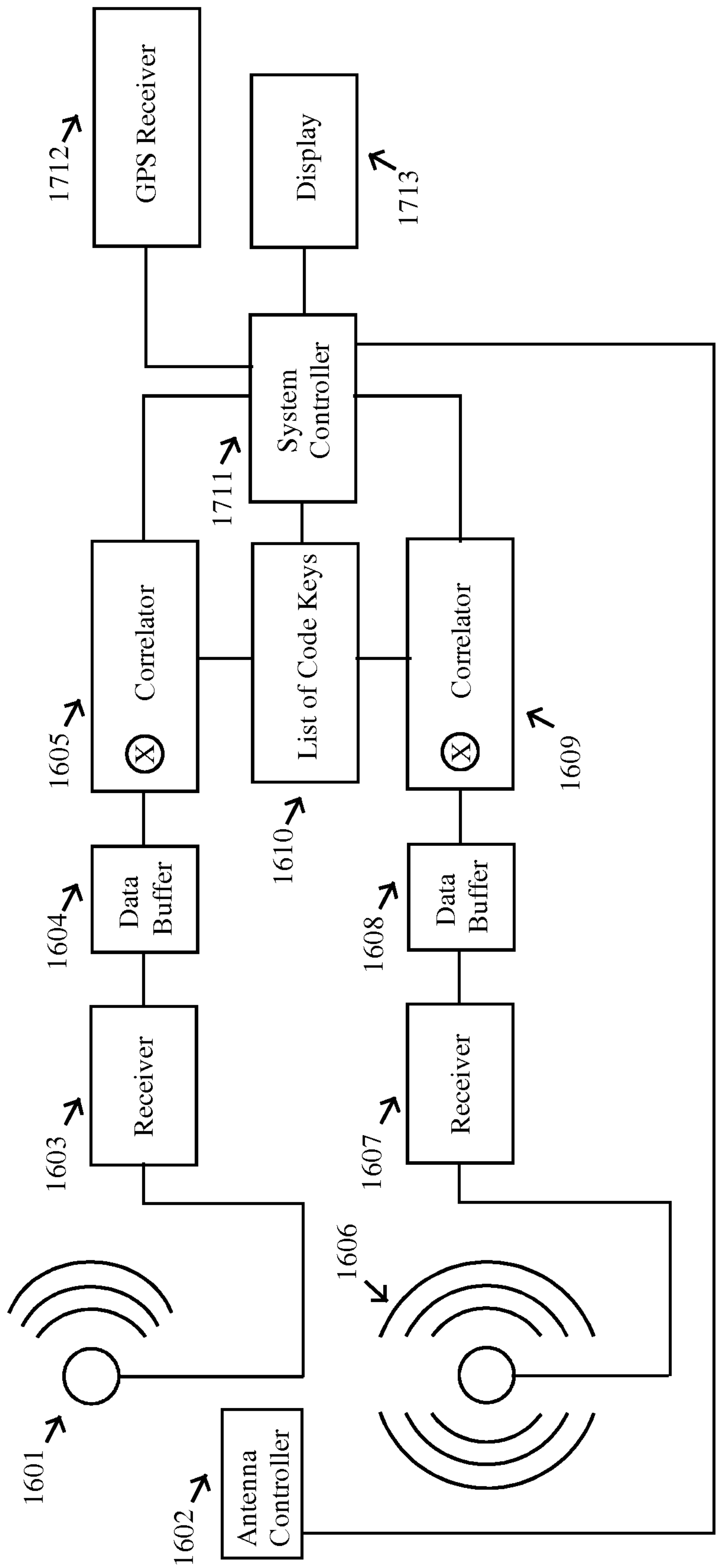
GPS Receiver
1712
Display
1713
System Controller
1711
Correlator
1605
List of Code Keys
1610
Correlator
1609
Data Buffer
1604
Data Buffer
1608
Receiver
1603
Receiver
1607
1606
1601
Antenna Controller
1602

Fig. 17

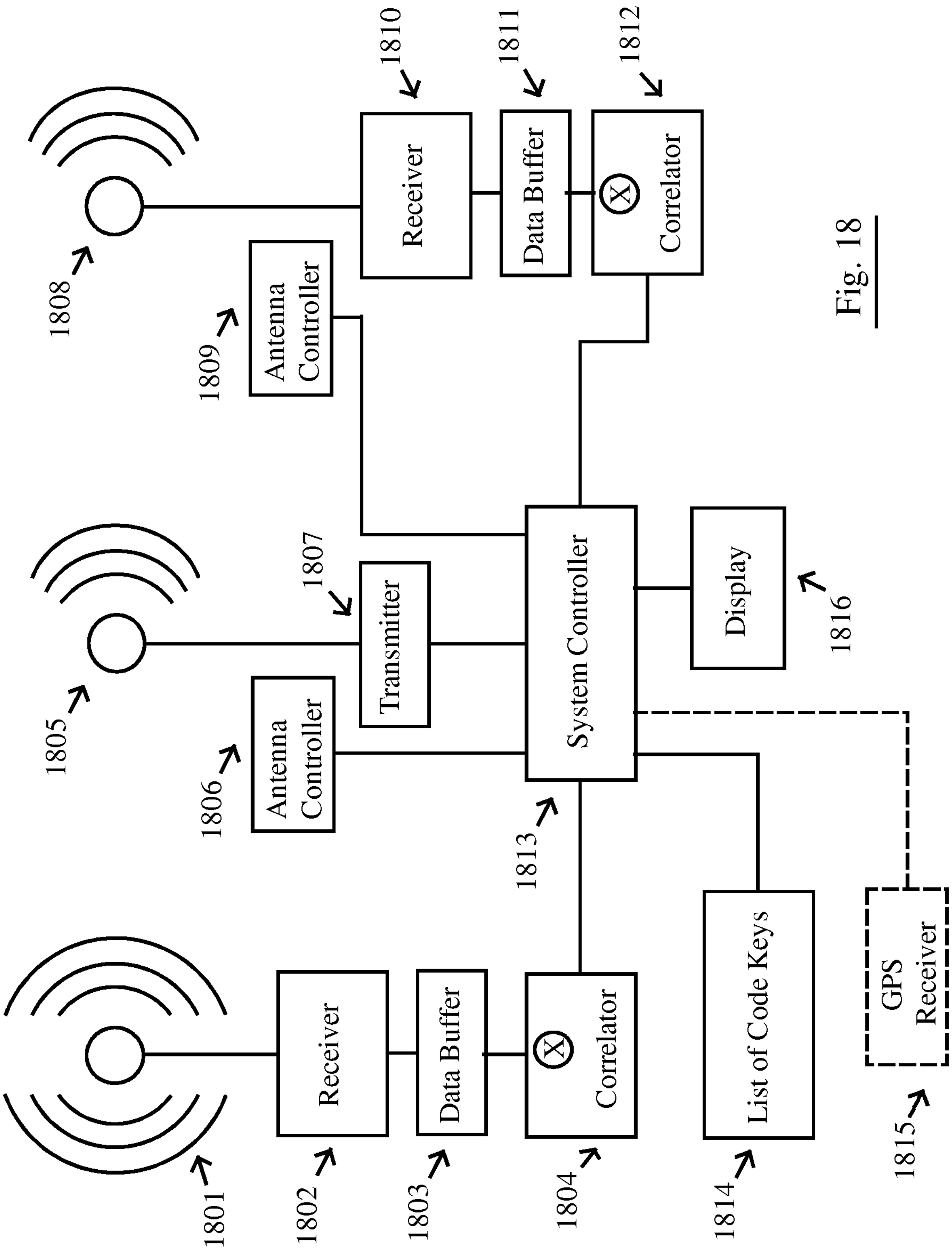
1801
1802
Receiver
1803
Data Buffer
1804
X
Correlator
1813
System Controller
1814
List of Code Keys
1815
GPS
Receiver
1805
1806
Antenna
Controller
1807
Transmitter
1816
Display
1808
1809
Antenna
Controller
1810
Receiver
1811
Data Buffer
1812
X
Correlator

Fig. 18

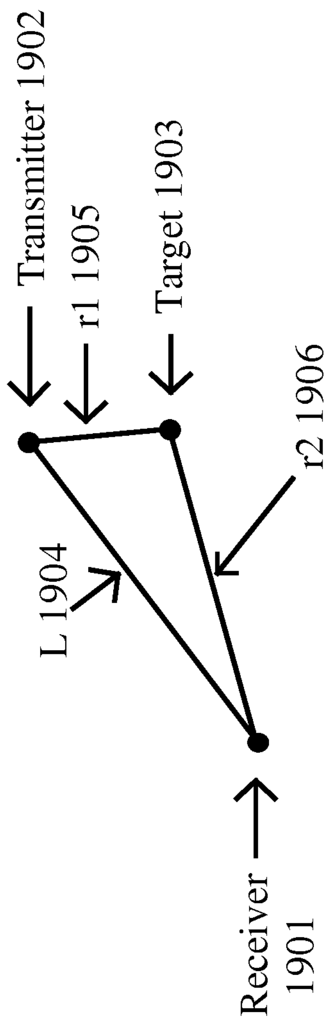
Transmitter 1902
r1 1905
Target 1903
r2 1906
L 1904
Receiver
1901

Fig. 19

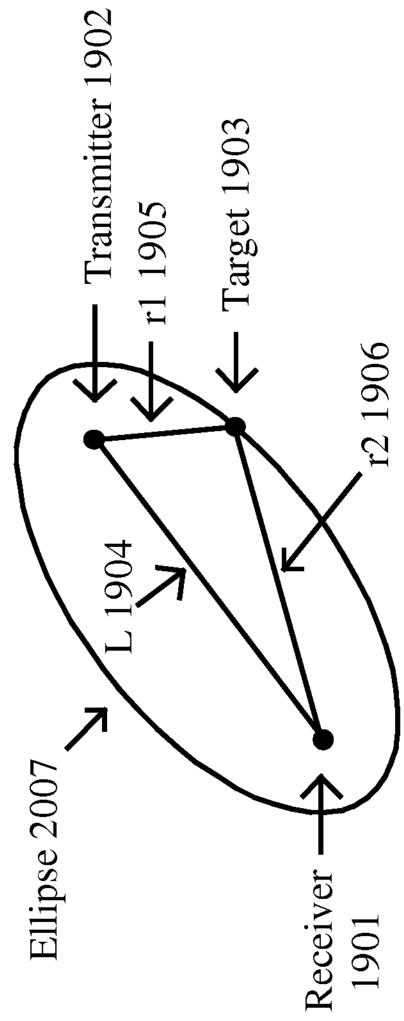
Transmitter 1902
r1 1905
Target 1903
r2 1906
L 1904
Ellipse 2007
Receiver
1901

Fig. 20

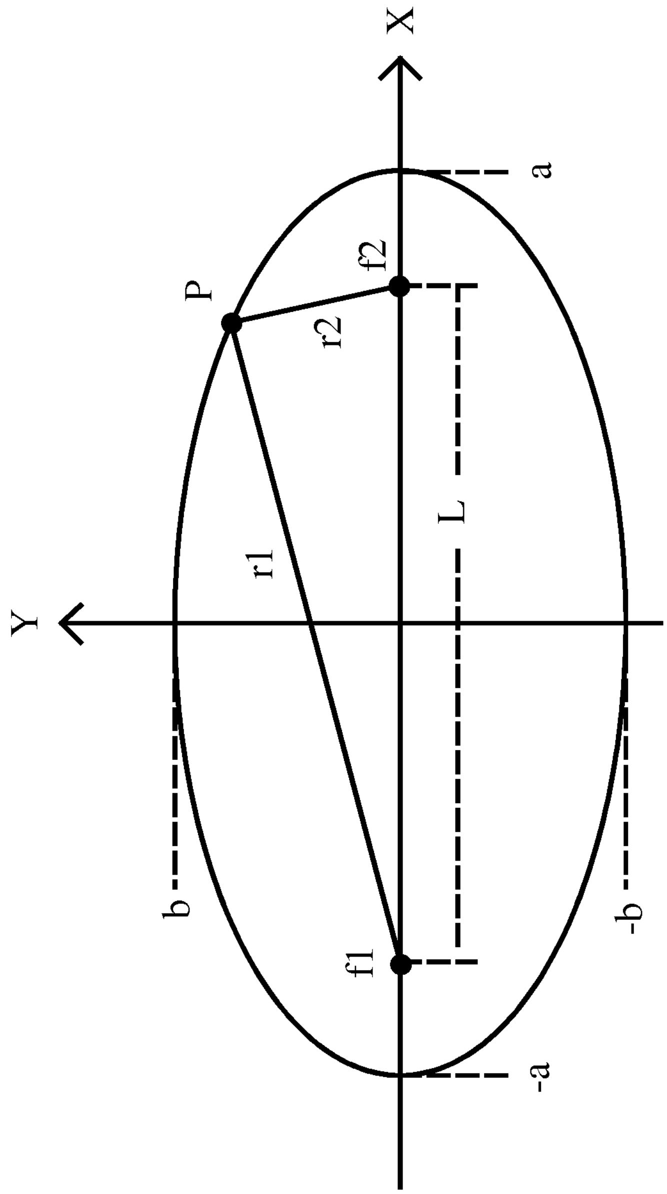

Fig. 21

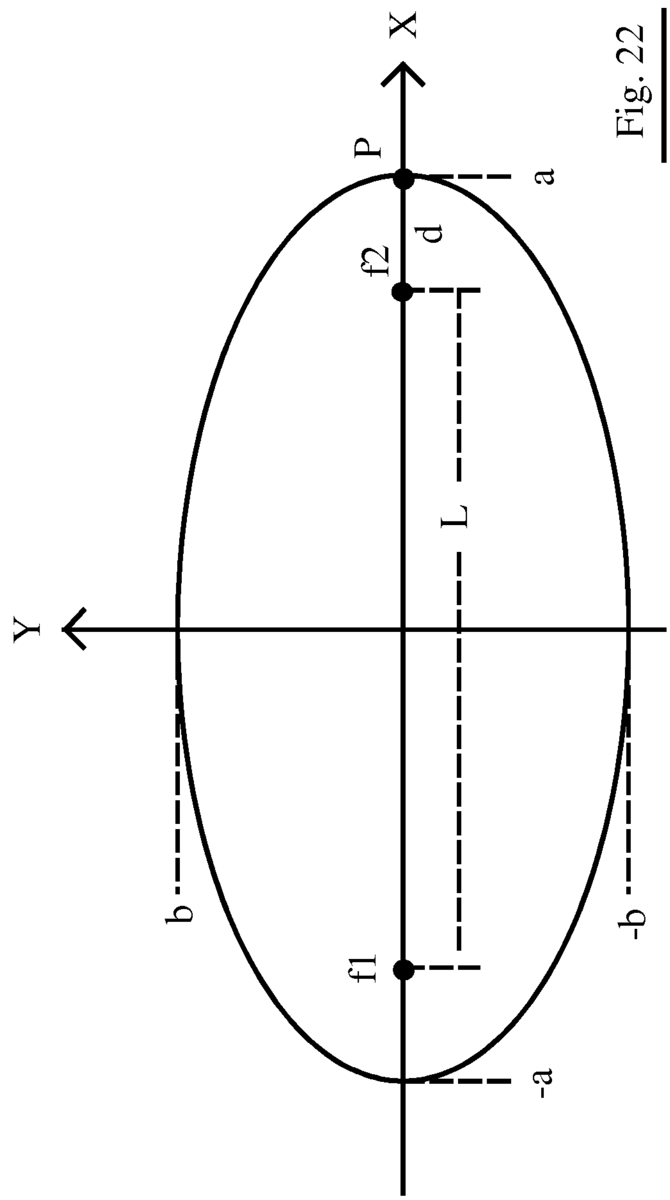

Fig. 22

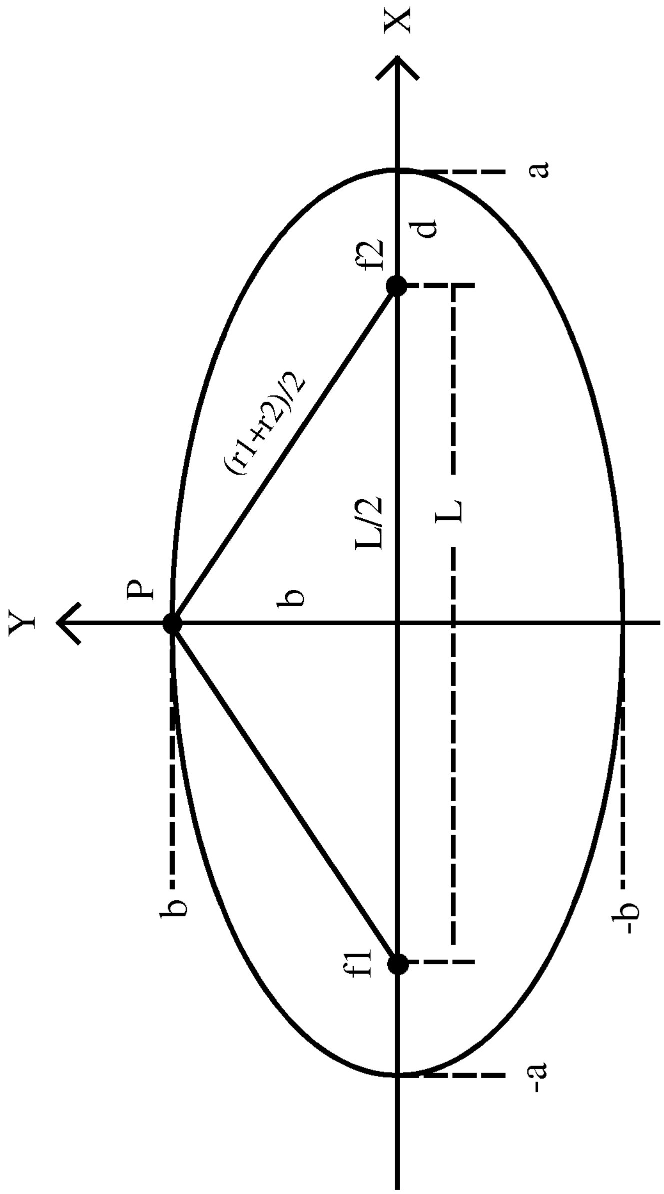

Fig. 23

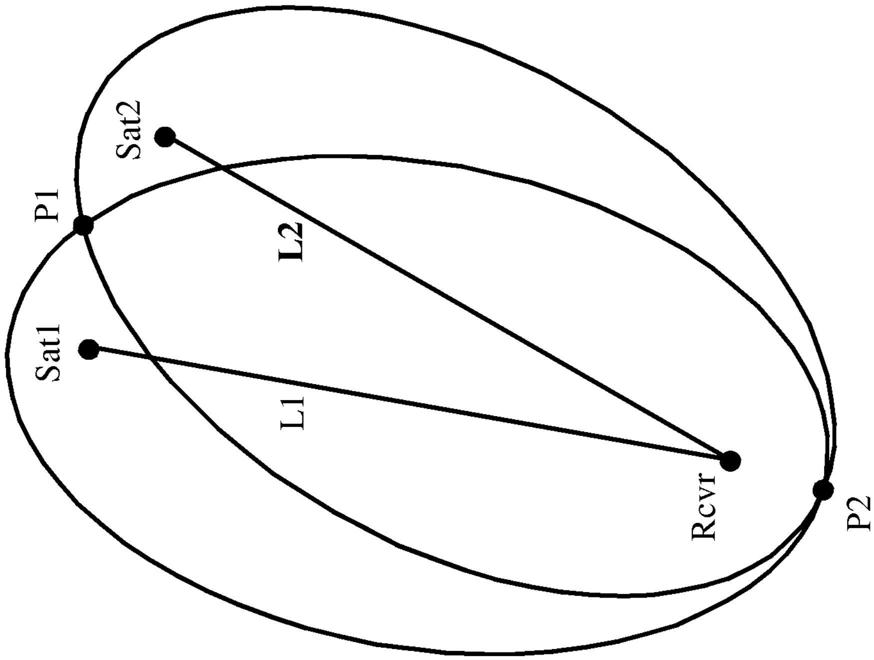

Fig. 25

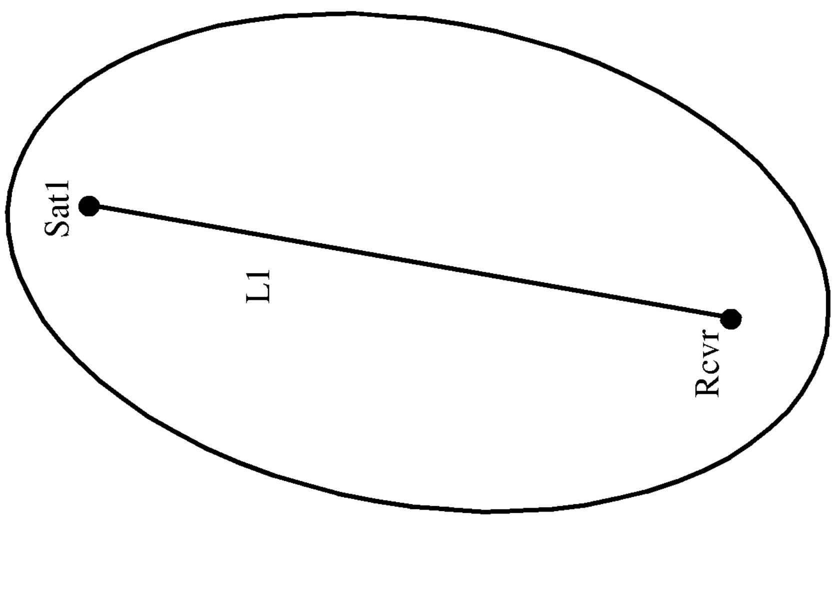

Fig. 24

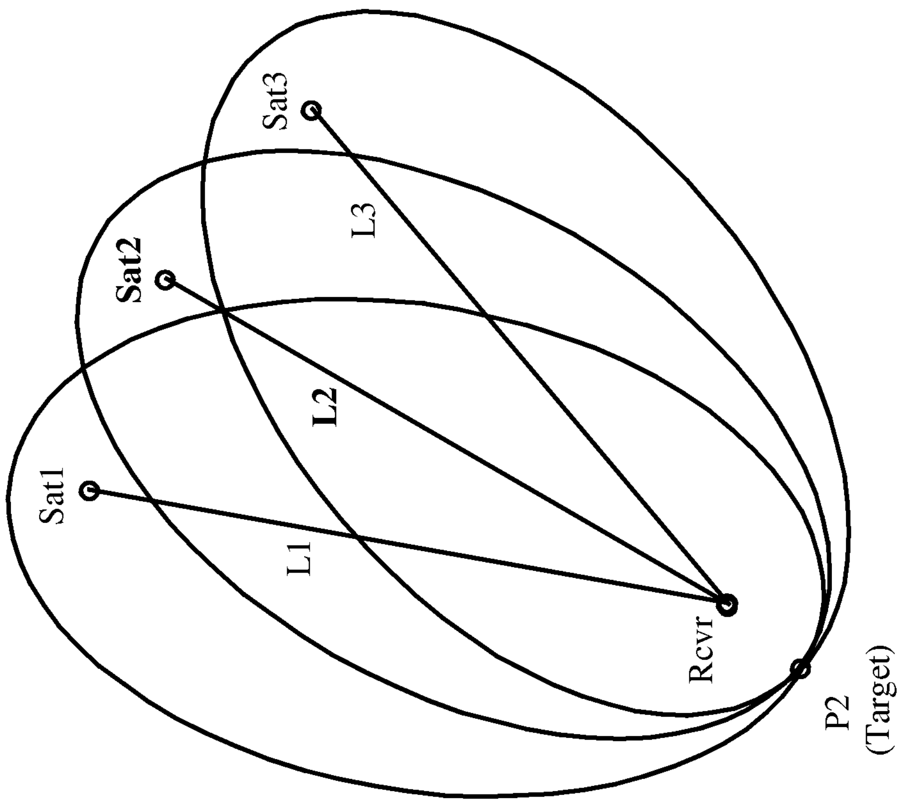

Fig. 26

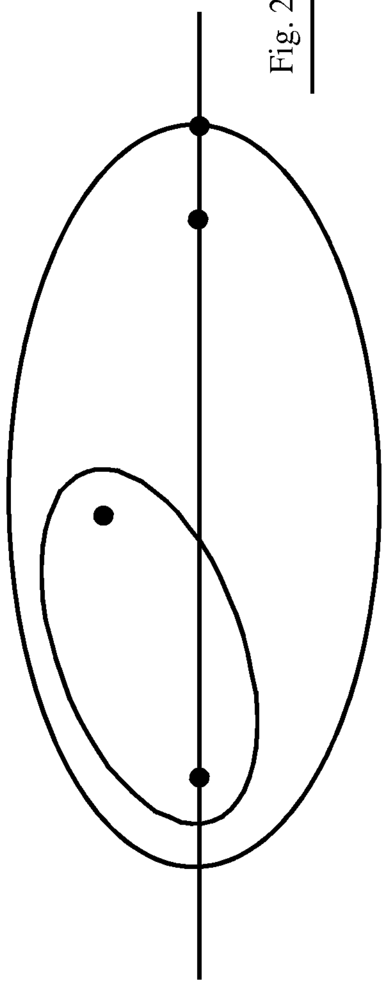

Fig. 27

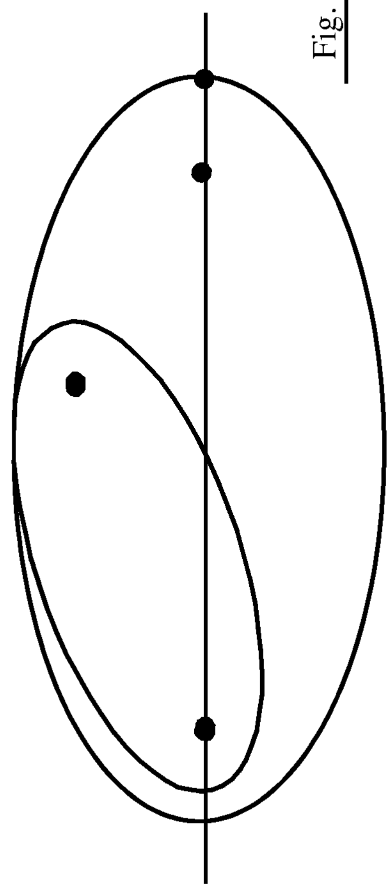

Fig. 28

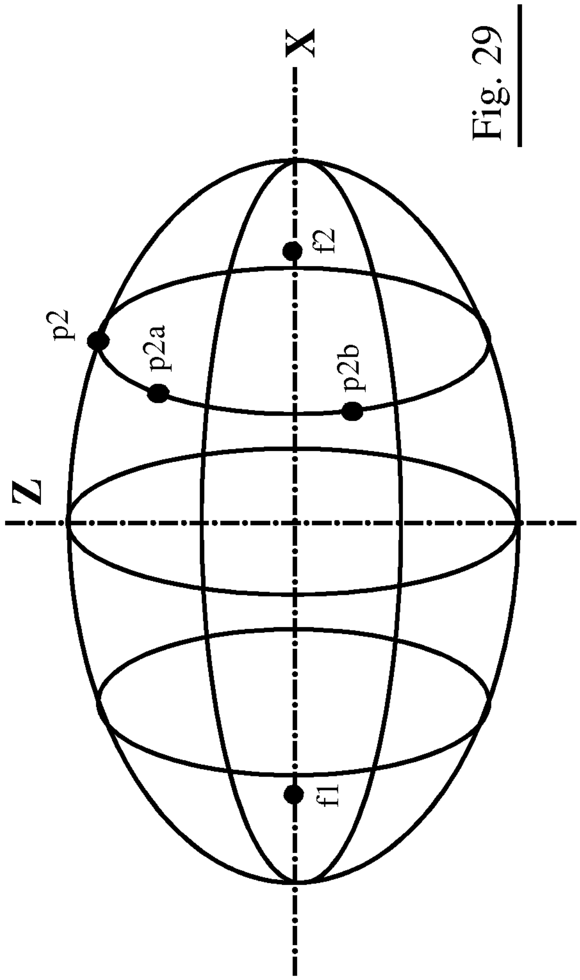

Fig. 29

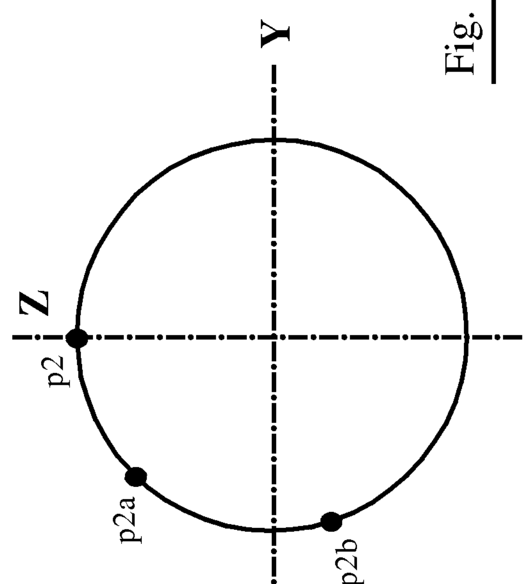

Fig. 30

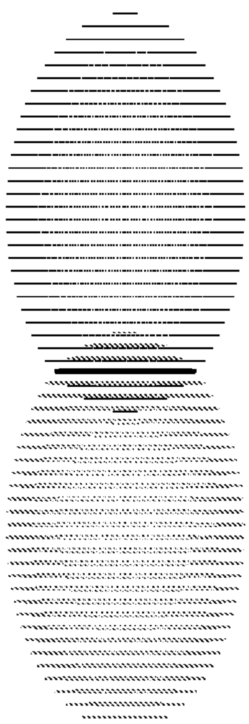

Fig. 31

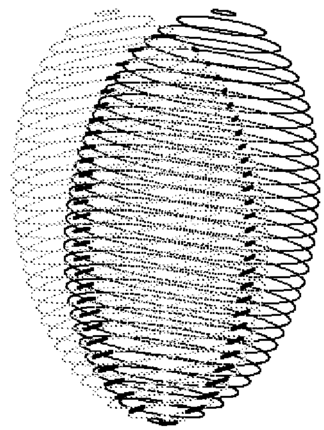

Fig. 33

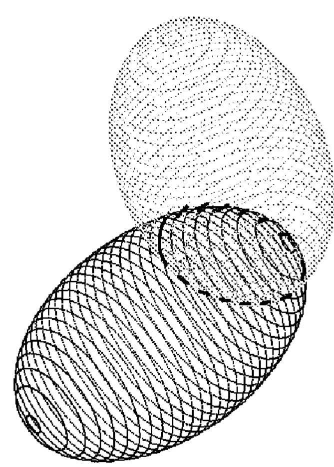

Fig. 32

Electronic Acknowledgement Receipt

EFS ID:	14365954
Application Number:	12910779
International Application Number:	
Confirmation Number:	8875
Title of Invention:	System for sensing aircraft and other objects
First Named Inventor/Applicant Name:	Jed Margolin
Customer Number:	23497
Filer:	Jed Margolin
Filer Authorized By:	
Attorney Docket Number:	
Receipt Date:	03-DEC-2012
Filing Date:	22-OCT-2010
Time Stamp:	14:03:25
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	no

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Supplemental Response or Supplemental Amendment	jm_supplemental_response_all .pdf	549011 9fe662f2db807c0d11ef7dbf67c185910db78518	no	36

Warnings:

Information:

Total Files Size (in bytes):	549011

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New Applications Under 35 U.S.C. 111
If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

National Stage of an International Application under 35 U.S.C. 371
If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

New International Application Filed with the USPTO as a Receiving Office
If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

PTO/SB/06 (07-06)
Approved for use through 1/31/2007. OMB 0651-0032
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

PATENT APPLICATION FEE DETERMINATION RECORD Substitute for Form PTO-875	Application or Docket Number 12/910,779	Filing Date 10/22/2010	☐ To be Mailed

APPLICATION AS FILED – PART I

FOR	NUMBER FILED (Column 1)	NUMBER EXTRA (Column 2)	SMALL ENTITY ☒ RATE ($)	FEE ($)	OR	OTHER THAN SMALL ENTITY RATE ($)	FEE ($)
☐ BASIC FEE (37 CFR 1.16(a), (b), or (c))	N/A	N/A	N/A			N/A	
☐ SEARCH FEE (37 CFR 1.16(k), (i), or (m))	N/A	N/A	N/A			N/A	
☐ EXAMINATION FEE (37 CFR 1.16(o), (p), or (q))	N/A	N/A	N/A			N/A	
TOTAL CLAIMS (37 CFR 1.16(i))	minus 20 =	*	X $ =		OR	X $ =	
INDEPENDENT CLAIMS (37 CFR 1.16(h))	minus 3 =	*	X $ =			X $ =	
☐ APPLICATION SIZE FEE (37 CFR 1.16(s))	If the specification and drawings exceed 100 sheets of paper, the application size fee due is $250 ($125 for small entity) for each additional 50 sheets or fraction thereof. See 35 U.S.C. 41(a)(1)(G) and 37 CFR 1.16(s).						
☐ MULTIPLE DEPENDENT CLAIM PRESENT (37 CFR 1.16(j))							
			TOTAL			TOTAL	

* If the difference in column 1 is less than zero, enter "0" in column 2.

APPLICATION AS AMENDED – PART II

AMENDMENT 12/03/2012	CLAIMS REMAINING AFTER AMENDMENT (Column 1)		HIGHEST NUMBER PREVIOUSLY PAID FOR (Column 2)	PRESENT EXTRA (Column 3)	SMALL ENTITY RATE ($)	ADDITIONAL FEE ($)	OR	OTHER THAN SMALL ENTITY RATE ($)	ADDITIONAL FEE ($)
Total (37 CFR 1.16(i))	* 7	Minus	** 20	= 0	X $31 =	0	OR	X $ =	
Independent (37 CFR 1.16(h))	* 3	Minus	***7	= 0	X $125 =	0	OR	X $ =	
☐ Application Size Fee (37 CFR 1.16(s))									
☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))							OR		
					TOTAL ADD'L FEE	**0**	OR	TOTAL ADD'L FEE	

AMENDMENT	CLAIMS REMAINING AFTER AMENDMENT (Column 1)		HIGHEST NUMBER PREVIOUSLY PAID FOR (Column 2)	PRESENT EXTRA (Column 3)	RATE ($)	ADDITIONAL FEE ($)		RATE ($)	ADDITIONAL FEE ($)
Total (37 CFR 1.16(i))	*	Minus	**	=	X $ =		OR	X $ =	
Independent (37 CFR 1.16(h))	*	Minus	***	=	X $ =		OR	X $ =	
☐ Application Size Fee (37 CFR 1.16(s))									
☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))							OR		
					TOTAL ADD'L FEE		OR	TOTAL ADD'L FEE	

* If the entry in column 1 is less than the entry in column 2, write "0" in column 3.
** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20".
*** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, enter "3".
The "Highest Number Previously Paid For" (Total or Independent) is the highest number found in the appropriate box in column 1.

Legal Instrument Examiner:
/DORIS KING/

This collection of information is required by 37 CFR 1.16. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

If you need assistance in completing the form, call 1-800-PTO-9199 and select option 2.

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application of Jed Margolin

Serial No.: 12/910,779

Filed: 10/22/2010

For: SYSTEM FOR SENSING AIRCRAFT AND OTHER OBJECTS

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Dear Sir:

This is in response to the Office Action mailed 11/13/2012 in which the Examiner:

1. Asked for Applicant's cooperation in correcting any errors he may be aware of in the specification.
2. Rejected claims 7 – 9.
3. Allowed claims 10 – 16.

Applicant responds:

1. After reviewing the specification Applicant has found a minor error in Paragraph 086 (substitute specification filed 11/13/2012) page 23 first full sentence.

> The time delay between when the TCAS Interrogation signal is sent out by TCAS Interrogation Transmitter 105 and when a transponder signal from other aircraft is received by TCAS Transponder Receiver 108 is used to determine the range to the responding aircraft.

2. Claims 7 – 9 are hereby canceled without prejudice. The current claims list is appended.

3. Since claims 10 – 16 have been allowed Applicant's application is now in condition for allowance and Applicant requests that a Notice of Allowance be issued.

In a separate matter, Applicant submitted his drawings in landscape mode but the Patent Office software treated them as being in portrait mode. (See Patent Publication US 2011/0169684.) This resulted in the figures being smaller than Applicant intended and difficult to read. It appears that the Patent Office software cannot handle landscape mode files. (The original files are contained in PAIR in the tab labeled "Supplemental Content - Other Supplemental Content Items – Item ID 09323b6780f6eaea".) Applicant has redone the drawings so that, while the PDF files are in portrait mode, the figures are in landscape mode. Applicant is submitting substitute drawings in hopes that the Patent Office software will handle the drawings so they will appear in the issued patent as Applicant intended. The substitute drawings contain no new matter.

Applicant requests that Figure 13 be used on the front page of the issued patent.

Respectfully submitted,

/Jed Margolin/ Date: November 27, 2012

Jed Margolin

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775-847-7845

Claims

1. (Previously Withdrawn) A system for sensing aircraft and other objects comprising:

(a) an ADS-B transmitter;

(b) an ADS-B receiver;

(c) an ADS-B antenna;

(d) an ADS-B antenna multiplexer;

(e) an ADS-B processor;

(f) a radar processor;

(g) a display;

whereby

(a) said ADS-B antenna multiplexer is controlled by said ADS-B processor and allows said ADS-B antenna to be used by either said ADS-B transmitter or said ADS-B receiver,

(b) said ADS-B processor and said radar processor work together,

(c) said ADS-B processor periodically causes said ADS-B transmitter to emit a transmitted signal through said ADS-B antenna,

(d) said transmitted signal is reflected by a target producing a reflected signal,

(e) said reflected signal is received by said ADS-B antenna and sent to said ADS-B receiver,

(f) said radar processor processes said reflected signal from said ADS-B receiver and said transmitted signal from said ADS-B transmitter to determine a range to said target, and

(g) displays said range on said display.

2. (Previously Withdrawn) The system of claim 1 wherein said radar processor is incorporated into said ADS-B processor.

3. (Previously Withdrawn) A system for sensing aircraft and other objects comprising:

(a) an ADS-B transmitter;

(b) an ADS-B receiver;

(c) an ADS-B antenna;

(d) an ADS-B antenna multiplexer;

(e) an ADS-B processor;

(f) a radar processor;

(g) a second antenna;

(h) an antenna controller;

(i) a second receiver;

(j) a display;

whereby

(a) said second antenna is directional and the direction of said second antenna is controlled by said antenna controller under control of said radar processor,

(b) said ADS-B antenna multiplexer is controlled by said ADS-B processor and allows said ADS-B transmitter to use either said ADS-B antenna or said second antenna and also allows said ADS-B receiver to use either said ADS-B antenna or said second antenna,

(c) said ADS-B processor and said radar processor work together,

(d) said ADS-B processor periodically causes said ADS-B transmitter to emit a transmitted signal through either said ADS-B antenna or said second antenna through said ADS-B antenna multiplexer,

(e) said transmitted signal is reflected by a target producing a reflected signal,

(f) said reflected signal is received by either said ADS-B antenna or said second antenna through said ADS-B antenna multiplexer, which sends said reflected signal to said second receiver,

(g) said radar processor processes said reflected signal from said second receiver and said transmitted signal from said ADS-B transmitter to determine a range to said target,

(h) said radar processor uses the direction of said second antenna to determine a bearing to said target, and

(i) displays said range and said bearing on said display.

4. (Previously Withdrawn) The system of claim 3 wherein said radar processor is incorporated into said ADS-B processor.

5. (Previously Withdrawn) A system for sensing aircraft and other objects comprising:

(a) a TCAS Interrogation transmitter;

(b) a TCAS Interrogation Receiver;

(c) a first TCAS antenna;

(d) a second TCAS antenna;

(e) an antenna controller;

(f) a TCAS antenna diplexer;

(g) a TCAS processor;

(h) a radar processor;

(i) a display;

whereby

(a) said second TCAS antenna is directional and is controlled by said TCAS processor using said antenna controller,

(b) said TCAS processor and said radar processor work together,

(c) said TCAS antenna diplexer is controlled by said TCAS processor and allows said first TCAS antenna to be used by either said TCAS interrogation transmitter or said TCAS interrogation receiver and also allows said second TCAS antenna to be used by either said TCAS interrogation transmitter or said TCAS interrogation receiver,

(d) said TCAS processor periodically causes said TCAS interrogation transmitter to emit a transmitted signal through either said first TCAS antenna or said second TCAS antenna,

(e) said transmitted signal is reflected by a target producing a reflected signal,

(f) said reflected signal is received by either said first TCAS antenna or by said second TCAS antenna and sent to said TCAS interrogation receiver,

(g) said radar processor processes said reflected signal from said TCAS interrogation receiver and said transmitted signal from said TCAS interrogation transmitter to determine a range to said target,

(h) said radar processor uses the direction of said antenna controller to determine a bearing to said target, and

(i) displays said range and said bearing on said display.

6. (Previously Withdrawn) The system of claim 5 wherein said radar processor is incorporated into said TCAS processor.

7. (Canceled) A system for sensing spread-spectrum signals comprising:

(a) a first antenna;

(b) a first receiver for receiving spread-spectrum signals;

(c) a first data buffer;

(d) a second antenna;

(e) a second receiver for receiving spread-spectrum signals;

(f) a second data buffer;

(g) a cross-correlator with two inputs and one or more outputs;

(h) a system controller;

(i) a display;

whereby,

(a) said first antenna is connected to said first receiver,

(b) said first receiver provides data for said first data buffer,

(c) said second antenna is connected to said second receiver,

(d) said second receiver provides data for said second data buffer,

(e) the output of said first data buffer is connected to a first input of said two inputs to said cross-correlator,

(f) the output of said second data buffer is connected to a second input of said two inputs to said cross-correleator,

(g) under the direction of said system controller said cross-correlator performs a cross-correlation between said first input and said second input and produces an output, said output indicating the magnitude of the cross-correlation between a spread-spectrum signal received by both said first receiver and said second receiver,

(h) said one or more outputs of said cross-correlator is displayed on said display,

whereby a high cross-correlation between said first receiver and said second receiver indicates the presence of a spread-spectrum signal.

8. (Canceled) The system of claim 7 further comprising a distance between said first antenna and said second antenna whereby under the direction of said system controller said cross-correlator performs a cross-correlation between said first input and said second input and produces a second output, said second output indicating the phase of the cross-correlation between a spread-spectrum signal received by both said first receiver and said second receiver, and whereby said phase

indicates a bearing to the location of said spread-spectrum signal, and said bearing is displayed on said display.

9. (Canceled) The system of claim 7 further comprising:

(a) a distance between said first antenna and said second antenna;

(b) a first antenna controller for said first antenna;

(c) a second antenna controller for said second antenna;

whereby

(a) said first antenna is a directional antenna,

(b) said second antenna is a directional antenna,

(c) said system controller uses said first antenna controller to control the direction of said first antenna,

(d) said system controller uses said second antenna controller to control the direction of said second antenna,

(e) said system controller coordinates the direction of said first directional antenna with the direction of said second directional antenna to triangulate the source of said spread-spectrum signal to determine a range and a bearing to said spread-spectrum signal, and

(f) said range and said bearing to said spread-spectrum signal are displayed on said display.

10. A system for sensing aircraft and other objects comprising:

(a) four or more orbiting satellites;

(b) an antenna;

(c) a receiver;

(d) a data buffer;

(e) a cross-correlator with two or more inputs and one or more outputs;

(f) a system controller;

(g) a list of code keys;

(h) a display;

wherein

(a) each of said four or more orbiting satellites transmits a signal encoded by a unique code key selected from said list of code keys,

(b) said antenna is connected to said receiver,

(c) the output of said receiver is connected to the input of said data buffer,

(d) the output of said data buffer is connected to a first of said two or more inputs of said cross-correlator,

(e) said system controller provides a second of said two or more inputs of said cross-correlator,

(f) said system controller receives an output of said one or more outputs of said cross-correleator,

and whereby

(a) said system controller uses said signal transmitted by each of said four or more orbiting satellites, said list of code keys, and said cross-correlator to uniquely identify each of said four or more orbiting satellites,

(b) said system controller determines a distance and a direction to each uniquely identified satellite,

(c) said signal from said each uniquely identified satellite is reflected by a target producing a uniquely identifiable reflected signal,

(d) each said uniquely identifiable reflected signal is received by said antenna, which is connected to said receiver, which is connected to said data buffer, which is connected to said first of said two or more inputs of said cross-correlator,

(e) said system controller uses said list of code keys and said cross-correlator to identify each said uniquely identifiable reflected signal,

(f) said system controller uses each said uniquely identifiable reflected signal and said range and said direction to said each uniquely identified satellite to determine a range and a bearing to said target, and

(g) displays said range and said bearing on said display,

and wherein

(a) the range and direction to a first of said four or more orbiting satellites and the signal from said first of said four or more orbiting satellites reflected from said target produce a first ellipsoid with said first of said four or more orbiting satellites at one focal point of said first ellipsoid, said antenna at the other focal point of said first ellipsoid, and said target on the surface of said first ellipsoid,

(b) the range and direction to a second of said four or more orbiting satellites and the signal from said second of said four or more orbiting satellites reflected from said target produce a second ellipsoid with said second of said four or more orbiting satellites at one focal point of said second ellipsoid, said antenna at the other focal point of said second ellipsoid, and said target on the surface of said second ellipsoid,

(c) the range and direction to a third of said four or more orbiting satellites and the signal from said third of said four or more orbiting satellites reflected from said target produce a third ellipsoid with said third of said four or more orbiting satellites at one focal point of said third ellipsoid, said antenna at the other focal point of said third ellipsoid, and said target on the surface of said third ellipsoid,

(d) the range and direction to a fourth of said four or more orbiting satellites and the signal from said fourth of said four or more orbiting satellites reflected from said target produce a fourth ellipsoid with said fourth of said four or more orbiting satellites at one focal point of said fourth ellipsoid, said antenna at the other focal point of said fourth ellipsoid, and said target on the surface of said fourth ellipsoid,

(e) said first ellipsoid and said second ellipsoid intersect in an ellipse with said target located on said ellipse,

(f) said third ellipsoid and said ellipse intersect at two points with said target located at one of said two points,

(g) said fourth ellipsoid intersects with only one of said two points with said target located at said only one of said two points.

11. The system of claim 10 further comprising communications links between each of said four or more orbiting satellites.

12. The system of claim 10 wherein at least one of said four or more orbiting satellites is located in low earth orbit.

13. The system of claim 10 further comprising:

(a) a receiver in each of said four or more orbiting satellites;

(b) a transmitter;

whereby said receiver in each of said four or more orbiting satellites and said transmitter are used to send transmissions to at least one of said four or more orbiting satellites in order to provide two-way communications through said at least one of said four or more orbiting satellites.

14. The system of claim 11 further comprising a satellite receiver in at least two or more of said four or more orbiting satellites whereby a signal transmitted by said at least two or more of said four or more orbiting satellites and said satellite receiver are used to perform long baseline radar interferometric measurements of terrain elevations.

15. A system for sensing aircraft and other objects comprising:

(a) one or more orbiting satellites;

(b) a first antenna;

(c) a second antenna;

(d) a controller for said second antenna;

(e) an antenna multiplexer;

(f) a receiver;

(g) a data buffer;

(h) a cross-correlator with two or more inputs and one or more outputs;

(i) a system controller;

(j) a list of code keys;

(k) a display;

wherein

(a) said antenna multiplexer selects between said first antenna and said second antenna under control of said system controller,

(b) the output of said antenna multiplexer is connected to the input of said receiver,

(c) said second antenna is directional and is controlled by said antenna controller under control of said system controller,

(d) the output of said receiver is connected to the input of said data buffer,

(e) the output of said data buffer is connected to a first of said two or more inputs of said cross-correlator,

(f) said system controller provides a second of said two or more inputs of said cross-correlator,

(g) said system controller receives an output of said one or more outputs of said cross-correleator,

and whereby

(a) said first antenna is selected by said system controller,

(b) said one or more orbiting satellites transmits a signal encoded by a unique code key selected from said list of code keys,

(c) said system controller uses said signal transmitted by said one or more orbiting satellites, said list of code keys, and said cross-correlator to uniquely identify said one or more orbiting satellites,

(d) said system controller determines a distance to a uniquely identified satellite,

(e) said signal from said uniquely identified satellite is reflected by a target producing a uniquely identifiable reflected signal,

(f) said uniquely identifiable reflected signal is received by said second antenna, which is connected to said receiver, which is connected to said data buffer, which is connected to said first of said two or more inputs of said cross-correlator,

(g) said system controller uses said list of code keys and said cross-correlator to identify said uniquely identifiable reflected signal,

(h) said system controller uses said antenna controller to direct said second antenna at the source of said uniquely identifiable reflected signal to produce a bearing to said uniquely identifiable reflected signal,

(i) said system controller uses said uniquely identifiable reflected signal and said range to said uniquely identified satellite to determine a range and a bearing to said target, and

(j) displays said range and said bearing on said display,

and wherein

(a) the range and direction to said one or more orbiting satellites and the signal from said one or more orbiting satellites reflected from said target produces an ellipsoid with said one or more orbiting satellites at one focal point of said ellipsoid, said antenna at the other focal point of said ellipsoid, and said target on the surface of said ellipsoid,

(b) said second antenna is aimed to receive said signal from said one or more orbiting satellites reflected from said target, and

(c) the direction of said second antenna is used to determine the location of said target on said ellipsoid.

16. A system for sensing aircraft and other objects during daytime comprising:

(a) a first directional antenna;

(b) a first antenna controller;

(c) a first receiver;

(d) a first data buffer;

(e) a second directional antenna;

(f) a second antenna controller;

(g) a second receiver;

(h) a second data buffer;

(i) a cross-correlator;

(j) a system controller;

(k) a display;

whereby

(a) the position of said first directional antenna is controlled by said first antenna controller under the control of said system controller,

(b) the position of said second directional antenna is controlled by said second antenna controller under the control of said system controller,

(c) said cross-correlator has two inputs and one output,

(d) said first directional antenna is connected to the input of said first receiver,

(e) the output of said first receiver is connected to the input of said first data buffer,

(f) the output of said first data buffer is connected to a first input of said cross-correlator under control of said system controller,

(g) said second directional antenna is connected to the input of said second receiver,

(h) the output of said second receiver is connected to the input of said second data buffer,

(i) the output of said second data buffer is connected to a second input of said cross-correlator under control of said system controller,

(j) said system controller directs said first antenna controller to point said first directional antenna at the Sun to produce a first signal,

(k) said system controller directs said cross-correlator to perform a cross-correlation between said first received from said first directional antenna which is stored in said first data buffer and a second signal received from said second directional antenna which is stored in said second data buffer,

(l) said system controller directs said second antenna controller to point said second directional antenna to produce said second signal to maximize said output of said cross-correlator where said second directional antenna is not pointed at said Sun,

whereas

(a) said second signal is a reflection of said first signal produced by said Sun, said reflection being produced by a target,

(b) a time delay between said first signal and said second signal is used to determine an ellipsoid with said first directional antenna located at one focal point of said ellipsoid, said Sun located at the other focal point of said ellipsoid and said target on the surface of said ellipsoid,

(c) the direction of said second directional antenna is used to determine the location of said target on said ellipsoid,

(d) said system controller uses said location of said target on said ellipsoid to produce a range and a bearing to said target, and

(e) displays said range and said bearing on said display.

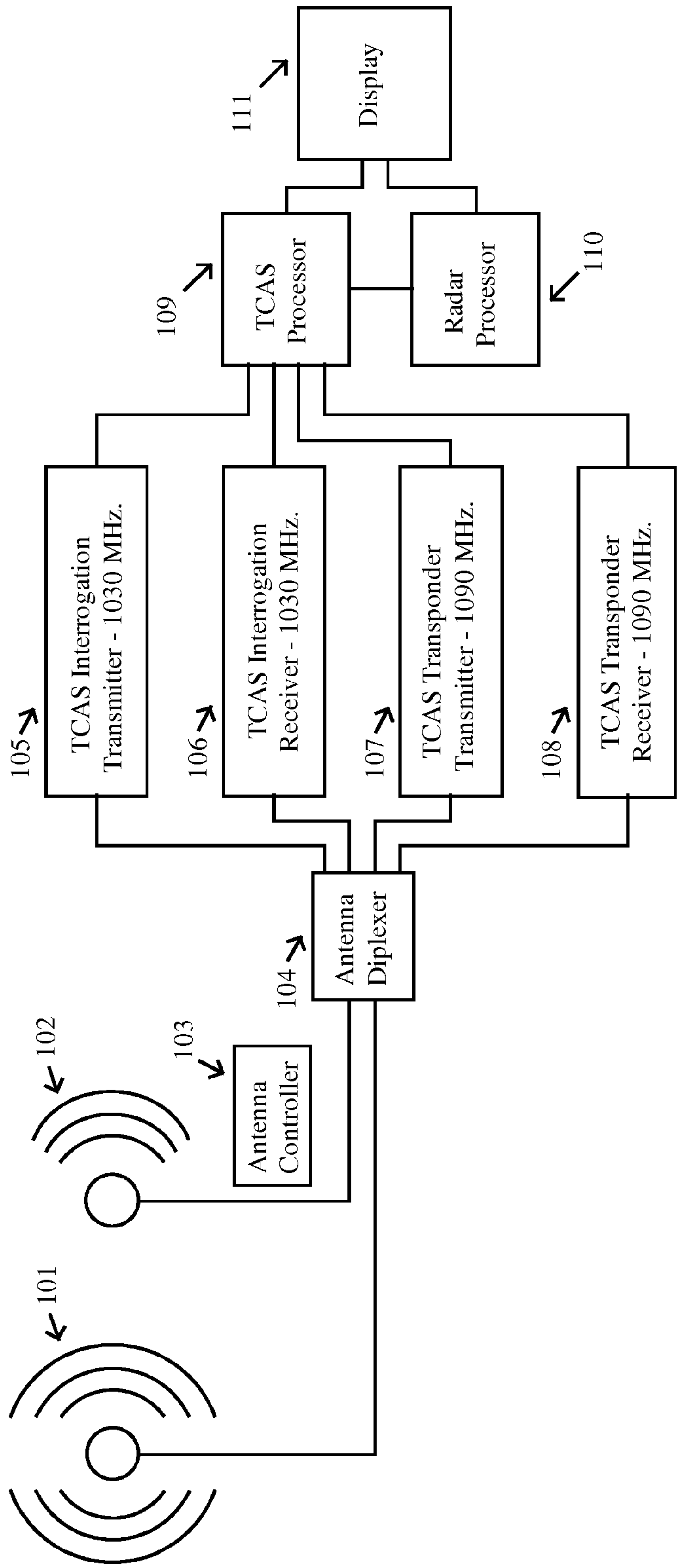

101
102
103
Antenna Controller
104
Antenna Diplexer
105
TCAS Interrogation Transmitter - 1030 MHz.
106
TCAS Interrogation Receiver - 1030 MHz.
107
TCAS Transponder Transmitter - 1090 MHz.
108
TCAS Transponder Receiver - 1090 MHz.
109
TCAS Processor
110
Radar Processor
111
Display

Fig. 1

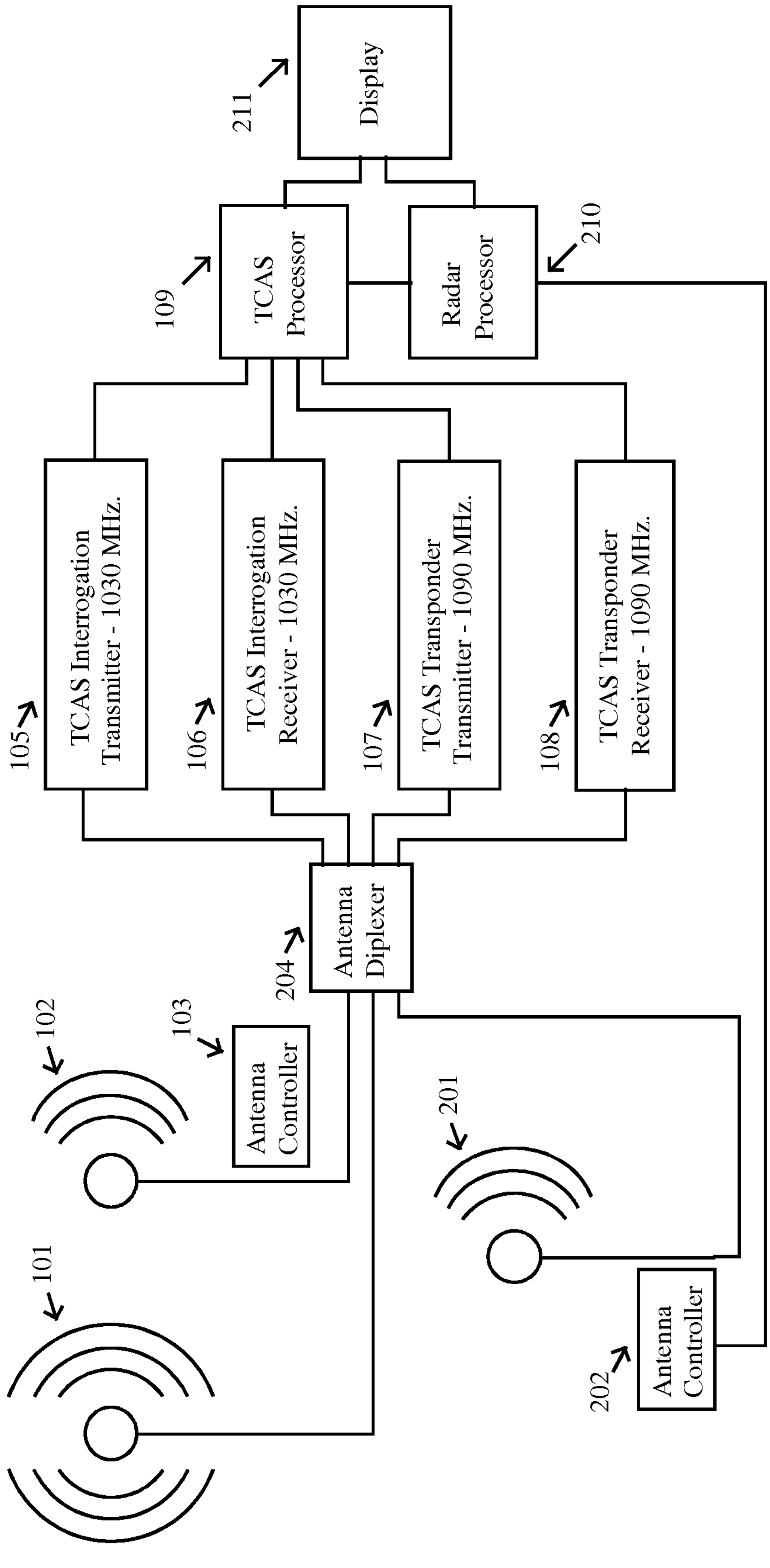

211
Display
109
TCAS Processor
Radar Processor
210
105
TCAS Interrogation Transmitter - 1030 MHz.
106
TCAS Interrogation Receiver - 1030 MHz.
107
TCAS Transponder Transmitter - 1090 MHz.
108
TCAS Transponder Receiver - 1090 MHz.
204
Antenna Diplexer
102
103
Antenna Controller
101
201
202
Antenna Controller

Fig. 2

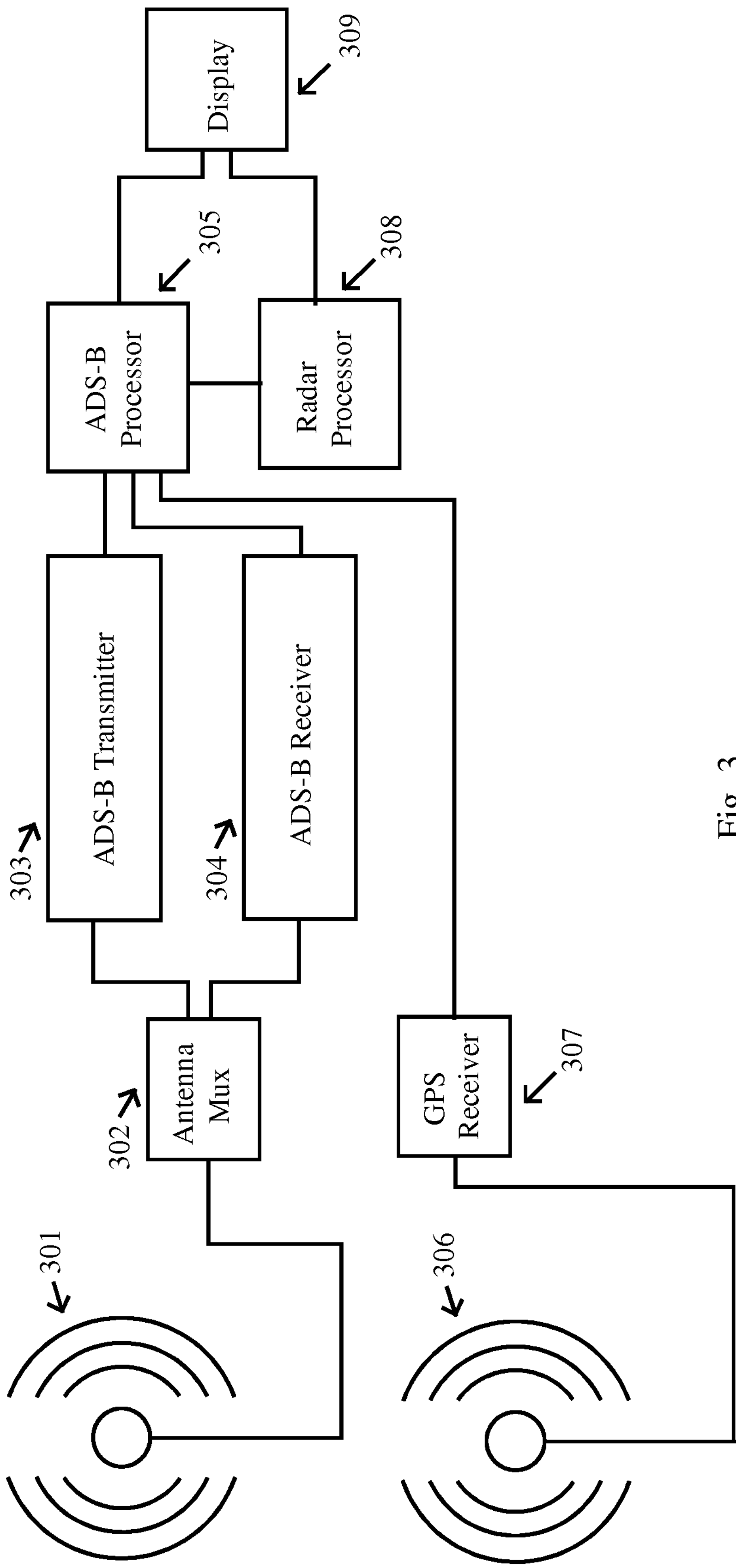

Display
309
305
308
ADS-B Processor
Radar Processor
ADS-B Transmitter
ADS-B Receiver
303
304
Antenna Mux
302
GPS Receiver
307
301
306

Fig. 3

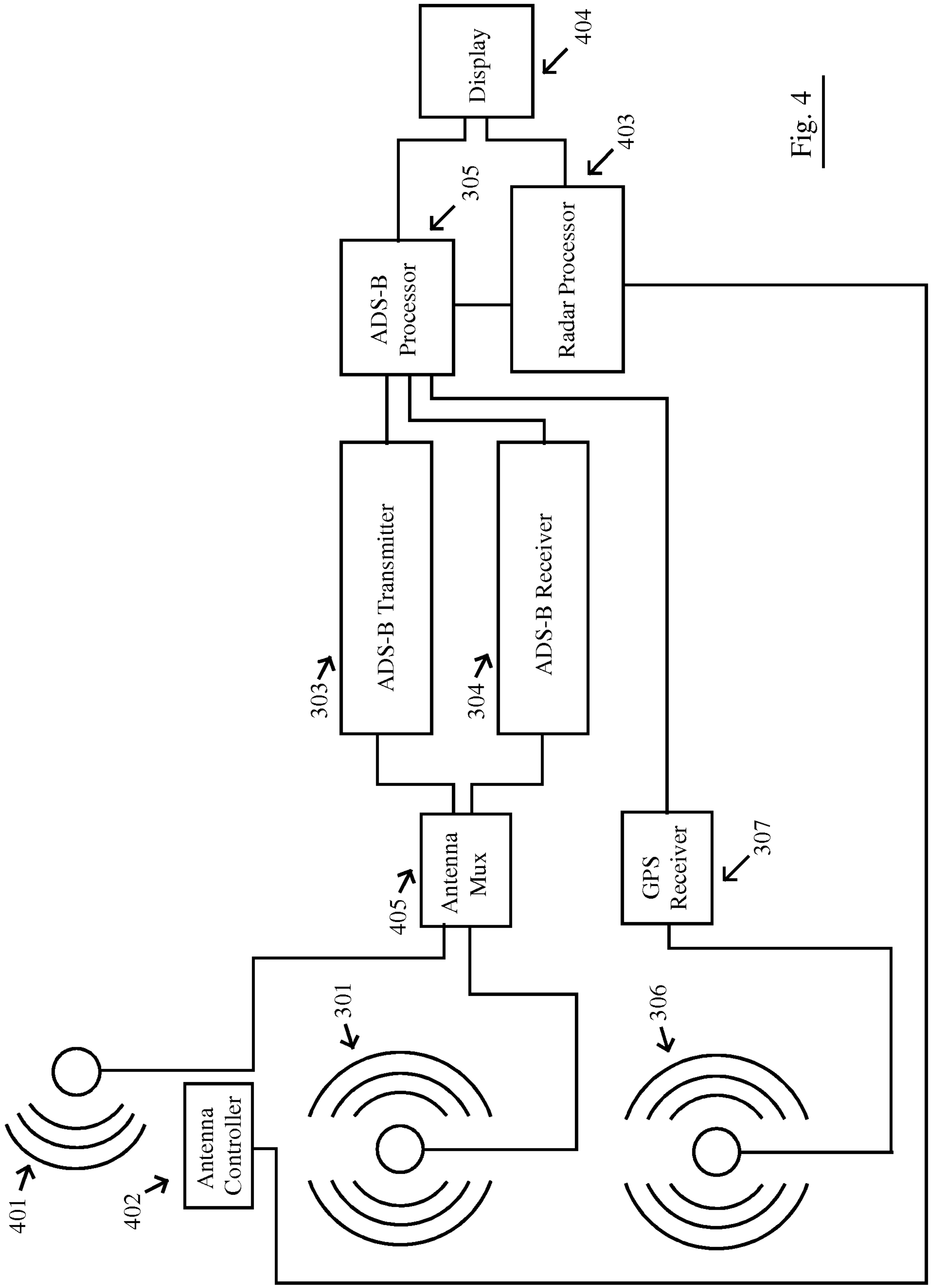

Display
404
403
305
ADS-B Processor
Radar Processor
ADS-B Transmitter
ADS-B Receiver
303
304
Antenna Mux
405
GPS Receiver
307
301
306
401
402
Antenna Controller

Fig. 4

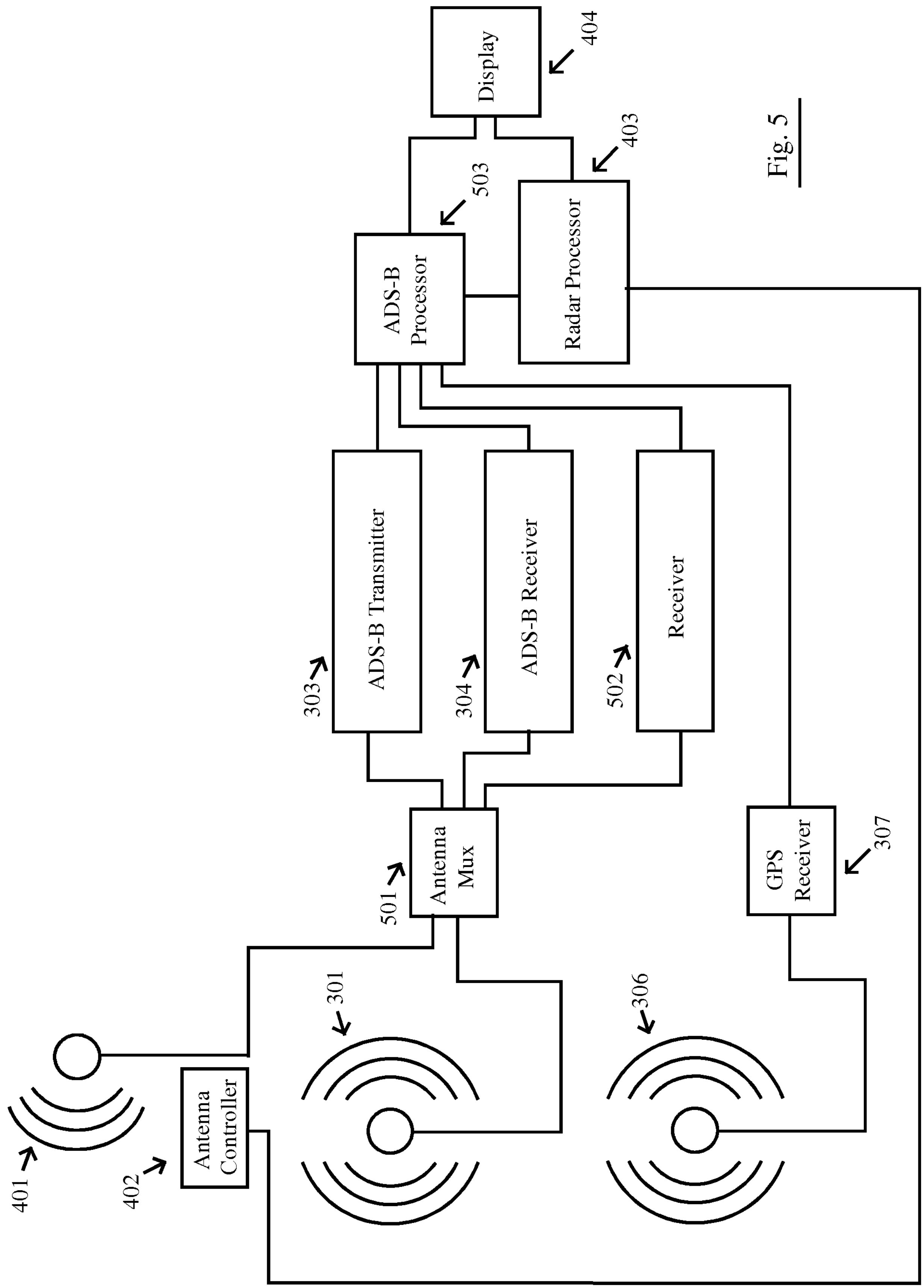

Display
404
503
403
ADS-B Processor
Radar Processor
ADS-B Transmitter
ADS-B Receiver
Receiver
303
304
502
Antenna Mux
501
GPS Receiver
307
301
306
Antenna Controller
401
402

Fig. 5

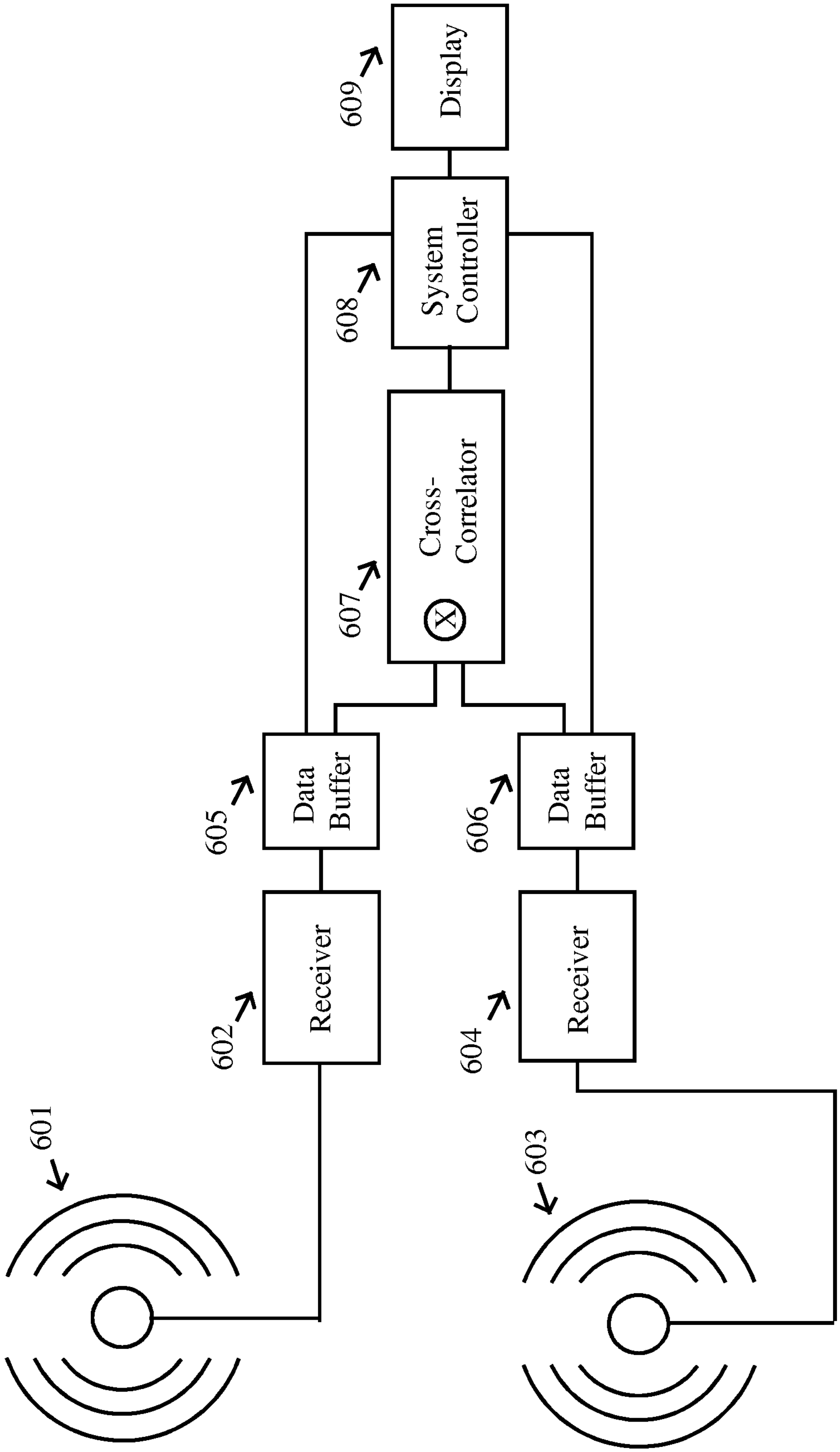

601
602
Receiver
605
Data Buffer
603
604
Receiver
606
Data Buffer
607
X
Cross-Correlator
608
System Controller
609
Display

Fig. 6

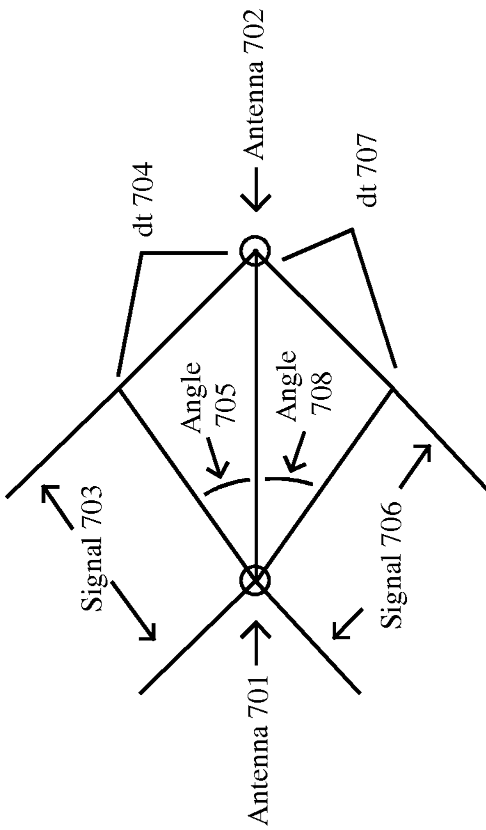

Antenna 702
dt 704
dt 707
Angle 705
Angle 708
Signal 703
Signal 706
Antenna 701

Fig. 7

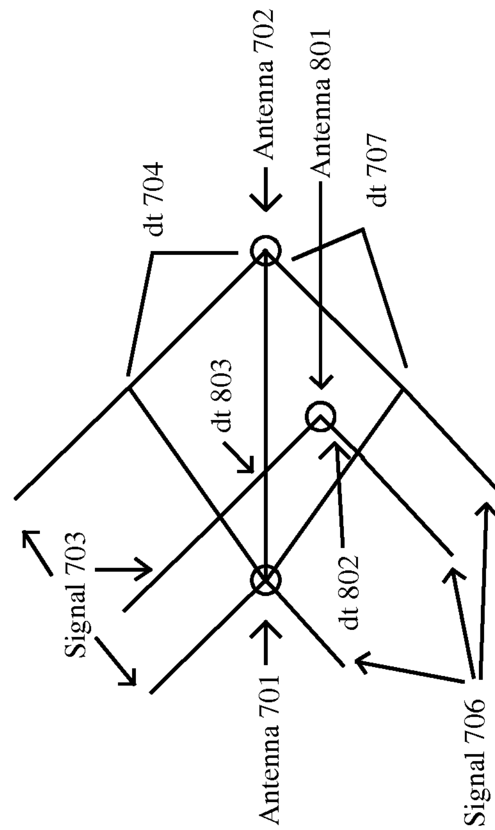

Antenna 702
Antenna 801
dt 704
dt 707
dt 803
dt 802
Signal 703
Signal 706
Antenna 701

Fig. 8

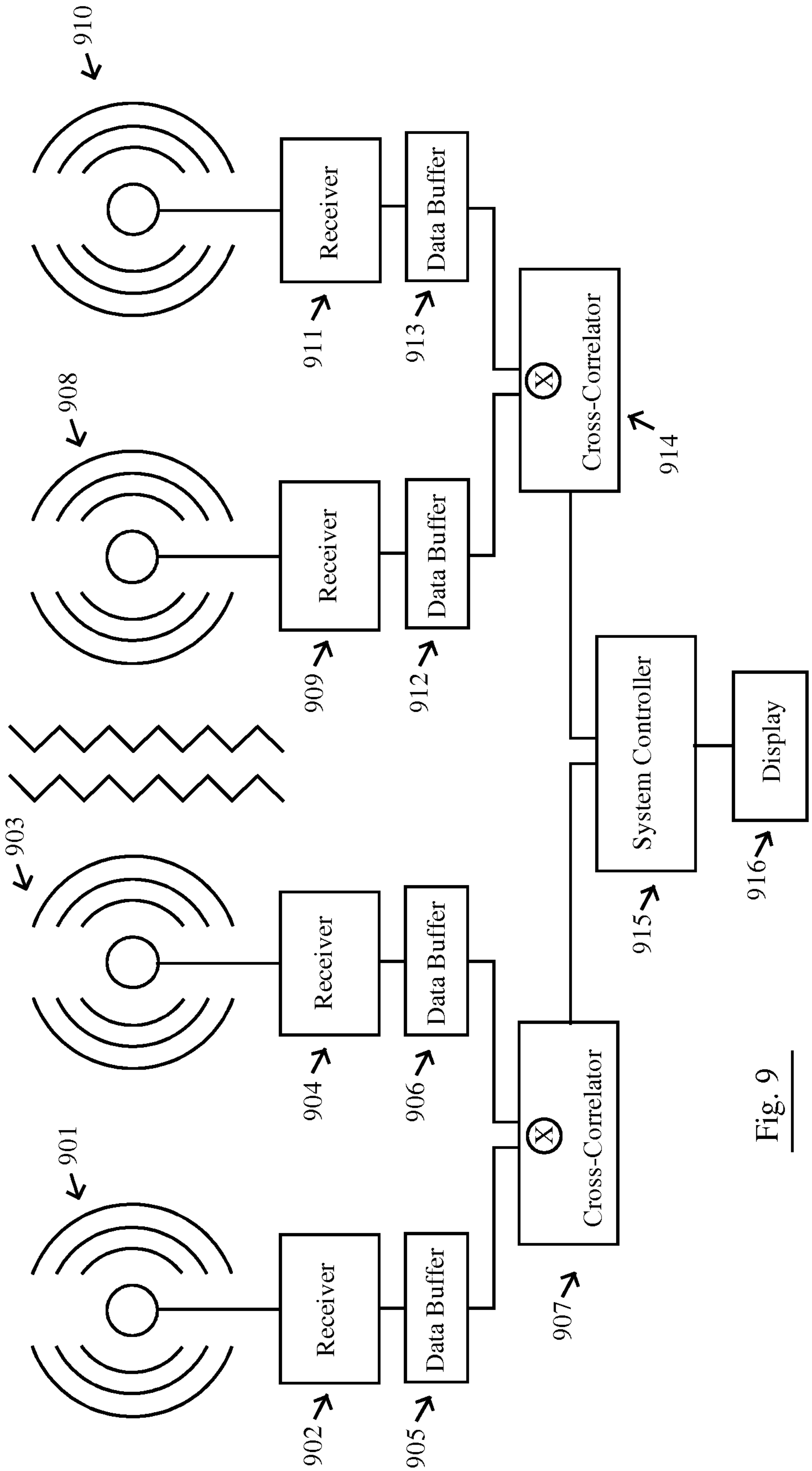

910
908
903
901
Receiver
Receiver
Receiver
Receiver
Data Buffer
Data Buffer
Data Buffer
Data Buffer
911
913
909
912
904
906
902
905
Cross-Correlator
Cross-Correlator
914
907
System Controller
915
Display
916

Fig. 9

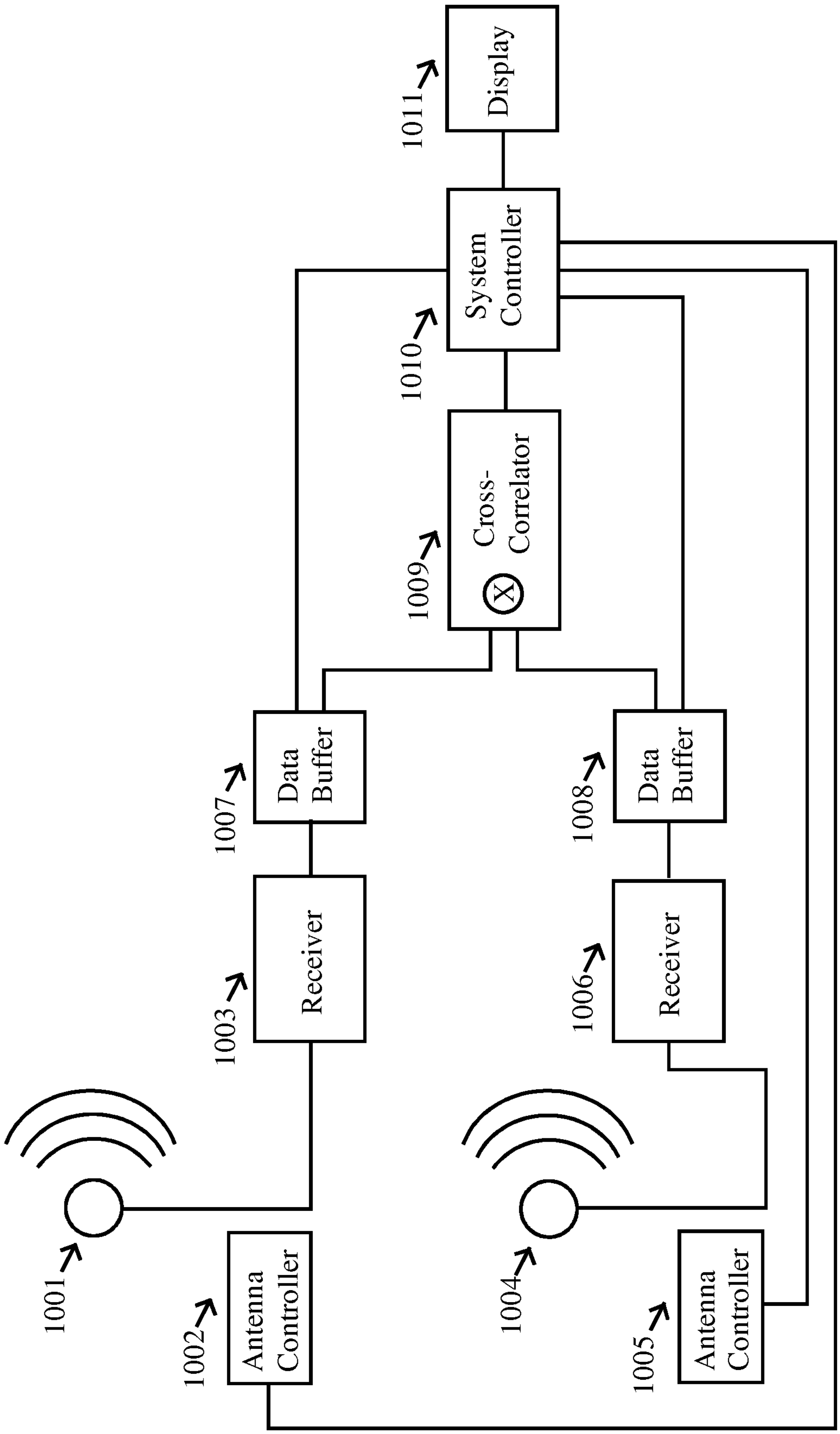

1011
Display
1010
System Controller
1009
Cross-Correlator
X
1007
Data Buffer
1008
Data Buffer
1003
Receiver
1006
Receiver
1001
1004
1002
Antenna Controller
1005
Antenna Controller

Fig. 10

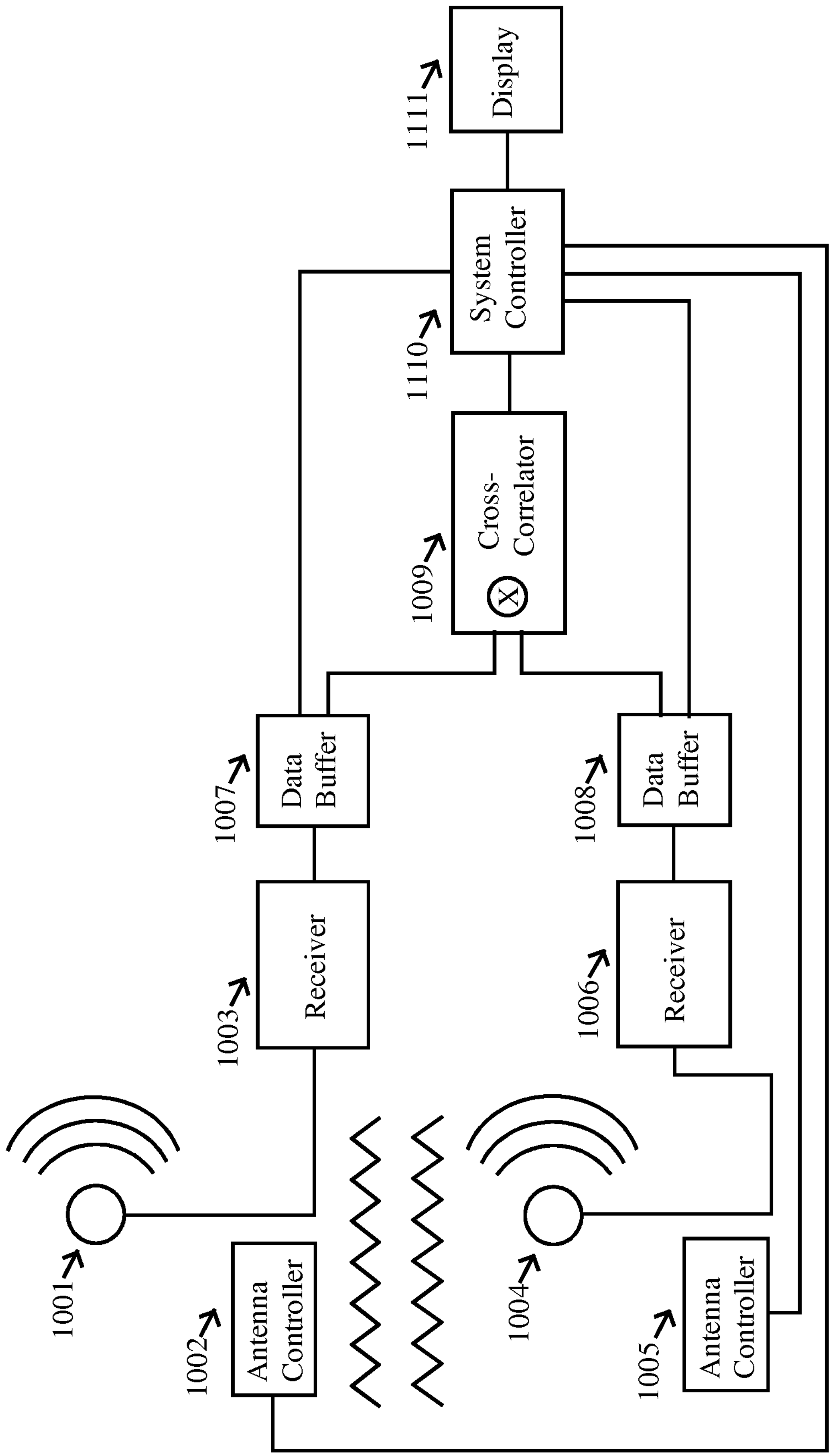

1111
Display
1110
System Controller
1009
Cross-Correlator
X
1007
Data Buffer
1008
Data Buffer
1003
Receiver
1006
Receiver
1001
1002
Antenna Controller
1004
1005
Antenna Controller

Fig. 11

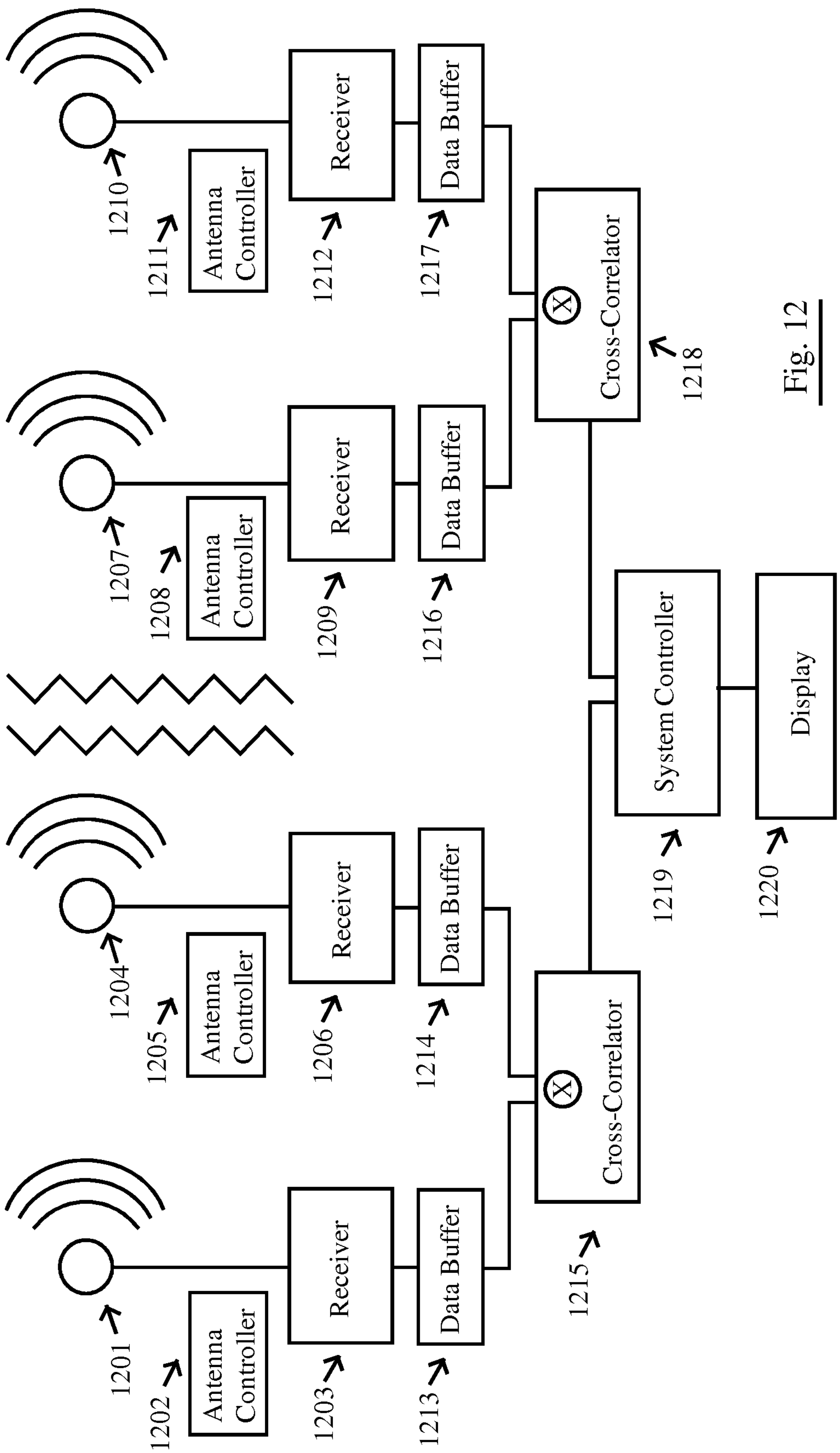

1201
1202
Antenna Controller
1203
Receiver
1213
Data Buffer
1204
1205
Antenna Controller
1206
Receiver
1214
Data Buffer
X
Cross-Correlator
1215
1207
1208
Antenna Controller
1209
Receiver
1216
Data Buffer
1210
1211
Antenna Controller
1212
Receiver
1217
Data Buffer
X
Cross-Correlator
1218
System Controller
1219
Display
1220

Fig. 12

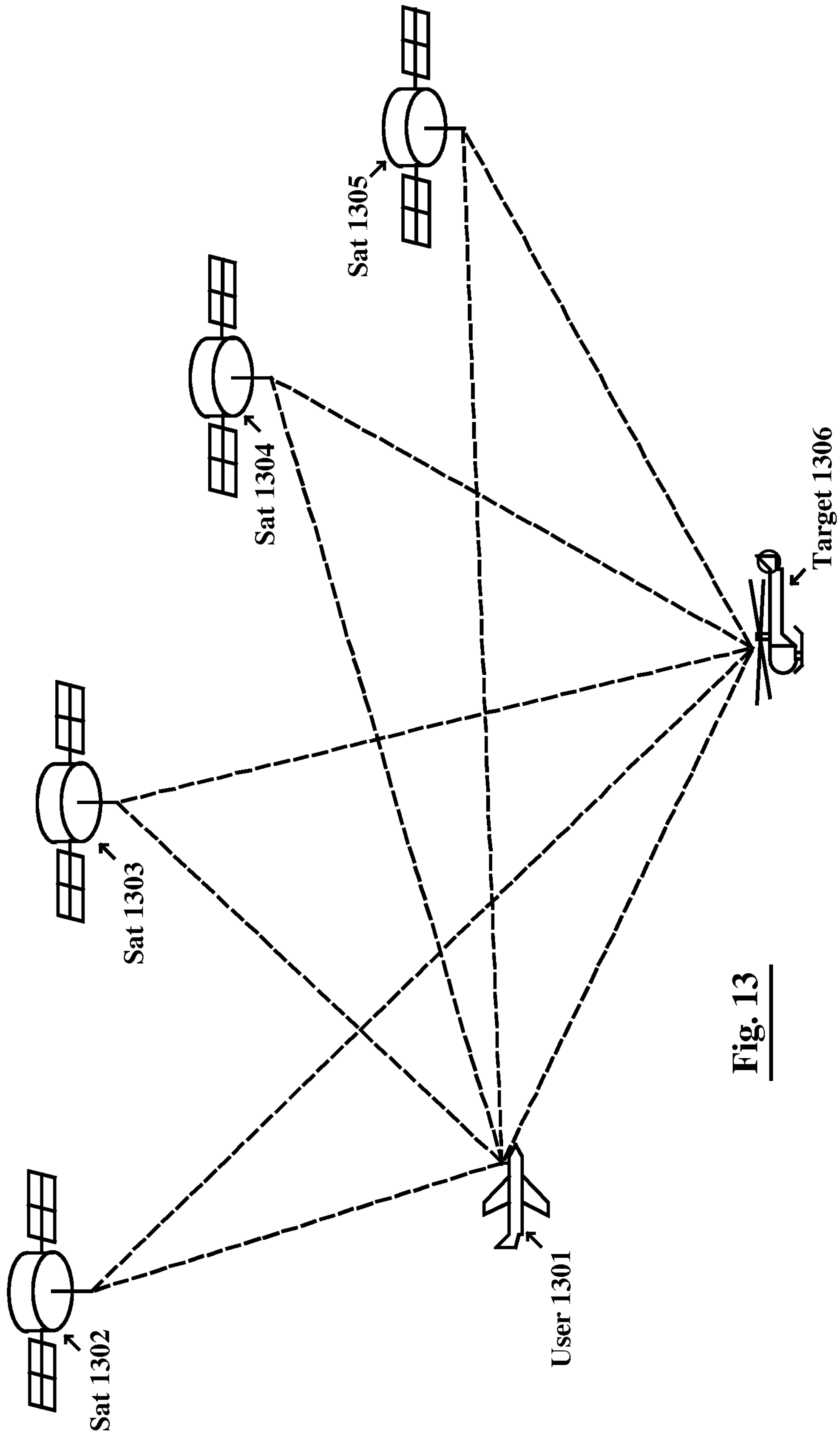


Fig. 13

Fig. 14

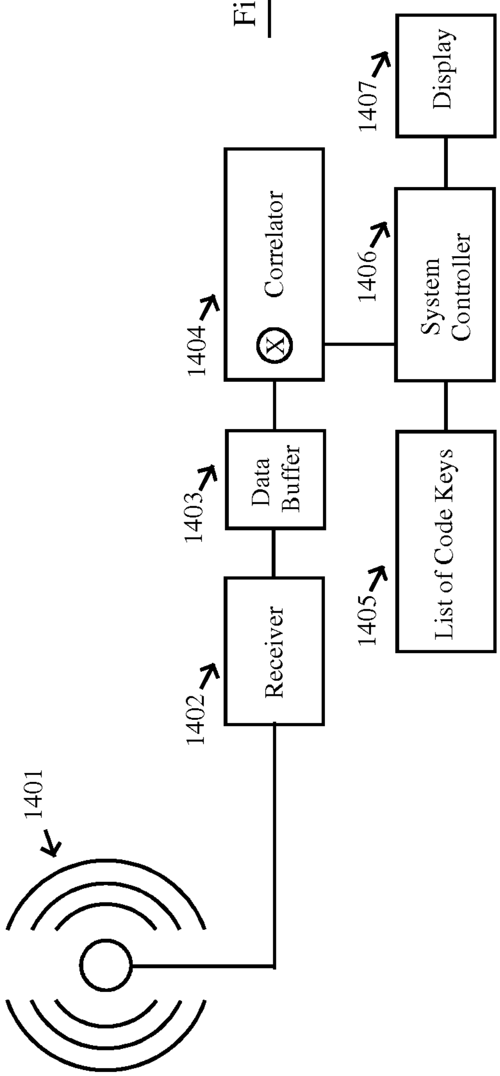
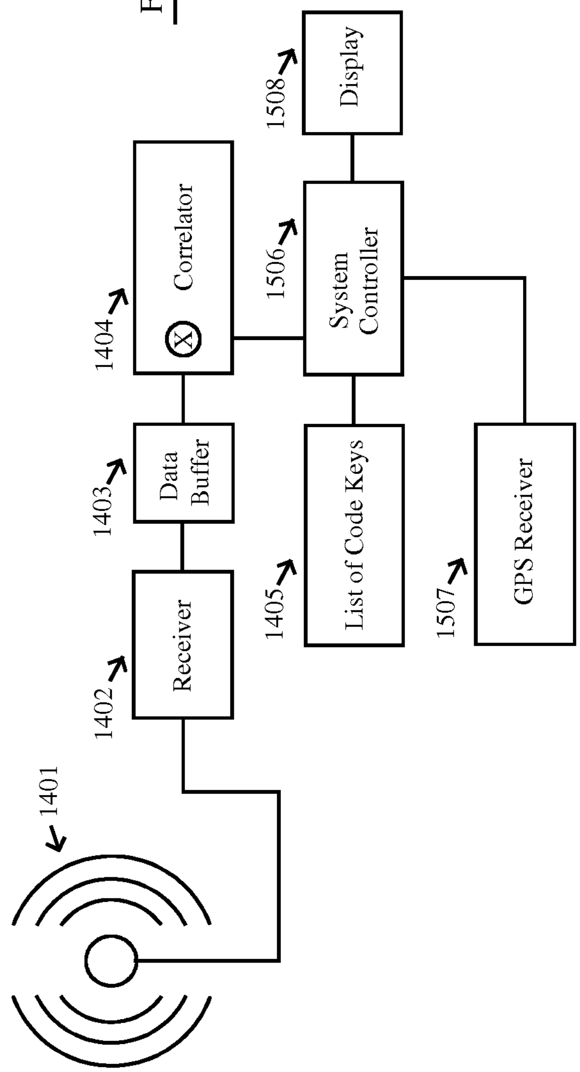

1401
1402
Receiver
1403
Data Buffer
1404
Correlator
1405
List of Code Keys
1406
System Controller
1407
Display

Fig. 15


1401
1402
Receiver
1403
Data Buffer
1404
Correlator
1405
List of Code Keys
1506
System Controller
1507
GPS Receiver
1508
Display

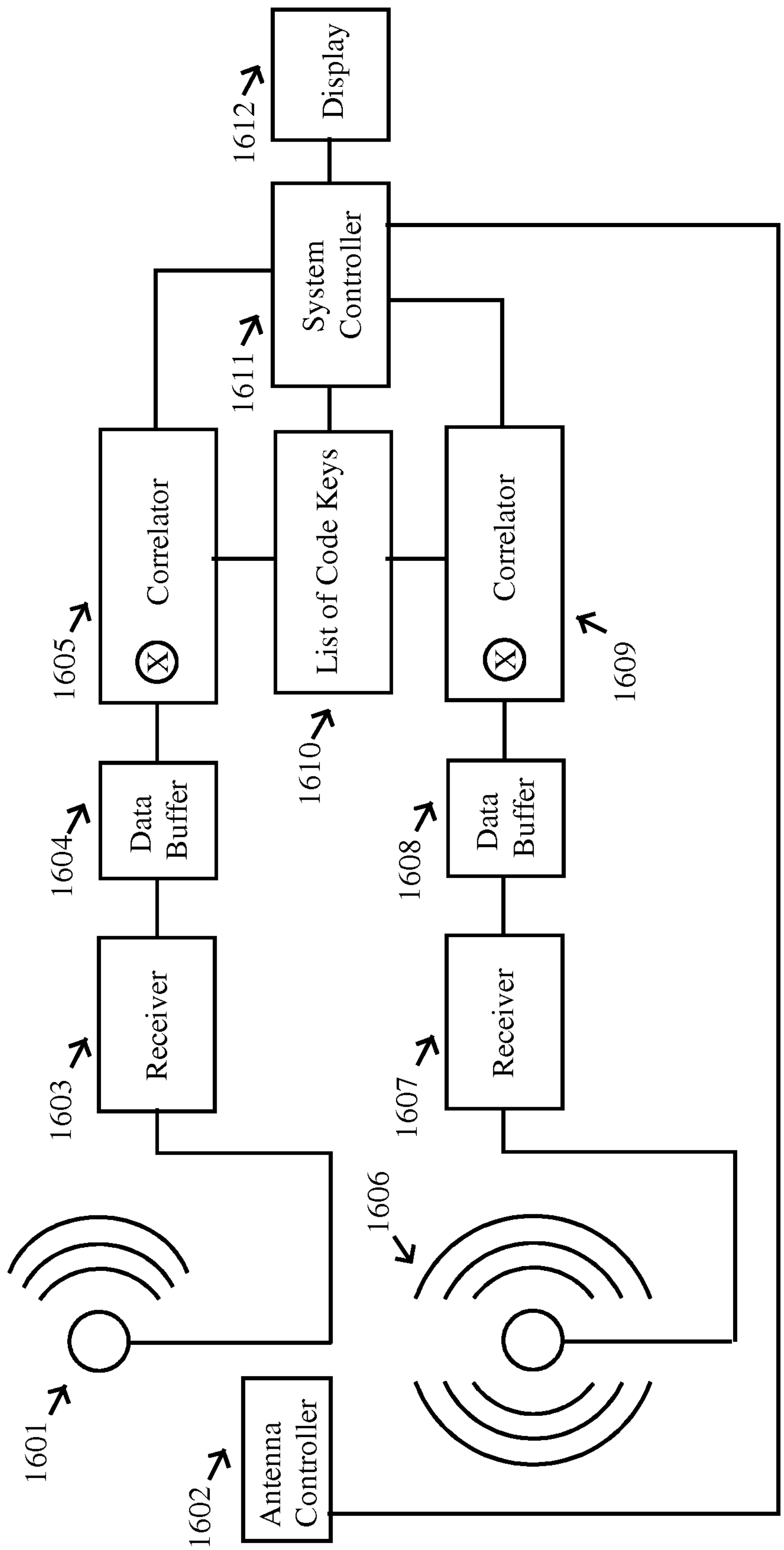

Display
1612
System Controller
1611
Correlator
1605
List of Code Keys
1610
Correlator
1609
Data Buffer
1604
Data Buffer
1608
Receiver
1603
Receiver
1607
1606
1601
Antenna Controller
1602

Fig. 16

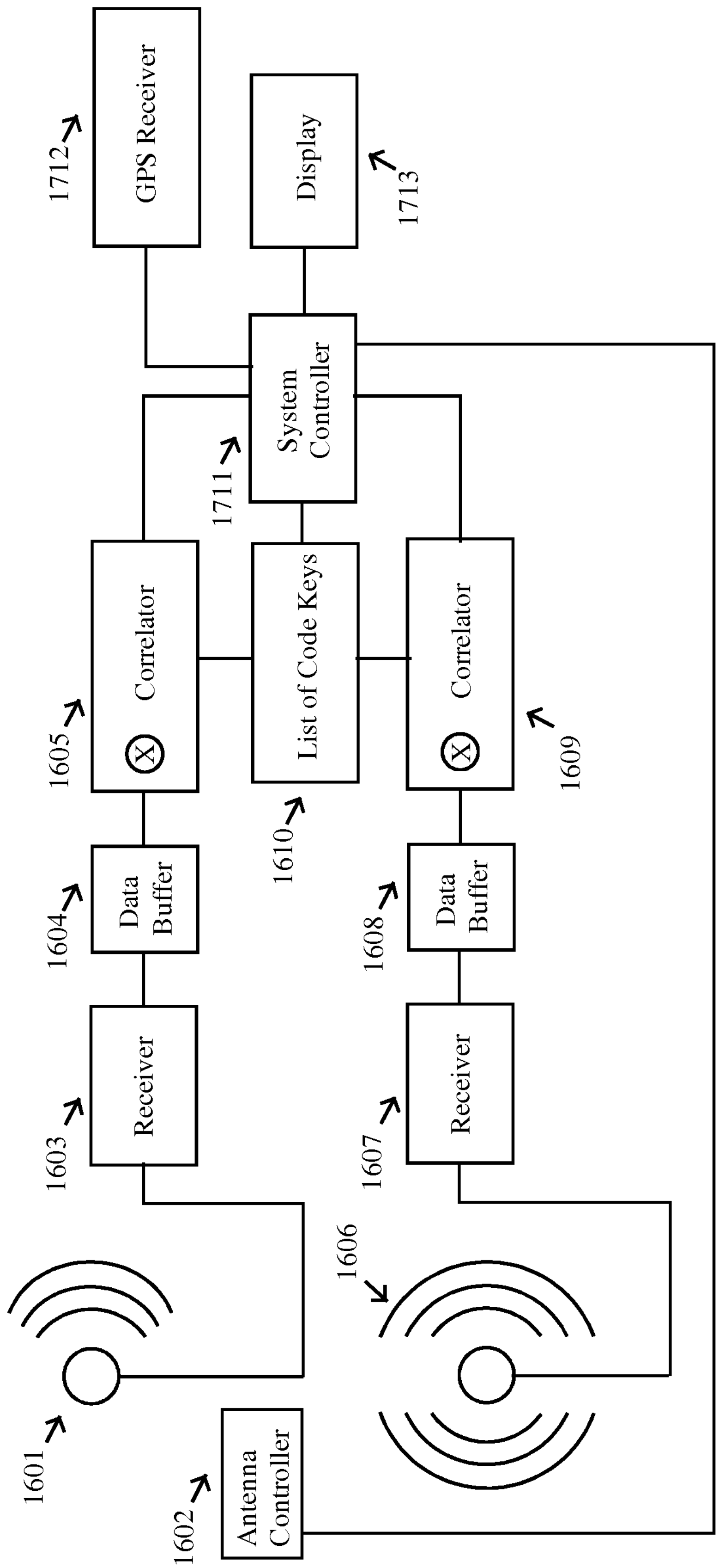

GPS Receiver
1712
Display
1713
System Controller
1711
Correlator
1605
List of Code Keys
1610
Correlator
1609
Data Buffer
1604
Data Buffer
1608
Receiver
1603
Receiver
1607
1606
1601
Antenna Controller
1602

Fig. 17

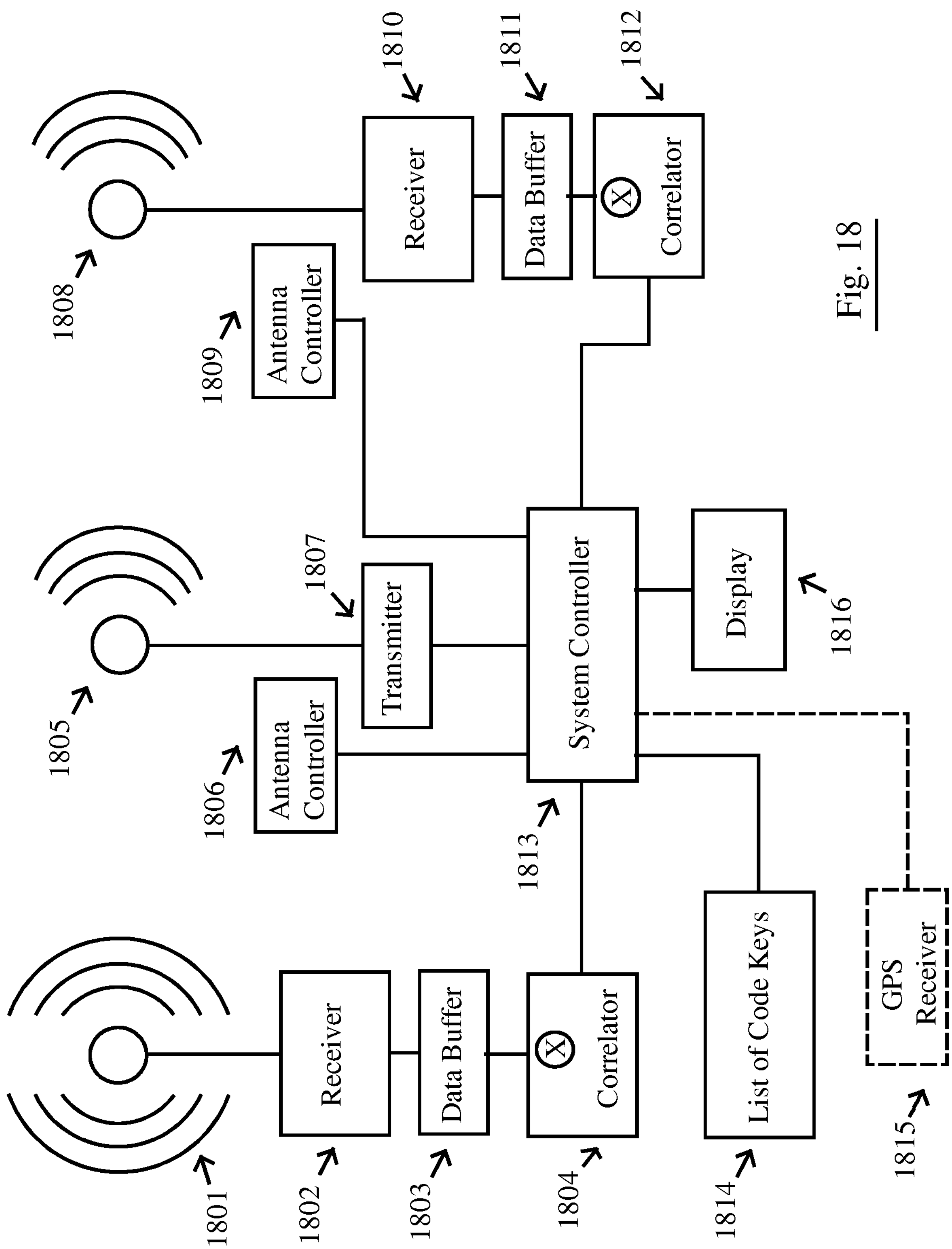

1801
Receiver
1802
Data Buffer
1803
Correlator
1804
List of Code Keys
1814
GPS Receiver
1815
1813
System Controller
Antenna Controller
1806
1805
Transmitter
1807
Display
1816
1808
Antenna Controller
1809
Receiver
1810
Data Buffer
1811
Correlator
1812

Fig. 18

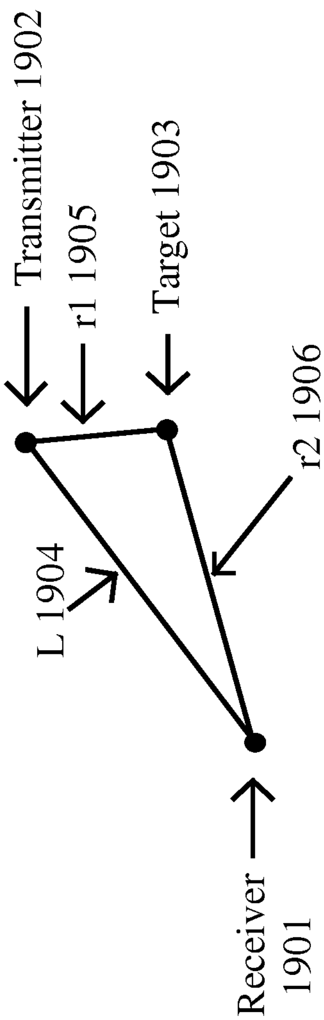

Transmitter 1902
r1 1905
Target 1903
r2 1906
L 1904
Receiver 1901

Fig. 19

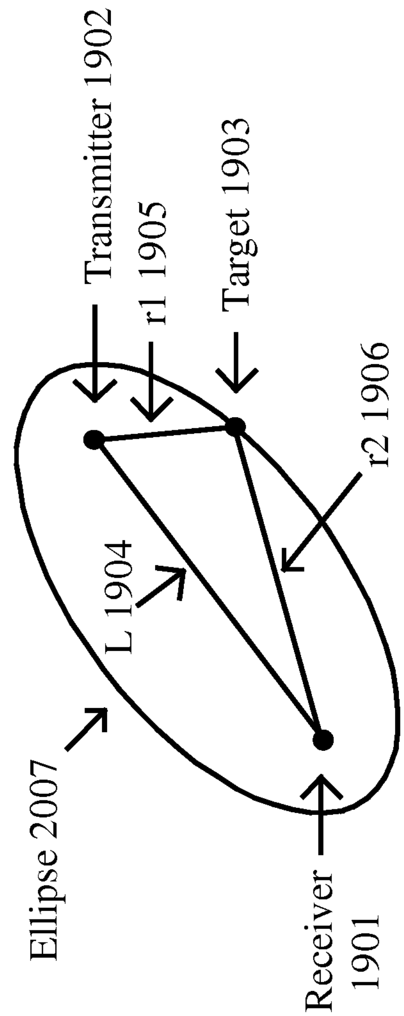

Transmitter 1902
r1 1905
Target 1903
r2 1906
L 1904
Ellipse 2007
Receiver 1901

Fig. 20

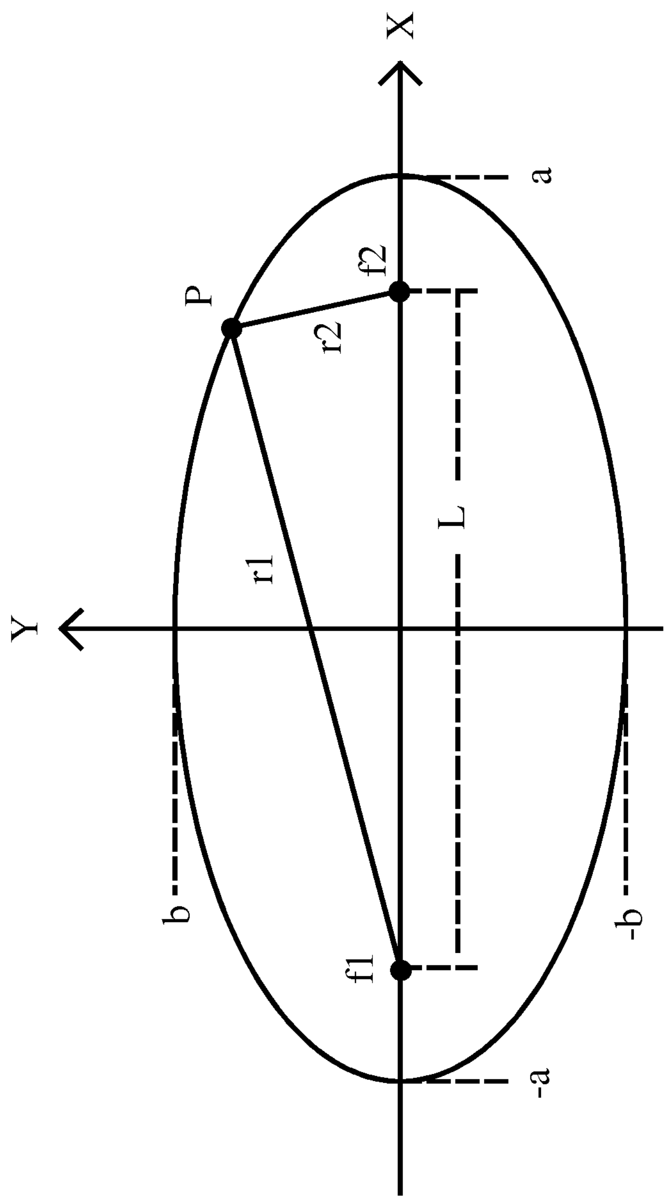


Fig. 21

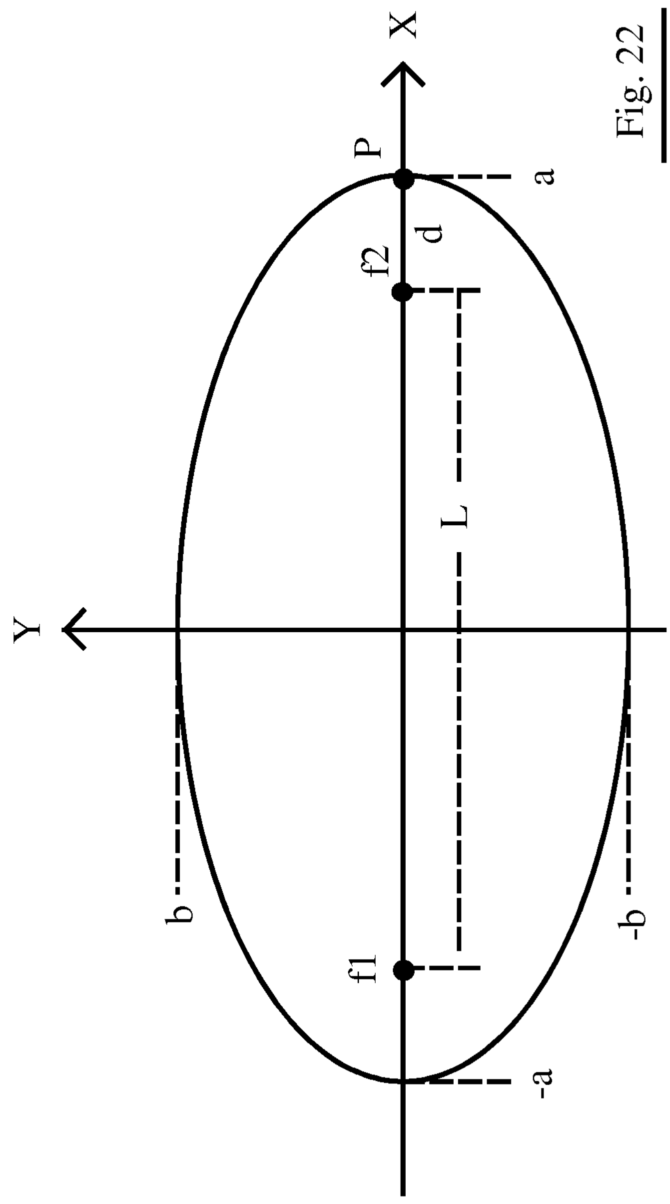


Fig. 22

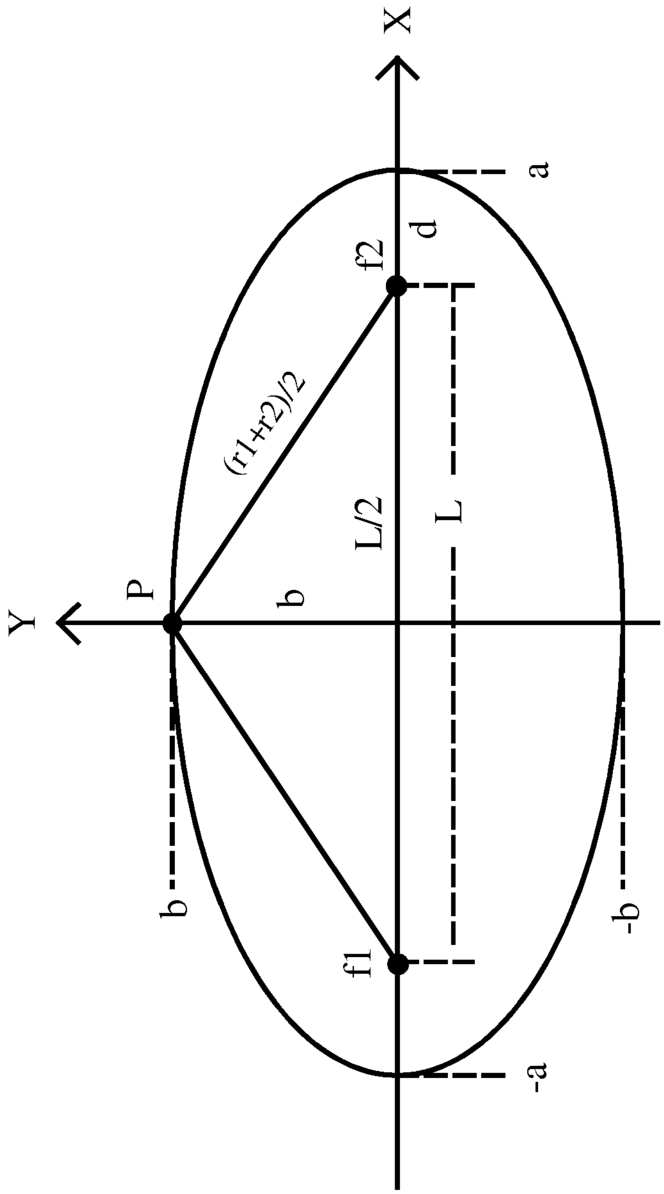


Fig. 23

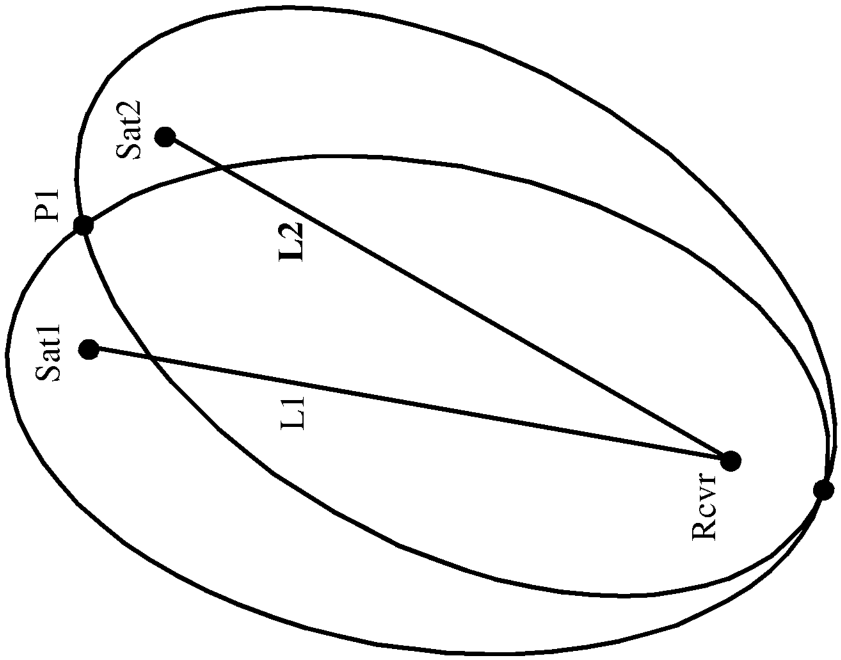


Fig. 25

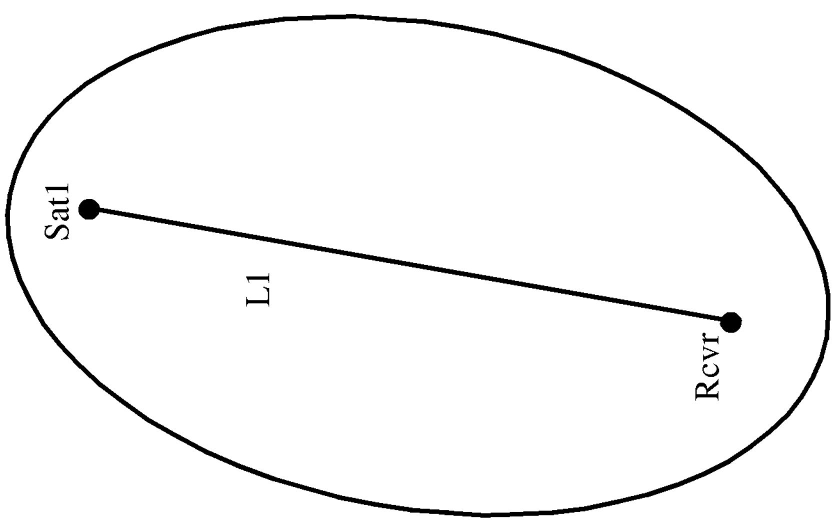


Fig. 24

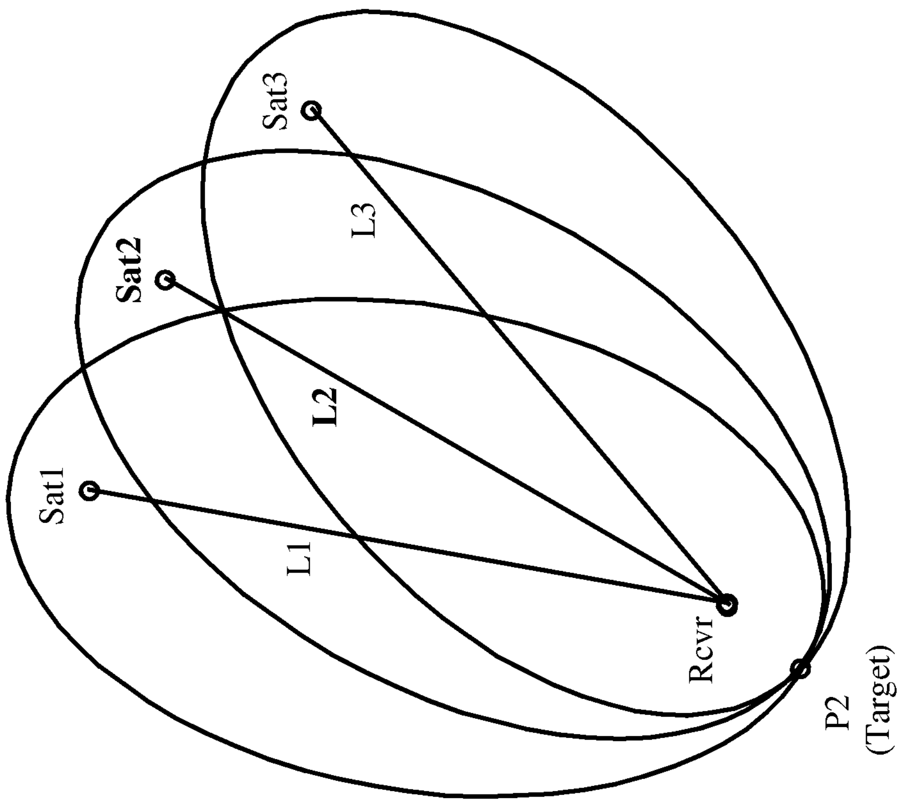


Fig. 26

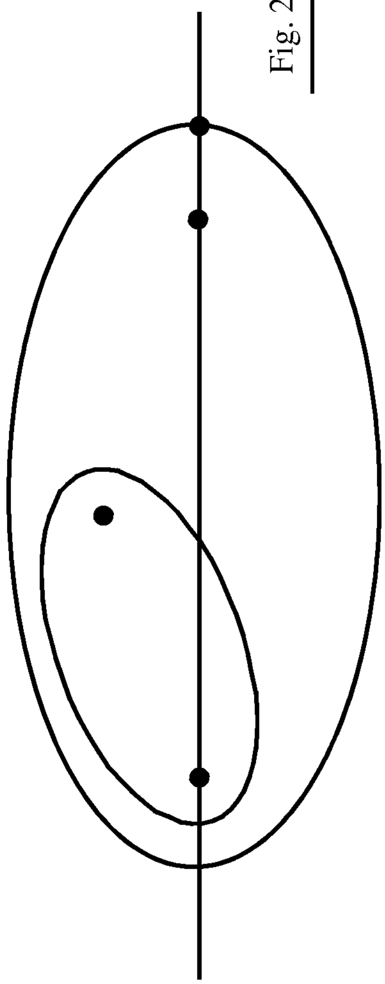


Fig. 27

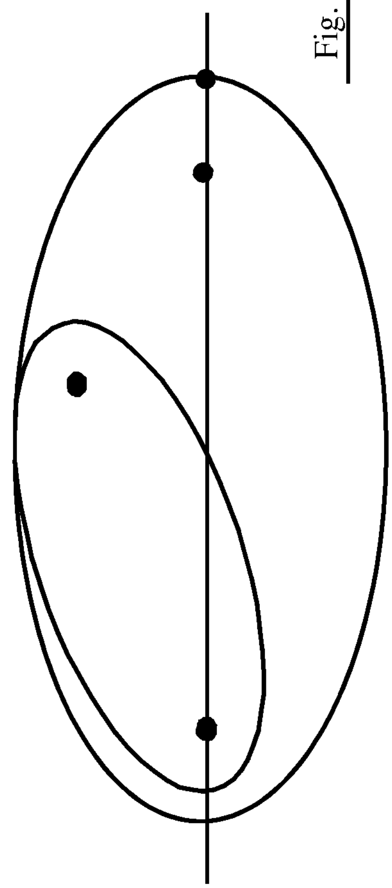


Fig. 28

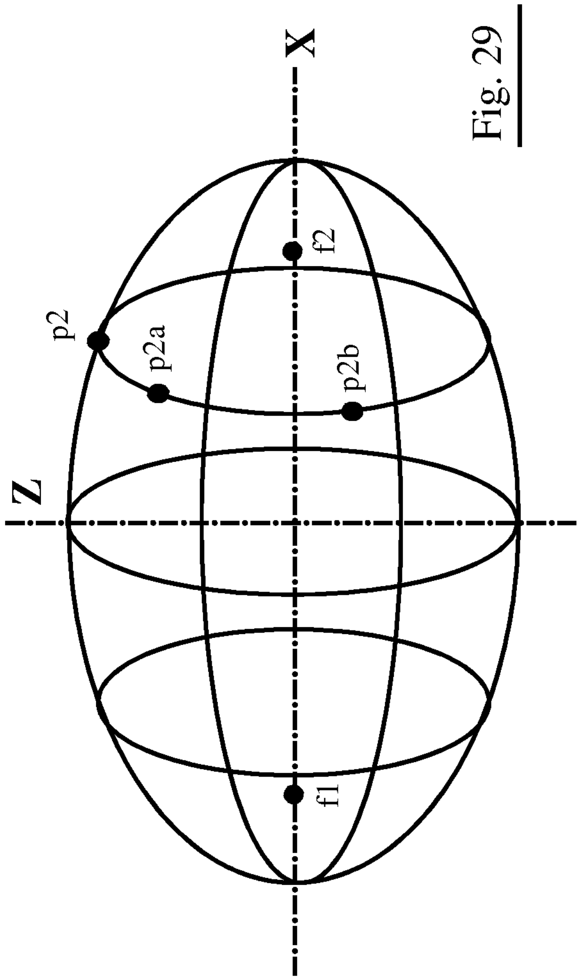


Fig. 29

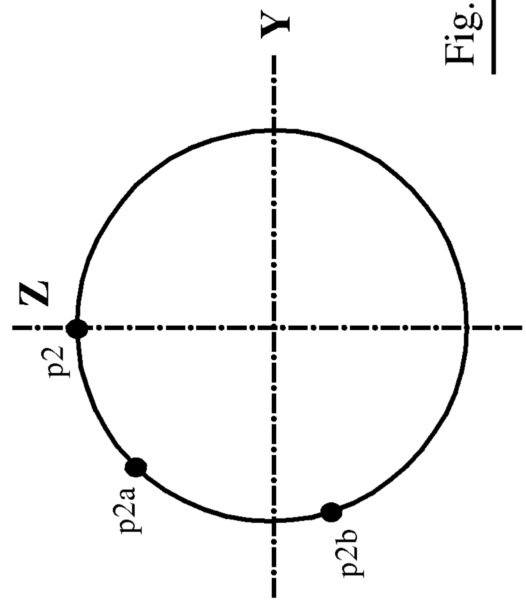


Fig. 30

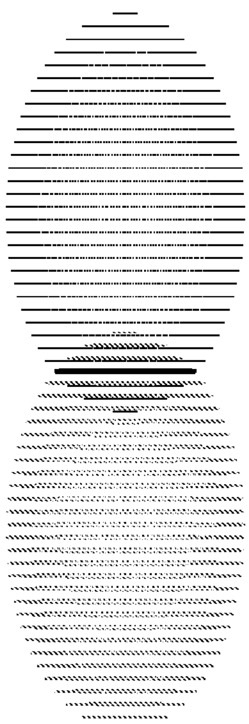


Fig. 31

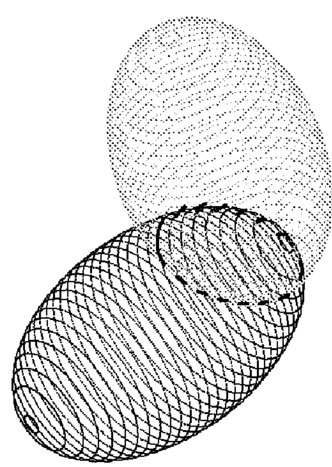


Fig. 32

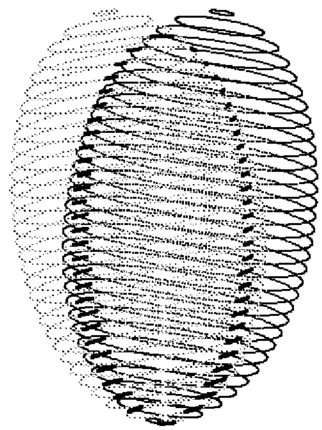


Fig. 33

Electronic Acknowledgement Receipt

EFS ID:	14313404
Application Number:	12910779
International Application Number:	
Confirmation Number:	8875
Title of Invention:	System for sensing aircraft and other objects
First Named Inventor/Applicant Name:	Jed Margolin
Customer Number:	23497
Filer:	Jed Margolin
Filer Authorized By:	
Attorney Docket Number:	
Receipt Date:	27-NOV-2012
Filing Date:	22-OCT-2010
Time Stamp:	12:08:40
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	no

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Applicant Arguments/Remarks Made in an Amendment	jm_foa_response.pdf	62320 f2b5aa662d445b900a984534e3ddab32849cb720	no	16

Warnings:

Information:

2	Drawings-only black and white line drawings	jm_figures_rotated_substitute.pdf	493210 9e462f8b89f36f382f29bee9fc29cb47fa9f068b	no	25
Warnings:					
Information:					
		Total Files Size (in bytes):	555530		

This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.

<u>New Applications Under 35 U.S.C. 111</u>
If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

<u>National Stage of an International Application under 35 U.S.C. 371</u>
If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

<u>New International Application Filed with the USPTO as a Receiving Office</u>
If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

PTO/SB/06 (07-06)
Approved for use through 1/31/2007. OMB 0651-0032
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE

PATENT APPLICATION FEE DETERMINATION RECORD Substitute for Form PTO-875	Application or Docket Number 12/910,779	Filing Date 10/22/2010	☐ To be Mailed

APPLICATION AS FILED – PART I

FOR	NUMBER FILED (Column 1)	NUMBER EXTRA (Column 2)	SMALL ENTITY ☒ RATE ($)	FEE ($)	OR	OTHER THAN SMALL ENTITY RATE ($)	FEE ($)
☐ BASIC FEE (37 CFR 1.16(a), (b), or (c))	N/A	N/A	N/A			N/A	
☐ SEARCH FEE (37 CFR 1.16(k), (i), or (m))	N/A	N/A	N/A			N/A	
☐ EXAMINATION FEE (37 CFR 1.16(o), (p), or (q))	N/A	N/A	N/A			N/A	
TOTAL CLAIMS (37 CFR 1.16(i))	minus 20 =	*	X $ =		OR	X $ =	
INDEPENDENT CLAIMS (37 CFR 1.16(h))	minus 3 =	*	X $ =			X $ =	
☐ APPLICATION SIZE FEE (37 CFR 1.16(s))	If the specification and drawings exceed 100 sheets of paper, the application size fee due is $250 ($125 for small entity) for each additional 50 sheets or fraction thereof. See 35 U.S.C. 41(a)(1)(G) and 37 CFR 1.16(s).						
☐ MULTIPLE DEPENDENT CLAIM PRESENT (37 CFR 1.16(j))							
			TOTAL			TOTAL	

* If the difference in column 1 is less than zero, enter "0" in column 2.

APPLICATION AS AMENDED – PART II

AMENDMENT 11/27/2012	CLAIMS REMAINING AFTER AMENDMENT (Column 1)		HIGHEST NUMBER PREVIOUSLY PAID FOR (Column 2)	PRESENT EXTRA (Column 3)	SMALL ENTITY RATE ($)	ADDITIONAL FEE ($)	OR	OTHER THAN SMALL ENTITY RATE ($)	ADDITIONAL FEE ($)
Total (37 CFR 1.16(i))	* 7	Minus	** 20	= 0	X $31 =	0	OR	X $ =	
Independent (37 CFR 1.16(h))	* 4	Minus	***7	= 0	X $125 =	0	OR	X $ =	
☐ Application Size Fee (37 CFR 1.16(s))									
☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))							OR		
					TOTAL ADD'L FEE	**0**	OR	TOTAL ADD'L FEE	

AMENDMENT	CLAIMS REMAINING AFTER AMENDMENT (Column 1)		HIGHEST NUMBER PREVIOUSLY PAID FOR (Column 2)	PRESENT EXTRA (Column 3)	RATE ($)	ADDITIONAL FEE ($)		RATE ($)	ADDITIONAL FEE ($)
Total (37 CFR 1.16(i))	*	Minus	**	=	X $ =		OR	X $ =	
Independent (37 CFR 1.16(h))	*	Minus	***	=	X $ =		OR	X $ =	
☐ Application Size Fee (37 CFR 1.16(s))									
☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))							OR		
					TOTAL ADD'L FEE		OR	TOTAL ADD'L FEE	

* If the entry in column 1 is less than the entry in column 2, write "0" in column 3.
** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20".
*** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, enter "3".
The "Highest Number Previously Paid For" (Total or Independent) is the highest number found in the appropriate box in column 1.

Legal Instrument Examiner:
/JOSEPHINE DOUGLAS/

UNITED STATES PATENT AND TRADEMARK OFFICE

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APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
12/910,779	10/22/2010	Jed Margolin		8875

23497 7590 11/13/2012

JED MARGOLIN
1981 EMPIRE ROAD
RENO, NV 89521-7430

EXAMINER	
BARKER, MATTHEW M	
ART UNIT	**PAPER NUMBER**
3646	
MAIL DATE	**DELIVERY MODE**
11/13/2012	PAPER

Please find below and/or attached an Office communication concerning this application or proceeding.

The time period for reply, if any, is set in the attached communication.

Office Action Summary	**Application No.**	**Applicant(s)**	
	12/910,779	MARGOLIN, JED	
	Examiner	**Art Unit**	
	MATTHEW M. BARKER	3646	

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address --

Period for Reply

A SHORTENED STATUTORY PERIOD FOR REPLY IS SET TO EXPIRE *3* MONTH(S) OR THIRTY (30) DAYS, WHICHEVER IS LONGER, FROM THE MAILING DATE OF THIS COMMUNICATION.

- Extensions of time may be available under the provisions of 37 CFR 1.136(a). In no event, however, may a reply be timely filed after SIX (6) MONTHS from the mailing date of this communication.
- If NO period for reply is specified above, the maximum statutory period will apply and will expire SIX (6) MONTHS from the mailing date of this communication.
- Failure to reply within the set or extended period for reply will, by statute, cause the application to become ABANDONED (35 U.S.C. § 133). Any reply received by the Office later than three months after the mailing date of this communication, even if timely filed, may reduce any earned patent term adjustment. See 37 CFR 1.704(b).

Status

1)☒ Responsive to communication(s) filed on *25 August 2012*.

2a)☐ This action is **FINAL**. 2b)☒ This action is non-final.

3)☐ An election was made by the applicant in response to a restriction requirement set forth during the interview on _____; the restriction requirement and election have been incorporated into this action.

4)☐ Since this application is in condition for allowance except for formal matters, prosecution as to the merits is closed in accordance with the practice under *Ex parte Quayle*, 1935 C.D. 11, 453 O.G. 213.

Disposition of Claims

5)☒ Claim(s) *1-16* is/are pending in the application.

5a) Of the above claim(s) *1-6* is/are withdrawn from consideration.

6)☒ Claim(s) *10-16* is/are allowed.

7)☒ Claim(s) *7-9* is/are rejected.

8)☐ Claim(s) _____ is/are objected to.

9)☐ Claim(s) _____ are subject to restriction and/or election requirement.

Application Papers

10)☐ The specification is objected to by the Examiner.

11)☒ The drawing(s) filed on *22 December 2010* is/are: a)☒ accepted or b)☐ objected to by the Examiner.

Applicant may not request that any objection to the drawing(s) be held in abeyance. See 37 CFR 1.85(a).

Replacement drawing sheet(s) including the correction is required if the drawing(s) is objected to. See 37 CFR 1.121(d).

12)☐ The oath or declaration is objected to by the Examiner. Note the attached Office Action or form PTO-152.

Priority under 35 U.S.C. § 119

13)☐ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).

a)☐ All b)☐ Some * c)☐ None of:

1.☐ Certified copies of the priority documents have been received.

2.☐ Certified copies of the priority documents have been received in Application No. _____.

3.☐ Copies of the certified copies of the priority documents have been received in this National Stage application from the International Bureau (PCT Rule 17.2(a)).

* See the attached detailed Office action for a list of the certified copies not received.

Attachment(s)

1) ☒ Notice of References Cited (PTO-892)
2) ☐ Notice of Draftsperson's Patent Drawing Review (PTO-948)
3) ☒ Information Disclosure Statement(s) (PTO/SB/08) Paper No(s)/Mail Date _____.
4) ☐ Interview Summary (PTO-413) Paper No(s)/Mail Date. _____ .
5) ☐ Notice of Informal Patent Application
6) ☐ Other: _____.

DETAILED ACTION

Election/Restrictions

1. Applicant's election without traverse of species III in the reply filed on 8/25/2012 is acknowledged.

Specification

2. The lengthy specification has not been checked to the extent necessary to determine the presence of all possible minor errors. Applicant's cooperation is requested in correcting any errors of which applicant may become aware in the specification.

Claim Rejections - 35 USC § 112

3. The following is a quotation of 35 U.S.C. 112(a):
(a) IN GENERAL.—The specification shall contain a written description of the invention, and of the manner and process of making and using it, in such full, clear, concise, and exact terms as to enable any person skilled in the art to which it pertains, or with which it is most nearly connected, to make and use the same, and shall set forth the best mode contemplated by the inventor or joint inventor of carrying out the invention.

The following is a quotation of 35 U.S.C. 112 (pre-AIA), first paragraph:
The specification shall contain a written description of the invention, and of the manner and process of making and using it, in such full, clear, concise, and exact terms as to enable any person skilled in the art to which it pertains, or with which it is most nearly connected, to make and use the same and shall set forth the best mode contemplated by the inventor of carrying out his invention.

4. Claims 7-9 are rejected under 35 U.S.C. 112(a) or 35 U.S.C. 112 (pre-AIA), first paragraph, because the specification, while being enabling for sensing spread spectrum radar signals, does not reasonably provide enablement for all forms of spread spectrum signals. The specification does not enable any person skilled in the art to which it

pertains, or with which it is most nearly connected, to make and use the invention commensurate in scope with these claims. Section [090] of the specification begins discussion of the embodiment of claims 7-9, which pertains strictly to spread spectrum radar. However, spread spectrum techniques are applied to many technologies including digital RF communication and non-radio applications as well, including optical and acoustic signals. The claims encompass all applications of spread spectrum technology. Applicant should amend the claims to specify that the signals received are radar signals.

Claim Rejections - 35 USC § 103

5. The following is a quotation of 35 U.S.C. 103(a) which forms the basis for all obviousness rejections set forth in this Office action:

> (a) A patent may not be obtained though the invention is not identically disclosed or described as set forth in section 102 of this title, if the differences between the subject matter sought to be patented and the prior art are such that the subject matter as a whole would have been obvious at the time the invention was made to a person having ordinary skill in the art to which said subject matter pertains. Patentability shall not be negatived by the manner in which the invention was made.

6. Claims 7 and 8 are rejected under 35 U.S.C. 103(a) as being unpatentable over Houghton et al. (5,955,993) in view of Brown et al. (6,650,694) and Afendykiw (3,943,514).

Houghton discloses a system for sensing spread spectrum radar signals (Figure 1) including first and second antennas (11, 12), first receiver (13,16), second receiver (14, 17), cross-correlator with two inputs and one or more outputs (18), and system controller (19). The cross-correlator performs a cross correlation between the inputs and produces an output indicating the magnitude of the cross correlation between a spread spectrum signal received by both receivers (column 3, lines 16-30; column 6, lines 18-22). Houghton has an output indicating the phase of the cross-correlation and therefor bearing to the target (column 6, lines 23-31).

Houghton does not disclose first and second data buffers between the receivers and cross correlator. Houghton instead discloses an Acousto-optic correlator that does not use buffers. However, input buffers are common for digital cross-correlators, as shown for example by Brown et al. (Figure 1), which uses input buffers (102) for each source, e.g. a received signal from an antenna (column 9, line 49-column 10, line 2) for cross correlator (100). It would have been obvious to one of ordinary skill in the art to modify Houghton to use a digital cross-correlator and buffers as taught by Brown in order to quickly process more signal information.

Houghton shows graphs of the cross correlator output (Figures 4-9) but does not explicitly disclose a display. Afendykiw discloses a cross-correlator to correlate two antenna outputs and a display (62) to display the output of the correlator (column 3, lines 15-19). It would have been obvious to one of ordinary skill in the art to display the outputs of Houghton as taught by Afendykiw in order to visualize the signal information.

Allowable Subject Matter

7. Claims 10-16 are allowed.

Conclusion

8. The prior art made of record and not relied upon is considered pertinent to applicant's disclosure. The cited art relates to signal detection.

9. Any inquiry concerning this communication or earlier communications from the examiner should be directed to MATTHEW M. BARKER whose telephone number is (571)272-3103. The examiner can normally be reached on M-F, 8:30 AM-5:00 PM.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Jack Keith can be reached on (571)272-6878. The fax phone number for the organization where this application or proceeding is assigned is 571-273-8300.

Information regarding the status of an application may be obtained from the Patent Application Information Retrieval (PAIR) system. Status information for published applications may be obtained from either Private PAIR or Public PAIR. Status information for unpublished applications is available through Private PAIR only. For more information about the PAIR system, see http://pair-direct.uspto.gov. Should you have questions on access to the Private PAIR system, contact the Electronic Business Center (EBC) at 866-217-9197 (toll-free). If you would like assistance from a USPTO Customer Service Representative or access to the automated information system, call 800-786-9199 (IN USA OR CANADA) or 571-272-1000.

/MATTHEW M BARKER/
Examiner, Art Unit 3646

Notice of References Cited	Application/Control No. 12/910,779	Applicant(s)/Patent Under Reexamination MARGOLIN, JED	
	Examiner MATTHEW M. BARKER	Art Unit 3646	Page 1 of 2

U.S. PATENT DOCUMENTS

*		Document Number Country Code-Number-Kind Code	Date MM-YYYY	Name	Classification
*	A	US-3,171,126 A	02-1965	WILEY CARL A	342/458
*	B	US-3,812,493 A	05-1974	Afendykiw et al.	342/145
*	C	US-3,943,514 A	03-1976	Afendykiw et al.	342/156
*	D	US-5,181,041 A	01-1993	Lind et al.	342/453
*	E	US-5,955,993 A	09-1999	Houghton et al.	342/417
*	F	US-6,148,041 A	11-2000	Dent, Paul W.	375/340
*	G	US-6,650,694 B1	11-2003	Brown et al.	375/150
*	H	US-6,744,408 B1	06-2004	Stockmaster, Michael H.	342/453
*	I	US-7,012,552 B2	03-2006	Baugh et al.	340/945
*	J	US-7,027,492 B2	04-2006	Bertrand et al.	375/148
*	K	US-7,138,944 B2	11-2006	Lawrence et al.	342/357.72
*	L	US-7,292,663 B1	11-2007	Van Wechel et al.	375/350
*	M	US-2009/0167607 A1	07-2009	Holder, Ernest Jefferson	342/453

FOREIGN PATENT DOCUMENTS

*		Document Number Country Code-Number-Kind Code	Date MM-YYYY	Country	Name	Classification
	N					
	O					
	P					
	Q					
	R					
	S					
	T					

NON-PATENT DOCUMENTS

*		Include as applicable: Author, Title Date, Publisher, Edition or Volume, Pertinent Pages)
	U	
	V	
	W	
	X	

*A copy of this reference is not being furnished with this Office action. (See MPEP § 707.05(a).)
Dates in MM-YYYY format are publication dates. Classifications may be US or foreign.

Notice of References Cited	Application/Control No. 12/910,779	Applicant(s)/Patent Under Reexamination MARGOLIN, JED	
	Examiner MATTHEW M. BARKER	Art Unit 3646	Page 2 of 2

U.S. PATENT DOCUMENTS

*		Document Number Country Code-Number-Kind Code	Date MM-YYYY	Name	Classification
*	A	US-2010/0246547 A1	09-2010	YOON, Young-Suk	370/338
	B	US-			
	C	US-			
	D	US-			
	E	US-			
	F	US-			
	G	US-			
	H	US-			
	I	US-			
	J	US-			
	K	US-			
	L	US-			
	M	US-			

FOREIGN PATENT DOCUMENTS

*		Document Number Country Code-Number-Kind Code	Date MM-YYYY	Country	Name	Classification
	N					
	O					
	P					
	Q					
	R					
	S					
	T					

NON-PATENT DOCUMENTS

*		Include as applicable: Author, Title Date, Publisher, Edition or Volume, Pertinent Pages)
	U	
	V	
	W	
	X	

*A copy of this reference is not being furnished with this Office action. (See MPEP § 707.05(a).)
Dates in MM-YYYY format are publication dates. Classifications may be US or foreign.

Substitute for form 1449/PTO

INFORMATION DISCLOSURE STATEMENT BY APPLICANT

(Use as many sheets as necessary)

Sheet 1 of 4

Complete if Known	
Application Number	
Filing Date	
First Named Inventor	Jed Margolin
Art Unit	
Examiner Name	
Attorney Docket Number	

U. S. PATENT DOCUMENTS

Examiner Initials*	Cite No.[1]	Document Number Number-Kind Code[2] (if known)	Publication Date MM-DD-YYYY	Name of Patentee or Applicant of Cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear
	3	US- 4,782,450	11-01-1998	Flax	Abstract
	5	US- 5,153,836	10-06-1992	Fraughton, et al.	Abstract
	7	US- 5,187,485	02-16-1993	Tsui, et al.	
	9	US- 5,724,041	03-03-1998	Inoue, et al.	Abstract
	11	US- 4,195,293	03-25-1980	Margolin	
	12	US- 3,986,168	12-12-1976	Anderson	
	13	US- 3,515,805	06-02-1970	Fracassi et al.	
	25	US- 6,377,436 B1	05-23-2002	Margolin	
		US- 7,737,878	06-15-2008	va Tooren, et al.	
		US- 5,036,330	07-30-1991	Imae, et al.	
		US- 5,955,993	09-21-1999	Houghton, et al.	
		US- 6,031,485	02-29-2000	Cellai, et al.	
		US-			
		US-			
		US-			
		US-			
		US-			
		US-			
		US-			

FOREIGN PATENT DOCUMENTS

Examiner Initials*	Cite No.[1]	Foreign Patent Document Country Code[3]-Number[4]-Kind Code[5] (if known)	Publication Date MM-DD-YYYY	Name of Patentee or Applicant of Cited Document	Pages, Columns, Lines, Where Relevant Passages Or Relevant Figures Appear	T[6]

Examiner Signature		Date Considered	

*EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP 609. Draw line through citation if not in conformance and not considered. Include copy of this form with next communication to applicant. [1] Applicant's unique citation designation number (optional). [2] See Kinds Codes of USPTO Patent Documents at www.uspto.gov or MPEP 901.04. [3] Enter Office that issued the document, by the two-letter code (WIPO Standard ST.3). [4] For Japanese patent documents, the indication of the year of the reign of the Emperor must precede the serial number of the patent document. [5] Kind of document by the appropriate symbols as indicated on the document under WIPO Standard ST.16 if possible. [6] Applicant is to place a check mark here if English language Translation is attached.

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /M.B./

Substitute for form 1449/PTO

INFORMATION DISCLOSURE STATEMENT BY APPLICANT

(Use as many sheets as necessary)

Complete if Known	
Application Number	
Filing Date	
First Named Inventor	Jed Margolin
Art Unit	
Examiner Name	
Attorney Docket Number	

Sheet 2 of 4

NON PATENT LITERATURE DOCUMENTS

Examiner Initials*	Cite No.[1]	Include name of the author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc.), date, page(s), volume-issue number(s), publisher, city and/or country where published.	T[2]
	1	14 CFR § 91.113(b) Right-of-way rules: Except water operations.	
	2	14 CFR § 91.115(a) Right-of-way rules: Water operations.	
	4	Introduction to TCAS II Version 7, United States Department of Transportation, Federal Aviation Administration November 2000, Page 11	
	6	Gulf of Mexico Helo Ops Ready for ADS-B, Aviation Week & Space Technology, FRANCIS FIORINO, 02/26/2007, page 56.	
	8	Test Results from a Novel Passive Bistatic GPS Radar Using a Phased Sensor Array, ALISON BROWN and BEN MATHEWS, NAVSYS Corporation, Proceedings of ION NTM 2007, San Diego, CA, January 2007. www.navsys.com/Papers/07-01-002.pdf	
	10	Shift Register With Feedback Generates White Noise, MARC DAMASHEK, Electronics magazine, May 27, 1976.	
	14	Shift Register Sequences, S. GOLOMB (Holden-Day Inc., San Francisco, 1967, and Aegean Park Press, 1982)	
	15	The ABCs of Spread Spectrum - A Tutorial, RANDY ROBERTS, Director of RF/Spread Spectrum Consulting. http://sss-mag.com/ss.html	
	16	Undetectable Radar? (Probably Not), ERIK HUNDMAN, Defensetech.org, August 3, 2006. http://www.defensetech.org/archives/002641.html	

Examiner Signature		Date Considered	

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1 Applicant's unique citation designation number (optional). 2 Applicant is to place a check mark here if English language Translation is attached.

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PTO/SB/08b (07-09)
Approved for use through 07/31/2012. OMB 0651-0031
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INFORMATION DISCLOSURE STATEMENT BY APPLICANT

(Use as many sheets as necessary)

Sheet 3 of 4

Complete if Known	
Application Number	
Filing Date	
First Named Inventor	Jed Margolin
Art Unit	
Examiner Name	
Attorney Docket Number	

NON PATENT LITERATURE DOCUMENTS

Examiner Initials*	Cite No.[1]	Include name of the author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc.), date, page(s), volume-issue number(s), publisher, city and/or country where published.	T[2]
	17	From a Different Perspective: Principles, Practice, and Potential of Bistatic Radar by H.D. GRIFFITHS, Dept. of Electron. & Electr. Eng., Univ. Coll. London, UK; Radar Conference, 2003. Proceedings of the International; Publication Date: 3-5 Sept. 2003; ISBN: 0-7803-7870-9; INSPEC Accession Number: 7892750, Abstract	
	18	Sensing Requirements for Unmanned Air Vehicles, AFRL's Air Vehicles Directorate, Control Sciences Division, Systems Development Branch, Wright-Patterson AFB OH, June 2004, http://www.afrlhorizons.com/Briefs/Jun04/VA0306.html .	
	19	Presentation entitled, Developing Sense & Avoid Requirements for Meeting an Equivalent Level of Safety (6MB | ppt), given by RUSS WOLFE, Technology IPT Lead, Access 5 Project at UVS Tech 2006. 18 January 2006.	
	20	Presentation: Integration into the National Airspace System (NAS) given by JOHN TIMMERMAN of the FAA's Air Traffic Organization (July 12, 2005)	
	21	Zone Ready for Drone, April 7, 2006, on the web site for the FAA's Air Traffic Organization Employees, http://www.ato.faa.gov/DesktopDefault.aspx?tabindex=4&tabid=17&itemid=937&mid=103	

Examiner Signature		Date Considered	

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PTO/SB/08b (07-09)
Approved for use through 07/31/2012. OMB 0651-0031
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INFORMATION DISCLOSURE STATEMENT BY APPLICANT

(Use as many sheets as necessary)

Complete if Known	
Application Number	
Filing Date	
First Named Inventor	Jed Margolin
Art Unit	
Examiner Name	
Attorney Docket Number	

Sheet 4 of 4

NON PATENT LITERATURE DOCUMENTS

Examiner Initials*	Cite No.[1]	Include name of the author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc.), date, page(s), volume-issue number(s), publisher, city and/or country where published.	T[2]
	22	Quadrennial Roles and Missions Review Report, Department of Defense, January 2009, Page 29 (PDF page 37) www.defenselink.mil/news/Jan2009/QRMFinalReport_v26Jan.pdf	
	23	Analog Devices, Inc. AD9481: 8-Bit, 250 MSPS, 3.3 V A/D Converter http://www.analog.com/en/analog-to-digital-converters/ad-converters/ad9481/products /product.html	
	24	Texas Instruments C6713B http://focus.ti.com/docs/prod/folders/print/tms320c6713b.html#features	
	26	Simple Solutions for Hyperbolic and Related Position Fixes, BERTRAND T. FANG, The Analytic Sciences Corp.; IEE Transactions on Aerospace and Electronic Systems, Publication Date: Sep 1990; Volume: 26, Issue: 5; page(s): 748-753; ISSN: 0018-9251, Page 751 https://svn.v2.nl/andres/Documentation/TDOA/Simple_Solutions_for_TDOA-fang.pdf	
	27	Lissajous Figures, JED MARGOLIN, May 2001; http://www.jmargolin.com/mtest/LJfigs.htm	

Examiner Signature	/Matthew Barker/	Date Considered	11/08/2012

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Search Strategy from ProQuest Dialog

October 29 2012 15:54

Search Strategy

Set#	Searched for	Databases	Results
S1	correlator or correlate or correlating	Inspec®	63160
S2	spread spectrum	Inspec®	29758
S3	buffer	Inspec®	73764
S4	antennas	Inspec®	210709
S5	s1 and s2 and s3 and s4	Inspec®	0
S6	s1 and s2 and s4	Inspec®	42
S7	directional	Inspec®	64098
S8	s7 n/5 s4	Inspec®	4078
S9	s1 and s2 and s8	Inspec®	0
S10	satellite	Inspec®	216079
S11	s1 and s2 and s10 and s3	Inspec®	0
S12	ellipse or ellipsoid	Inspec®	19643
S13	sun	Inspec®	258114
S14	s1 and s2 and s10 and s12	Inspec®	0
S15	s1 and s10 and s12	Inspec®	3
S16	s1 and s13 and s12	Inspec®	3

EAST Search History

EAST Search History (Prior Art)

Ref #	Hits	Search Query	DBs	Default Operator	Plurals	Time Stamp
L1	2150	(342/74-81,146,147).CCLS.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2012/11/08 12:37
L2	36023	cross adj correlat$3	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2012/11/08 12:56
L3	60572	spread adj spectrum	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2012/11/08 12:56
L4	10	1 and 2 and 3	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2012/11/08 12:56
L21	30	("3515805" | "3986168" | "4195293" | "4782450" | "5036330" | "5153836" | "5187485" | "5724041" | "5955993" | "6031485" | "6377436" | "7737878").PN.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2012/11/08 13:28
S1	60384	spread adj spectrum	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2012/10/26 18:01
S3	35875	cross adj correlat$3	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2012/10/26 18:02
S4	1333	S1 same S3	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2012/10/26 18:04
S5	1558174	buffer	US-PGPUB; USPAT;	OR	ON	2012/10/26 18:04

			USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB			
S6	763066	antenna	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2012/10/26 18:04
S7	14	S4 same S5	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2012/10/26 18:05
S8	208078	antennas or second adj antenna	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2012/10/26 18:09
S9	898	S3 same S8	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2012/10/26 18:09
S10	292	S1 and S9	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2012/10/26 18:09
S11	1921	cross adj correlator	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2012/10/26 18:18
S14	162	S8 same S11	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2012/10/26 18:18
S15	129	S14 and S1	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2012/10/26 18:19
S16	16	("2962714" | "4225938" | "4297704" | "4326778" | "4468093" | "4558925" | "4652817" | "4845502" | "4847862" | "5016256" | "5121248" | "5296861").PN. OR ("5955993").URPN.	US-PGPUB; USPAT; USOCR	OR	ON	2012/10/26 18:26
S17	34186	correlator	US-PGPUB;	OR	ON	2012/10/26

			USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB			18:37
S18	1327	S8 same S17	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2012/10/26 18:37
S19	52	S18 same S5	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2012/10/26 18:38
S20	1558328	buffer	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2012/10/28 12:47
S21	1921	cross adj correlator	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2012/10/28 12:47
S22	39	S20 with S21	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2012/10/28 12:47
S23	60387	spread adj spectrum	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2012/10/28 13:44
S25	34186	correlator	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2012/10/28 13:44
S26	350	S25 with S20 and S23	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2012/10/28 13:44
S27	31	S26 and radar	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2012/10/28 13:44
S28	63630	input adj S20	US-PGPUB;	OR	ON	2012/10/28

			USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB			13:50
S29	27	S25 with S28 and S23	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2012/10/28 13:51
S30	4020538	display	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2012/10/29 12:34
S31	1921	cross adj correlator	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2012/10/29 12:34
S32	36	S30 with S31	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2012/10/29 12:34
S33	48460	triangulat$3	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2012/10/29 13:08
S34	29088	directional near2 antenna	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2012/10/29 13:08
S35	60387	spread adj spectrum	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2012/10/29 13:09
S37	114	S33 with S34	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2012/10/29 13:21
S38	33	S35 and S37	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2012/10/29 13:21
S39	930719	correlat$3	US-PGPUB;	OR	ON	2012/10/29

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S40	32	S39 and S38	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2012/10/29 13:22
S42	2	S37 and S31	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2012/10/29 13:33
S43	26	S37 and S39 not S40	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2012/10/29 13:34
S44	172	(342/353).CCLS.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2012/10/29 14:02
S45	247	(342/453).CCLS.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2012/10/29 14:09
S46	107951	ellipse or ellipsiod	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2012/10/29 14:58
S47	18	S45 and S46	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2012/10/29 14:58
S48	563575	sun	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2012/10/29 15:08
S49	5	S44 and S46	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2012/10/29 15:09
S50	6	S48 and S45	US-PGPUB;	OR	ON	2012/10/29

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S51	4	("3171126").PN.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2012/10/29 15:11
S52	22	("3171126").URPN.	USPAT	OR	ON	2012/10/29 15:13
S53	392900	satellite	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2012/10/29 15:57
S55	42821	S39 with code	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2012/10/29 15:59
S56	171	S55 and S53 and S46	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2012/10/29 15:59
S57	2450369	reflect$3	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2012/10/29 16:00
S58	105	S56 and S57	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2012/10/29 16:00

11/ 8/ 2012 1:32:47 PM
C:\ Users\ mbarker2\ Documents\ EAST\ Workspaces\ 12910779.wsp

Search Notes	Application/Control No.	Applicant(s)/Patent Under Reexamination
	12910779	MARGOLIN, JED
	Examiner	**Art Unit**
	MATTHEW M BARKER	3646

SEARCHED

Class	Subclass	Date	Examiner
342	147	11/8/2012	MMB

SEARCH NOTES

Search Notes	Date	Examiner
342/74-81, 146, 147, 353, 453 text search - see printout	11/8/2012	MMB
EAST text search - see printout	10/29/2012	MMB
INSPEC NPL search - see printout	11/29/2012	MMB
PALM inventor name search	11/8/2012	MMB
Consult JB Sotomayor	11/7/2012	MMB

INTERFERENCE SEARCH

Class	Subclass	Date	Examiner

Index of Claims	Application/Control No. 12910779	Applicant(s)/Patent Under Reexamination MARGOLIN, JED
	Examiner MATTHEW M BARKER	Art Unit 3646

✓	Rejected		-	Cancelled		N	Non-Elected		A	Appeal
=	Allowed		÷	Restricted		I	Interference		O	Objected

☐ **Claims renumbered in the same order as presented by applicant** ☐ **CPA** ☐ **T.D.** ☐ **R.1.47**

CLAIM		DATE								
Final	Original	11/08/2012								
	1	N								
	2	N								
	3	N								
	4	N								
	5	N								
	6	N								
	7	✓								
	8	✓								
	9	✓								
	10	=								
	11	=								
	12	=								
	13	=								
	14	=								
	15	=								
	16	=								

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BIB DATA SHEET

CONFIRMATION NO. 8875

SERIAL NUMBER	FILING or 371(c) DATE	CLASS	GROUP ART UNIT	ATTORNEY DOCKET NO.
12/910,779	10/22/2010 RULE	342	3646	

APPLICANTS

Jed Margolin, VC Highlands, NV;

** **CONTINUING DATA** *************************

This appln claims benefit of 61/256,765 10/30/2009

** **FOREIGN APPLICATIONS** *************************

** **IF REQUIRED, FOREIGN FILING LICENSE GRANTED** ** ** SMALL ENTITY **

Foreign Priority claimed / 35 USC 119(a-d) conditions met / Verified and Acknowledged		STATE OR COUNTRY	SHEETS DRAWINGS	TOTAL CLAIMS	INDEPENDENT CLAIMS
Foreign Priority claimed ☐ Yes ☑ No 35 USC 119(a-d) conditions met ☐ Yes ☑ No Verified and Acknowledged /MATTHEW M BARKER/ Examiner's Signature	☐ Met after Allowance Initials	NV	25	16	7

ADDRESS

JED MARGOLIN
1981 EMPIRE ROAD
RENO, NV 89521-7430
UNITED STATES

TITLE

System for sensing aircraft and other objects

FILING FEE RECEIVED		
902	FEES: Authority has been given in Paper No.____________ to charge/credit DEPOSIT ACCOUNT No.____________ for following:	☐ All Fees ☐ 1.16 Fees (Filing) ☐ 1.17 Fees (Processing Ext. of time) ☐ 1.18 Fees (Issue) ☐ Other ________________ ☐ Credit

9-4-12

DEPARTMENT OF DEFENSE
ACCESS ACKNOWLEDGEMENT / SECRECY ORDER RECOMMENDATION
FOR PATENT APPLICATION

Application Serial No: DP12910779 Date Referred: 10/29/2010

I hereby acknowledge that the Department of Defense reviewers have inspected this application in administration of 35 USC 181 on behalf of the Agencies/Commands specified below. DoD reviewers will not divulge any information from this application for any purpose other than administration of 35 USC 181.

Defense Agency	Recommendation	Reviewer Name	Date Reviewed
Air Force	Secrecy Not Recommended	Richard Jennings	18 Nov 2010

Defense Agency	Reviewer Name	Date Viewed PDF
DTSA	Sean Harbottle	04 Nov 2010 09:33

Instructions to Reviewers:

1. All DoD personnel reviewing this application will be listed on this form regardless of whether they are making a secrecy order recommendation.

2. This form will be forwarded to USPTO once all assigned DoD entities have provided their secrecy order recommendation.

DoD Completion of Review: Final

Forwarded to USPTO: 11/18/2010 By:

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application of Jed Margolin

Serial No.: 12/910,779

Filed: 10/22/2010

For: SYSTEM FOR SENSING AIRCRAFT AND OTHER OBJECTS

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Dear Sir:

This is in response to the Office Action mailed 8/21/2012 in which the Examiner issued a restriction and/or election requirement for the following species:

1. This application contains claims directed to the following patentably distinct species:

   I. The embodiment shown in Figures 1 and 2 (TCAS).

   II. The embodiment shown in Figures 3-5 (ADS-B).

   III. The embodiment shown in Figures 6, and 9-18 (spread spectrum/satellite).

These embodiments are claimed as follows:

1. The TCAS (Figures 1 and 2) embodiment is claimed in claims 5 and 6.

2. The ADS-B (Figures 3-5) embodiment is claimed in claims 1-4.

3. The Spread Spectrum/Satellite (Figures 6, and 9-18) embodiment is claimed in claims 7-16.

In order to comply with the Examiner's restriction and/or election requirement, Applicant hereby elects the Spread Spectrum/Satellite species for examination and withdraws claims 1-6. Applicant withdraws these claims without prejudice and reserves the right to file divisional applications for the ADS-B and TCAS species.

Applicant makes this election without traverse.

The current claims list is appended.

Respectfully submitted,

/Jed Margolin/ Date: August 25, 2012

Jed Margolin

Jed Margolin
1981 Empire Rd.
Reno, NV 89521-7430
775-847-7845

Claims

1. (Withdrawn) A system for sensing aircraft and other objects comprising:

(a) an ADS-B transmitter;

(b) an ADS-B receiver;

(c) an ADS-B antenna;

(d) an ADS-B antenna multiplexer;

(e) an ADS-B processor;

(f) a radar processor;

(g) a display;

whereby

(a) said ADS-B antenna multiplexer is controlled by said ADS-B processor and allows said ADS-B antenna to be used by either said ADS-B transmitter or said ADS-B receiver,

(b) said ADS-B processor and said radar processor work together,

(c) said ADS-B processor periodically causes said ADS-B transmitter to emit a transmitted signal through said ADS-B antenna,

(d) said transmitted signal is reflected by a target producing a reflected signal,

(e) said reflected signal is received by said ADS-B antenna and sent to said ADS-B receiver,

(f) said radar processor processes said reflected signal from said ADS-B receiver and said transmitted signal from said ADS-B transmitter to determine a range to said target, and

(g) displays said range on said display.

2. (Withdrawn) The system of claim 1 wherein said radar processor is incorporated into said ADS-B processor.

3. (Withdrawn) A system for sensing aircraft and other objects comprising:

(a) an ADS-B transmitter;

(b) an ADS-B receiver;

(c) an ADS-B antenna;

(d) an ADS-B antenna multiplexer;

(e) an ADS-B processor;

(f) a radar processor;

(g) a second antenna;

(h) an antenna controller;

(i) a second receiver;

(j) a display;

whereby

(a) said second antenna is directional and the direction of said second antenna is controlled by said antenna controller under control of said radar processor,

(b) said ADS-B antenna multiplexer is controlled by said ADS-B processor and allows said ADS-B transmitter to use either said ADS-B antenna or said second antenna and also allows said ADS-B receiver to use either said ADS-B antenna or said second antenna,

(c) said ADS-B processor and said radar processor work together,

(d) said ADS-B processor periodically causes said ADS-B transmitter to emit a transmitted signal through either said ADS-B antenna or said second antenna through said ADS-B antenna multiplexer,

(e) said transmitted signal is reflected by a target producing a reflected signal,

(f) said reflected signal is received by either said ADS-B antenna or said second antenna through said ADS-B antenna multiplexer, which sends said reflected signal to said second receiver,

(g) said radar processor processes said reflected signal from said second receiver and said transmitted signal from said ADS-B transmitter to determine a range to said target,

(h) said radar processor uses the direction of said second antenna to determine a bearing to said target, and

(i) displays said range and said bearing on said display.

4. (Withdrawn) The system of claim 3 wherein said radar processor is incorporated into said ADS-B processor.

5. (Withdrawn) A system for sensing aircraft and other objects comprising:

(a) a TCAS Interrogation transmitter;

(b) a TCAS Interrogation Receiver;

(c) a first TCAS antenna;

(d) a second TCAS antenna;

(e) an antenna controller;

(f) a TCAS antenna diplexer;

(g) a TCAS processor;

(h) a radar processor;

(i) a display;

whereby

(a) said second TCAS antenna is directional and is controlled by said TCAS processor using said antenna controller,

(b) said TCAS processor and said radar processor work together,

(c) said TCAS antenna diplexer is controlled by said TCAS processor and allows said first TCAS antenna to be used by either said TCAS interrogation transmitter or said TCAS interrogation receiver and also allows said second TCAS antenna to be used by either said TCAS interrogation transmitter or said TCAS interrogation receiver,

(d) said TCAS processor periodically causes said TCAS interrogation transmitter to emit a transmitted signal through either said first TCAS antenna or said second TCAS antenna,

(e) said transmitted signal is reflected by a target producing a reflected signal,

(f) said reflected signal is received by either said first TCAS antenna or by said second TCAS antenna and sent to said TCAS interrogation receiver,

(g) said radar processor processes said reflected signal from said TCAS interrogation receiver and said transmitted signal from said TCAS interrogation transmitter to determine a range to said target,

(h) said radar processor uses the direction of said antenna controller to determine a bearing to said target, and

(i) displays said range and said bearing on said display.

6. (Withdrawn) The system of claim 5 wherein said radar processor is incorporated into said TCAS processor.

7. A system for sensing spread-spectrum signals comprising:

(a) a first antenna;

(b) a first receiver for receiving spread-spectrum signals;

(c) a first data buffer;

(d) a second antenna;

(e) a second receiver for receiving spread-spectrum signals;

(f) a second data buffer;

(g) a cross-correlator with two inputs and one or more outputs;

(h) a system controller;

(i) a display;

whereby,

(a) said first antenna is connected to said first receiver,

(b) said first receiver provides data for said first data buffer,

(c) said second antenna is connected to said second receiver,

(d) said second receiver provides data for said second data buffer,

(e) the output of said first data buffer is connected to a first input of said two inputs to said cross-correlator,

(f) the output of said second data buffer is connected to a second input of said two inputs to said cross-correleator,

(g) under the direction of said system controller said cross-correlator performs a cross-correlation between said first input and said second input and produces an output, said output indicating the magnitude of the cross-correlation between a spread-spectrum signal received by both said first receiver and said second receiver,

(h) said one or more outputs of said cross-correlator is displayed on said display,

whereby a high cross-correlation between said first receiver and said second receiver indicates the presence of a spread-spectrum signal.

8. The system of claim 7 further comprising a distance between said first antenna and said second antenna whereby under the direction of said system controller said cross-correlator performs a cross-correlation between said first input and said second input and produces a second output, said second output indicating the phase of the cross-correlation between a spread-spectrum signal

received by both said first receiver and said second receiver, and whereby said phase indicates a bearing to the location of said spread-spectrum signal, and said bearing is displayed on said display.

9. The system of claim 7 further comprising:

(a) a distance between said first antenna and said second antenna;
(b) a first antenna controller for said first antenna;
(c) a second antenna controller for said second antenna;

whereby

(a) said first antenna is a directional antenna,
(b) said second antenna is a directional antenna,
(c) said system controller uses said first antenna controller to control the direction of said first antenna,
(d) said system controller uses said second antenna controller to control the direction of said second antenna,
(e) said system controller coordinates the direction of said first directional antenna with the direction of said second directional antenna to triangulate the source of said spread-spectrum signal to determine a range and a bearing to said spread-spectrum signal, and
(f) said range and said bearing to said spread-spectrum signal are displayed on said display.

10. A system for sensing aircraft and other objects comprising:

(a) four or more orbiting satellites;
(b) an antenna;
(c) a receiver;
(d) a data buffer;
(e) a cross-correlator with two or more inputs and one or more outputs;
(f) a system controller;
(g) a list of code keys;
(h) a display;

wherein

(a) each of said four or more orbiting satellites transmits a signal encoded by a unique code key selected from said list of code keys,

(b) said antenna is connected to said receiver,

(c) the output of said receiver is connected to the input of said data buffer,

(d) the output of said data buffer is connected to a first of said two or more inputs of said cross-correlator,

(e) said system controller provides a second of said two or more inputs of said cross-correlator,

(f) said system controller receives an output of said one or more outputs of said cross-correleator,

and whereby

(a) said system controller uses said signal transmitted by each of said four or more orbiting satellites, said list of code keys, and said cross-correlator to uniquely identify each of said four or more orbiting satellites,

(b) said system controller determines a distance and a direction to each uniquely identified satellite,

(c) said signal from said each uniquely identified satellite is reflected by a target producing a uniquely identifiable reflected signal,

(d) each said uniquely identifiable reflected signal is received by said antenna, which is connected to said receiver, which is connected to said data buffer, which is connected to said first of said two or more inputs of said cross-correlator,

(e) said system controller uses said list of code keys and said cross-correlator to identify each said uniquely identifiable reflected signal,

(f) said system controller uses each said uniquely identifiable reflected signal and said range and said direction to said each uniquely identified satellite to determine a range and a bearing to said target, and

(g) displays said range and said bearing on said display,

and wherein

(a) the range and direction to a first of said four or more orbiting satellites and the signal from said first of said four or more orbiting satellites reflected from said target produce a first ellipsoid with said first of said four or more orbiting satellites at one focal point of said first ellipsoid, said antenna at the other focal point of said first ellipsoid, and said target on the surface of said first ellipsoid,

(b) the range and direction to a second of said four or more orbiting satellites and the signal from said second of said four or more orbiting satellites reflected from said target produce a second ellipsoid with said second of said four or more orbiting satellites at one focal point of said second ellipsoid, said antenna at the other focal point of said second ellipsoid, and said target on the surface of said second ellipsoid,

(c) the range and direction to a third of said four or more orbiting satellites and the signal from said third of said four or more orbiting satellites reflected from said target produce a third ellipsoid with said third of said four or more orbiting satellites at one focal point of said third ellipsoid, said antenna at the other focal point of said third ellipsoid, and said target on the surface of said third ellipsoid,

(d) the range and direction to a fourth of said four or more orbiting satellites and the signal from said fourth of said four or more orbiting satellites reflected from said target produce a fourth ellipsoid with said fourth of said four or more orbiting satellites at one focal point of said fourth ellipsoid, said antenna at the other focal point of said fourth ellipsoid, and said target on the surface of said fourth ellipsoid,

(e) said first ellipsoid and said second ellipsoid intersect in an ellipse with said target located on said ellipse,

(f) said third ellipsoid and said ellipse intersect at two points with said target located at one of said two points,

(g) said fourth ellipsoid intersects with only one of said two points with said target located at said only one of said two points.

11. The system of claim 10 further comprising communications links between each of said four or more orbiting satellites.

12. The system of claim 10 wherein at least one of said four or more orbiting satellites is located in low earth orbit.

13. The system of claim 10 further comprising:

(a) a receiver in each of said four or more orbiting satellites;

(b) a transmitter;

whereby said receiver in each of said four or more orbiting satellites and said transmitter are used to send transmissions to at least one of said four or more orbiting satellites in order to provide two-way communications through said at least one of said four or more orbiting satellites.

14. The system of claim 11 further comprising a satellite receiver in at least two or more of said four or more orbiting satellites whereby a signal transmitted by said at least two or more of said four or more orbiting satellites and said satellite receiver are used to perform long baseline radar interferometric measurements of terrain elevations.

15. A system for sensing aircraft and other objects comprising:

(a) one or more orbiting satellites;

(b) a first antenna;

(c) a second antenna;

(d) a controller for said second antenna;

(e) an antenna multiplexer;

(f) a receiver;

(g) a data buffer;

(h) a cross-correlator with two or more inputs and one or more outputs;

(i) a system controller;

(j) a list of code keys;

(k) a display;

wherein

(a) said antenna multiplexer selects between said first antenna and said second antenna under control of said system controller,

(b) the output of said antenna multiplexer is connected to the input of said receiver,

(c) said second antenna is directional and is controlled by said antenna controller under control of said system controller,

(d) the output of said receiver is connected to the input of said data buffer,

(e) the output of said data buffer is connected to a first of said two or more inputs of said cross-correlator,

(f) said system controller provides a second of said two or more inputs of said cross-correlator,

(g) said system controller receives an output of said one or more outputs of said cross-correleator,

and whereby

(a) said first antenna is selected by said system controller,

(b) said one or more orbiting satellites transmits a signal encoded by a unique code key selected from said list of code keys,

(c) said system controller uses said signal transmitted by said one or more orbiting satellites, said list of code keys, and said cross-correlator to uniquely identify said one or more orbiting satellites,

(d) said system controller determines a distance to a uniquely identified satellite,

(e) said signal from said uniquely identified satellite is reflected by a target producing a uniquely identifiable reflected signal,

(f) said uniquely identifiable reflected signal is received by said second antenna, which is connected to said receiver, which is connected to said data buffer, which is connected to said first of said two or more inputs of said cross-correlator,

(g) said system controller uses said list of code keys and said cross-correlator to identify said uniquely identifiable reflected signal,

(h) said system controller uses said antenna controller to direct said second antenna at the source of said uniquely identifiable reflected signal to produce a bearing to said uniquely identifiable reflected signal,

(i) said system controller uses said uniquely identifiable reflected signal and said range to said uniquely identified satellite to determine a range and a bearing to said target, and

(j) displays said range and said bearing on said display,

and wherein

(a) the range and direction to said one or more orbiting satellites and the signal from said one or more orbiting satellites reflected from said target produces an ellipsoid with said one or more orbiting satellites at one focal point of said ellipsoid, said antenna at the other focal point of said ellipsoid, and said target on the surface of said ellipsoid,

(b) said second antenna is aimed to receive said signal from said one or more orbiting satellites reflected from said target, and

(c) the direction of said second antenna is used to determine the location of said target on said ellipsoid.

16. A system for sensing aircraft and other objects during daytime comprising:

(a) a first directional antenna;

(b) a first antenna controller;

(c) a first receiver;

(d) a first data buffer;

(e) a second directional antenna;

(f) a second antenna controller;

(g) a second receiver;

(h) a second data buffer;

(i) a cross-correlator;

(j) a system controller;

(k) a display;

whereby

(a) the position of said first directional antenna is controlled by said first antenna controller under the control of said system controller,

(b) the position of said second directional antenna is controlled by said second antenna controller under the control of said system controller,

(c) said cross-correlator has two inputs and one output,

(d) said first directional antenna is connected to the input of said first receiver,

(e) the output of said first receiver is connected to the input of said first data buffer,

(f) the output of said first data buffer is connected to a first input of said cross-correlator under control of said system controller,

(g) said second directional antenna is connected to the input of said second receiver,

(h) the output of said second receiver is connected to the input of said second data buffer,

(i) the output of said second data buffer is connected to a second input of said cross-correlator under control of said system controller,

(j) said system controller directs said first antenna controller to point said first directional antenna at the Sun to produce a first signal,

(k) said system controller directs said cross-correlator to perform a cross-correlation between said first received from said first directional antenna which is stored in said first data buffer and a second signal received from said second directional antenna which is stored in said second data buffer,

(l) said system controller directs said second antenna controller to point said second directional antenna to produce said second signal to maximize said output of said cross-correlator where said second directional antenna is not pointed at said Sun,

whereas

(a) said second signal is a reflection of said first signal produced by said Sun, said reflection being produced by a target,

(b) a time delay between said first signal and said second signal is used to determine an ellipsoid with said first directional antenna located at one focal point of said ellipsoid, said Sun located at the other focal point of said ellipsoid and said target on the surface of said ellipsoid,

(c) the direction of said second directional antenna is used to determine the location of said target on said ellipsoid,

(d) said system controller uses said location of said target on said ellipsoid to produce a range and a bearing to said target, and

(e) displays said range and said bearing on said display.

Electronic Acknowledgement Receipt

EFS ID:	13588977
Application Number:	12910779
International Application Number:	
Confirmation Number:	8875
Title of Invention:	System for sensing aircraft and other objects
First Named Inventor/Applicant Name:	Jed Margolin
Customer Number:	23497
Filer:	Jed Margolin
Filer Authorized By:	
Attorney Docket Number:	
Receipt Date:	25-AUG-2012
Filing Date:	22-OCT-2010
Time Stamp:	22:04:33
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	no

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Transmittal Letter	jm_restriction_letter.pdf	60690 0afb6a99574cb9570ef0d8c4edce3d5dbf0b7701	no	16

Warnings:

Information:

Total Files Size (in bytes):	60690

This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.

New Applications Under 35 U.S.C. 111
If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

National Stage of an International Application under 35 U.S.C. 371
If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

New International Application Filed with the USPTO as a Receiving Office
If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

PTO/SB/06 (07-06)
Approved for use through 1/31/2007. OMB 0651-0032
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE

PATENT APPLICATION FEE DETERMINATION RECORD
Substitute for Form PTO-875

Application or Docket Number	Filing Date	
12/910,779	10/22/2010	☐ To be Mailed

APPLICATION AS FILED – PART I

FOR	NUMBER FILED (Column 1)	NUMBER EXTRA (Column 2)	SMALL ENTITY ☒ RATE ($)	FEE ($)	OR	OTHER THAN SMALL ENTITY RATE ($)	FEE ($)
☐ BASIC FEE (37 CFR 1.16(a), (b), or (c))	N/A	N/A	N/A			N/A	
☐ SEARCH FEE (37 CFR 1.16(k), (i), or (m))	N/A	N/A	N/A			N/A	
☐ EXAMINATION FEE (37 CFR 1.16(o), (p), or (q))	N/A	N/A	N/A			N/A	
TOTAL CLAIMS (37 CFR 1.16(i))	minus 20 =	*	X $ =		OR	X $ =	
INDEPENDENT CLAIMS (37 CFR 1.16(h))	minus 3 =	*	X $ =			X $ =	
☐ APPLICATION SIZE FEE (37 CFR 1.16(s))	If the specification and drawings exceed 100 sheets of paper, the application size fee due is $250 ($125 for small entity) for each additional 50 sheets or fraction thereof. See 35 U.S.C. 41(a)(1)(G) and 37 CFR 1.16(s).						
☐ MULTIPLE DEPENDENT CLAIM PRESENT (37 CFR 1.16(j))							
			TOTAL			TOTAL	

* If the difference in column 1 is less than zero, enter "0" in column 2.

APPLICATION AS AMENDED – PART II

AMENDMENT 08/25/2012	CLAIMS REMAINING AFTER AMENDMENT (Column 1)		HIGHEST NUMBER PREVIOUSLY PAID FOR (Column 2)	PRESENT EXTRA (Column 3)	SMALL ENTITY RATE ($)	ADDITIONAL FEE ($)	OR	OTHER THAN SMALL ENTITY RATE ($)	ADDITIONAL FEE ($)
Total (37 CFR 1.16(i))	* 16	Minus	** 20	= 0	X $30 =	0	OR	X $ =	
Independent (37 CFR 1.16(h))	* 5	Minus	***7	= 0	X $125 =	0	OR	X $ =	
☐ Application Size Fee (37 CFR 1.16(s))									
☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))							OR		
					TOTAL ADD'L FEE	0	OR	TOTAL ADD'L FEE	

AMENDMENT	CLAIMS REMAINING AFTER AMENDMENT (Column 1)		HIGHEST NUMBER PREVIOUSLY PAID FOR (Column 2)	PRESENT EXTRA (Column 3)	RATE ($)	ADDITIONAL FEE ($)		RATE ($)	ADDITIONAL FEE ($)
Total (37 CFR 1.16(i))	*	Minus	**	=	X $ =		OR	X $ =	
Independent (37 CFR 1.16(h))	*	Minus	***	=	X $ =		OR	X $ =	
☐ Application Size Fee (37 CFR 1.16(s))									
☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))							OR		
					TOTAL ADD'L FEE		OR	TOTAL ADD'L FEE	

* If the entry in column 1 is less than the entry in column 2, write "0" in column 3.
** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20".
*** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, enter "3".
The "Highest Number Previously Paid For" (Total or Independent) is the highest number found in the appropriate box in column 1.

Legal Instrument Examiner:
/LAJUAN HICKSON/

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
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P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
12/910,779	10/22/2010	Jed Margolin		8875

23497 7590 08/21/2012

JED MARGOLIN
1981 EMPIRE ROAD
RENO, NV 89521-7430

EXAMINER	
BARKER, MATTHEW M	

ART UNIT	PAPER NUMBER
3646	

MAIL DATE	DELIVERY MODE
08/21/2012	PAPER

Please find below and/or attached an Office communication concerning this application or proceeding.

The time period for reply, if any, is set in the attached communication.

Office Action Summary	Application No.	Applicant(s)	
	12/910,779	MARGOLIN, JED	
	Examiner	Art Unit	
	MATTHEW M. BARKER	3646	

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address --

Period for Reply

A SHORTENED STATUTORY PERIOD FOR REPLY IS SET TO EXPIRE *1* MONTH(S) OR THIRTY (30) DAYS, WHICHEVER IS LONGER, FROM THE MAILING DATE OF THIS COMMUNICATION.

- Extensions of time may be available under the provisions of 37 CFR 1.136(a). In no event, however, may a reply be timely filed after SIX (6) MONTHS from the mailing date of this communication.
- If NO period for reply is specified above, the maximum statutory period will apply and will expire SIX (6) MONTHS from the mailing date of this communication.
- Failure to reply within the set or extended period for reply will, by statute, cause the application to become ABANDONED (35 U.S.C. § 133). Any reply received by the Office later than three months after the mailing date of this communication, even if timely filed, may reduce any earned patent term adjustment. See 37 CFR 1.704(b).

Status

1)☐ Responsive to communication(s) filed on _____.

2a)☐ This action is **FINAL**. 2b)☒ This action is non-final.

3)☐ An election was made by the applicant in response to a restriction requirement set forth during the interview on _____; the restriction requirement and election have been incorporated into this action.

4)☐ Since this application is in condition for allowance except for formal matters, prosecution as to the merits is closed in accordance with the practice under *Ex parte Quayle*, 1935 C.D. 11, 453 O.G. 213.

Disposition of Claims

5)☒ Claim(s) *1-16* is/are pending in the application.

5a) Of the above claim(s) _____ is/are withdrawn from consideration.

6)☐ Claim(s) _____ is/are allowed.

7)☐ Claim(s) _____ is/are rejected.

8)☐ Claim(s) _____ is/are objected to.

9)☒ Claim(s) *1-16* are subject to restriction and/or election requirement.

Application Papers

10)☐ The specification is objected to by the Examiner.

11)☐ The drawing(s) filed on _____ is/are: a)☐ accepted or b)☐ objected to by the Examiner.

Applicant may not request that any objection to the drawing(s) be held in abeyance. See 37 CFR 1.85(a).

Replacement drawing sheet(s) including the correction is required if the drawing(s) is objected to. See 37 CFR 1.121(d).

12)☐ The oath or declaration is objected to by the Examiner. Note the attached Office Action or form PTO-152.

Priority under 35 U.S.C. § 119

13)☐ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).

a)☐ All b)☐ Some * c)☐ None of:

1.☐ Certified copies of the priority documents have been received.

2.☐ Certified copies of the priority documents have been received in Application No. _____.

3.☐ Copies of the certified copies of the priority documents have been received in this National Stage application from the International Bureau (PCT Rule 17.2(a)).

* See the attached detailed Office action for a list of the certified copies not received.

Attachment(s)

1) ☐ Notice of References Cited (PTO-892)

2) ☐ Notice of Draftsperson's Patent Drawing Review (PTO-948)

3) ☐ Information Disclosure Statement(s) (PTO/SB/08) Paper No(s)/Mail Date _____.

4) ☐ Interview Summary (PTO-413) Paper No(s)/Mail Date. _____ .

5) ☐ Notice of Informal Patent Application

6) ☐ Other: _____.

DETAILED ACTION

Election/Restrictions

1. This application contains claims directed to the following patentably distinct species:

I. The embodiment shown in Figures 1 and 2 (TCAS).

II. The embodiment shown in Figures 3-5 (ADS-B).

III. The embodiment shown in Figures 6, and 9-18 (spread spectrum/satellite).

The species are independent or distinct because the claims to the different species recite the mutually exclusive characteristics of such species, e.g. TCAS, ADS-B, and spread spectrum/satellite hardware. In addition, these species are not obvious variants of each other based on the current record.

Applicant is required under 35 U.S.C. 121 to elect a single disclosed species, or a single grouping of patentably indistinct species, for prosecution on the merits to which the claims shall be restricted if no generic claim is finally held to be allowable. Currently, no claim is generic.

There is a search and/or examination burden for the patentably distinct species as set forth above because at least the following reason(s) apply:

the species or groupings of patentably indistinct species have acquired a separate status in the art in view of their different classification, and

the species or groupings of patentably indistinct species require a different field of search (e.g., searching different classes /subclasses or electronic resources, or employing different search strategies or search queries).

Applicant is advised that the reply to this requirement to be complete must include (i) an election of a species or a grouping of patentably indistinct species to be examined even though the requirement may be traversed (37 CFR 1.143) **and (ii) identification of the claims encompassing the elected species or grouping of patentably indistinct species**, including any claims subsequently added. An argument that a claim is allowable or that all claims are generic is considered nonresponsive unless accompanied by an election.

The election may be made with or without traverse. To preserve a right to petition, the election must be made with traverse. If the reply does not distinctly and specifically point out supposed errors in the election of species requirement, the election shall be treated as an election without traverse. Traversal must be presented at the time of election in order to be considered timely. Failure to timely traverse the requirement will result in the loss of right to petition under 37 CFR 1.144. If claims are added after the election, applicant must indicate which of these claims are readable on the elected species or grouping of patentably indistinct species.

Should applicant traverse on the ground that the species, or groupings of patentably indistinct species from which election is required, are not patentably distinct, applicant should submit evidence or identify such evidence now of record showing them to be obvious variants or clearly admit on the record that this is the case. In either instance, if the examiner finds one of the species unpatentable over the prior art, the evidence or admission may be used in a rejection under 35 U.S.C. 103(a) of the other species.

Upon the allowance of a generic claim, applicant will be entitled to consideration of claims to additional species which depend from or otherwise require all the limitations of an allowable generic claim as provided by 37 CFR 1.141.

DETAILED ACTION

2. Any inquiry concerning this communication or earlier communications from the examiner should be directed to MATTHEW M. BARKER whose telephone number is (571)272-3103. The examiner can normally be reached on M-F, 8:30 AM-5:00 PM.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Jack Keith can be reached on (571)272-6878. The fax phone number for the organization where this application or proceeding is assigned is 571-273-8300.

Information regarding the status of an application may be obtained from the Patent Application Information Retrieval (PAIR) system. Status information for published applications may be obtained from either Private PAIR or Public PAIR. Status information for unpublished applications is available through Private PAIR only. For more information about the PAIR system, see http://pair-direct.uspto.gov. Should you have questions on access to the Private PAIR system, contact the Electronic Business Center (EBC) at 866-217-9197 (toll-free). If you would like assistance from a USPTO Customer Service Representative or access to the automated information system, call 800-786-9199 (IN USA OR CANADA) or 571-272-1000.

/MATTHEW M BARKER/
Examiner, Art Unit 3646

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
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APPLICATION NUMBER	FILING OR 371(C) DATE	FIRST NAMED APPLICANT	ATTY. DOCKET NO./TITLE
12/910,779	10/22/2010	Jed Margolin	

CONFIRMATION NO. 8875

PUBLICATION NOTICE

OC000000048764939

23497
JED MARGOLIN
1981 EMPIRE ROAD
RENO, NV 89521-7430

Title: System for sensing aircraft and other objects

Publication No.US-2011-0169684-A1
Publication Date:07/14/2011

NOTICE OF PUBLICATION OF APPLICATION

The above-identified application will be electronically published as a patent application publication pursuant to 37 CFR 1.211, et seq. The patent application publication number and publication date are set forth above.

The publication may be accessed through the USPTO's publically available Searchable Databases via the Internet at www.uspto.gov. The direct link to access the publication is currently http://www.uspto.gov/patft/.

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In addition, information on the status of the application, including the mailing date of Office actions and the dates of receipt of correspondence filed in the Office, may also be accessed via the Internet through the Patent Electronic Business Center at www.uspto.gov using the public side of the Patent Application Information and Retrieval (PAIR) system. The direct link to access this status information is currently http://pair.uspto.gov/. Prior to publication, such status information is confidential and may only be obtained by applicant using the private side of PAIR.

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APPLICATION NUMBER	FILING OR 371(C) DATE	FIRST NAMED APPLICANT	ATTY. DOCKET NO./TITLE
12/910,779	10/22/2010	Jed Margolin	

CONFIRMATION NO. 8875

NEW OR REVISED PPD NOTICE

OC000000047010474

23497
JED MARGOLIN
1981 EMPIRE ROAD
RENO, NV 89521-7430

NOTICE OF NEW OR REVISED PROJECTED PUBLICATION DATE

The above-identified application has a new or revised projected publication date. The current projected publication date for this application is 07/14/2011. If this is a new projected publication date (there was no previous projected publication date), the application has been cleared by Licensing & Review or a secrecy order has been rescinded and the application is now in the publication queue.

If this is a revised projected publication date (one that is different from a previously communicated projected publication date), the publication date has been revised due to processing delays in the USPTO or the abandonment and subsequent revival of an application. The application is anticipated to be published on a date that is more than six weeks different from the originally-projected publication date.

More detailed publication information is available through the private side of Patent Application Information Retrieval (PAIR) System. The direct link to access PAIR is currently http://pair.uspto.gov. Further assistance in electronically accessing the publication, or about PAIR, is available by calling the Patent Electronic Business Center at 1-866-217-9197.

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APPLICATION NUMBER	FILING or 371(c) DATE	GRP ART UNIT	FIL FEE REC'D	ATTY.DOCKET.NO	TOT CLAIMS	IND CLAIMS
12/910,779	10/22/2010	3662	902		16	7

CONFIRMATION NO. 8875

23497
JED MARGOLIN
1981 EMPIRE ROAD
RENO, NV 89521-7430

UPDATED FILING RECEIPT

OC000000044589678

Date Mailed: 11/23/2010

Receipt is acknowledged of this non-provisional patent application. The application will be taken up for examination in due course. Applicant will be notified as to the results of the examination. Any correspondence concerning the application must include the following identification information: the U.S. APPLICATION NUMBER, FILING DATE, NAME OF APPLICANT, and TITLE OF INVENTION. Fees transmitted by check or draft are subject to collection. Please verify the accuracy of the data presented on this receipt. **If an error is noted on this Filing Receipt, please submit a written request for a Filing Receipt Correction. Please provide a copy of this Filing Receipt with the changes noted thereon. If you received a "Notice to File Missing Parts" for this application, please submit any corrections to this Filing Receipt with your reply to the Notice. When the USPTO processes the reply to the Notice, the USPTO will generate another Filing Receipt incorporating the requested corrections**

Applicant(s)

Jed Margolin, VC Highlands, NV;

Power of Attorney: None

Domestic Priority data as claimed by applicant

This appln claims benefit of 61/256,765 10/30/2009

Foreign Applications

Permission to Access - A proper **Authorization to Permit Access to Application by Participating Offices** (PTO/SB/39 or its equivalent) has been received by the USPTO.

Projected Publication Date: To Be Determined - pending completion of Security Review

Non-Publication Request: No

Early Publication Request: No

**** SMALL ENTITY ****

Title

System for sensing aircraft and other objects

Preliminary Class

342

PROTECTING YOUR INVENTION OUTSIDE THE UNITED STATES

Since the rights granted by a U.S. patent extend only throughout the territory of the United States and have no effect in a foreign country, an inventor who wishes patent protection in another country must apply for a patent in a specific country or in regional patent offices. Applicants may wish to consider the filing of an international application under the Patent Cooperation Treaty (PCT). An international (PCT) application generally has the same effect as a regular national patent application in each PCT-member country. The PCT process **simplifies** the filing of patent applications on the same invention in member countries, but **does not result** in a grant of "an international patent" and does not eliminate the need of applicants to file additional documents and fees in countries where patent protection is desired.

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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application of Jed Margolin

Serial No.: 12/910,779

Filed: 10/22/2010

For: SYSTEM FOR SENSING AIRCRAFT AND OTHER OBJECTS

Mail Stop Missing Parts
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Dear Sir:

This is in response to FORMALITIES LETTER, NOTICE TO FILE CORRECTED APPLICATIONS PAPERS mailed 11/05/2010 in the above application, which states:

NOTICE TO FILE CORRECTED APPLICATION PAPERS

Filing Date Granted

> An application number and filing date have been accorded to this application. The application is informal since it does not comply with the regulations for the reason(s) indicated below. Applicant is given TWO MONTHS from the date of this Notice within which to correct the informalities indicated below. Extensions of time may be obtained by

filing a petition accompanied by the extension fee under the provisions of 37 CFR 1.136(x).

The required item(s) identified below must be timely submitted to avoid abandonment:

- A substitute specification in compliance with 37 CFR 1.52, 1,121(b)(3), and 1.125, is required. The substitute specification must be submitted with markings and be accompanied by a clean version (without markings) as set forth in 37 CFR 1.125(c) and a statement that the substitute specification contains no new matter (see 37 CFR 1.125(b)). The specification, claims, and/or abstract page(s) submitted is not acceptable and cannot be scanned or properly stored because:
- The line spacing on the specification, claims, and/or abstract is not 1 1/2 or double spaced (see 37 CFR 1.52(b)).

Applicant is cautioned that correction of the above items may cause the specification and drawings page count to exceed 100 pages. If the specification and drawings exceed 100 pages, applicant will need to submit the required application size fee.

Applicant's Specification contained several passages where he single-spaced quoted references. Apparently, this is no longer an acceptable practice.

As required, Applicant is submitting a Substitute Specification. Applicant certifies that the Substitute Specification contains no new matter. Applicant further certifies that the Substitute Specification contains no changes other than to meet the required line spacing requirements and the changes in page numbering resulting therefrom.

Because these are the only changes to the Specification, Applicant does not believe he is required to file a marked Substitute Specification. If Application is incorrect, he requests he be promptly notified so he can submit a Marked Substitute Specification showing where he changed the line spacing and where the page numbers changed as a result. (He would also ask for guidance instructing him how he would accomplish such markings.)

Applicant's Claims do not contain any single-spaced lines but because the number of pages in the Specification have changed, the page numbering of the Claims has changed. Applicant does not believe he is required to submit a Substitute Claims as a result of the new page numbering. If Applicant is incorrect he requests he be promptly notified so he can submit a Substitute Claims with the new page numbers.

Applicant's Abstract does not contain any single-spaced lines but because the number of pages in the Specification have changed, the page number of the Abstract has changed. Applicant does not believe he is required to submit a Substitute Abstract as a result of the new page number. If Applicant is incorrect he requests he be promptly notified so he can submit a Substitute Abstract with the new page number.

Respectfully submitted,

/Jed Margolin/ Date: November 13, 2010

Jed Margolin

Jed Margolin

1981 Empire Rd.
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UNITED STATES PATENT APPLICATION FOR PATENT
FOR

SYSTEM FOR SENSING AIRCRAFT AND OTHER OBJECTS

INVENTOR: JED MARGOLIN

SYSTEM FOR SENSING AIRCRAFT AND OTHER OBJECTS

CROSS REFERENCES TO RELATED APPLICATIONS

[001] This application claims the benefit of U.S. Provisional Application No. 61/256,765 filed on October 30, 2009.

BACKGROUND OF THE INVENTION - Field of Invention

[002] This invention relates to the field of sensing aircraft and other objects and is part of the See and Avoid (SAA) function for manned aircraft and the Detect, Sense and Avoid (DSA) function for remotely piloted vehicles (RPVs) and unmanned aerial vehicles (UAVs). RPV is an older term for UAV. "UCAV" shall mean "Unmanned Combat Aerial Vehicle." UCAV is also sometimes defined as an "Uninhabited Combat Aerial Vehicle." UCAV is a UAV that is intended for use in combat. UAS means "Unmanned Aerial System." UCAS means "Unmanned Combat Air System." The characteristics all these vehicles have in common is that there is no human pilot onboard, and although they may be operated autonomously they can also be controlled by a remotely located operator or pilot. The term UAV shall be used as a generic term for such vehicles. Detect, Sense, and Avoid (DSA) is also commonly called Sense and Avoid (SAA) since "Detect" and "Sense" mostly mean the same thing. This invention is directed to the "See" in "See and Avoid" and the "Sense" in "Sense and Avoid." It may also be used by ground stations to sense aircraft and other objects.

BACKGROUND OF THE INVENTION – Prior Art

[003] In an aircraft with the pilot onboard, Sense and Avoid is called See and Avoid. FAA Regulations do not give much guidance for seeing other aircraft.

Right-of-way rules: Except water operations 14 CFR § 91.113(b) [*IDS Cite 1*]:

(b) General. When weather conditions permit, regardless of whether an operation is conducted under instrument flight rules or visual flight rules, vigilance shall be maintained by each person operating an aircraft so as to see and avoid other aircraft. When a rule of this section gives another aircraft the right-of-way, the pilot shall give way to that aircraft and may not pass over, under, or ahead of it unless well clear.

Right-of-way rules: Water operations 14 CFR § 91.115(a) [*IDS Cite. 2*]

(a) *General.* Each person operating an aircraft on the water shall, insofar as possible, keep clear of all vessels and avoid impeding their navigation, and shall give way to any vessel or other aircraft that is given the right-of-way by any rule of this section.

When operating under Visual Flight Rules the idea is to look out small windows providing a limited field of view and hope you see any nearby aircraft in time to avoid a collision. This is made more difficult because of the wide range of aircraft sizes and speeds. (Is it a large aircraft far away or a small aircraft much closer?) This is even more difficult under instrument flight rules where there may be no visibility.

[004] Radar can be used to sense aircraft. Ground-based Radar allows Air Traffic Control (ATC) to direct aircraft in controlled airspace and keep aircraft safely apart. Military aircraft are generally equipped with onboard radar.

[005] One type of collision avoidance system uses **Secondary Surveillance Radar** (**SSR**) where the **Primary Surveillance Radar (PSR)** used in air traffic control (ATC) detects and measures the position of aircraft and a secondary signal is transmitted that triggers a transponder in an aircraft that requests additional information from the aircraft itself such as its identity and altitude. Unlike Primary Surveillance Radar systems, which measure only the range and bearing to targets by detecting reflected radio signals, Secondary Surveillance Radar relies on its targets being equipped with a transponder which replies to each interrogation signal by transmitting its own response containing encoded data. U.S. Patent 4,782,450 **Method and apparatus for passive airborne collision avoidance and navigation** issued November 1, 1988 to Flax teaches that an aircraft can be equipped with a system that monitors the signals from the Secondary Surveillance Radar and the signals produced by each aircraft's transponders to produce its own onboard display of the locations of aircraft in the area. [*IDS Cite 3*]

[006] The **Traffic alert and Collision Avoidance System** (**TCAS**) is an aircraft collision avoidance system designed to reduce the incidence of mid-air collisions between aircraft. It monitors the airspace around an aircraft by interrogating the transponders of other TCAS-equipped aircraft via the 1030 MHz frequency. It then uses the received transponder signals (via the 1090 MHz. frequency) to compute distance, bearing and altitude relative to its own aircraft. This interrogation-and-response cycle may occur several times per second. From the FAA's **Introduction to TCAS II Version 7** [*IDS Cite 4*]

> The TCAS Computer Unit, or TCAS Processor, performs airspace surveillance, intruder tracking, its own aircraft altitude tracking, threat detection, RA maneuver determination and selection, and generation of advisories. The TCAS Processor uses pressure altitude, radar altitude, and discrete aircraft status inputs from its own aircraft to control the collision avoidance logic parameters that determine the protection volume around the TCAS aircraft. If a tracked aircraft is a collision threat, the processor selects an avoidance maneuver that will provide adequate vertical miss distance from the intruder while minimizing the perturbations to the existing flight path. If the threat aircraft is also equipped with TCAS II, the avoidance maneuver will be coordinated with the threat aircraft.

Where TCAS is relied upon to prevent mid-air collisions, an aircraft that does not have the equipment installed (or TCAS is broken or has been deliberately turned off) is a hazard to itself and other aircraft in the vicinity.

[007] The system by which an aircraft periodically transmits its identification, location, altitude, and heading is taught by U.S. Patent 5,153,836 **Universal dynamic navigation, surveillance, emergency location, and collision avoidance system and method** issued October 10, 1992 to Fraughton et al. [*IDS Cite 5*] and was materially adopted by the FAA as Automatic Dependent Surveillance-Broadcast (ADS-B). According to the article **Gulf of Mexico Helo Ops Ready for ADS-B** in Aviation Week & Space Technology (02/26/2007, page 56) [*IDS Cite 6*]:

> By the end of 2010, FAA expects to have the ADS-B system tested and operationally acceptable for the NAS, with Houston Center providing services in the Gulf region. By 2013, all of the U.S. is scheduled to be covered with ground infrastructure.

As with TCAS, where ADS-B is relied upon to prevent mid-air collisions, an aircraft that does not have the equipment installed (or ADS-B is broken or has been deliberately turned off) is a hazard to itself and other aircraft in the vicinity. ADS-B also comes with the risk that terrorists can use it to identify and track targets.

[008] A passive radar system is taught by U. S. Patent 5,187,485 **Passive ranging through global positioning system** issued February 16, 1993 to Tsui, et al. [*IDS Cite 7*] The patent teaches a method for determining the distance from a target to an observation station, using four GPS satellites as radiation sources, and a GPS receiver at the observation station to form a bistatic radar system, wherein an angle of arrival (AOA) of the target to the observation station has been measured first. Because the signal level from the GPS satellites is already low, the signal reflected from various objects is very low, requiring the use of a large antenna or more-powerful GPS satellites. See **Test Results from a Novel Passive Bistatic GPS Radar Using a Phased Sensor Array** by Alison Brown and Ben Mathews, NAVSYS Corporation. [*IDS Cite 8*]

[009] There are other types of radar that attempt to keep the presence and location of the emitter from being detected. Examples are Spread Spectrum, Frequency Hopping, Ultra Wideband, and Noise Radar. Although there are differences between them, what they have in common is that they are designed to transmit a signal that cannot be detected except by the originating entity. As a result, target echoes also cannot be detected except by the originating entity. They generally do this by using a much wider bandwidth than a standard radar.

Spread Spectrum will be used here as an example. An example of Spread Spectrum Radar is taught by U.S. Patent 5,724,041 **Spread spectrum radar device using pseudorandom noise signal for detection of an object** issued March 3, 1998 to Inoue, et al. [*IDS Cite 9*].

Abstract

> A radar device transmits by a transmitting part a wave whose band is spread by a PN code from a PN generator, receives at a receiving part a reflected wave from an object based on the wave and detects the object by detecting correlation between the received signal and the PN code. In this radar device, the received signal which is spread to a wide range is converted to a low-frequency band which is easy to be measured by a down converter so that a signal is generated when correlation is made by a delay of the PN code from a delay circuit, and generates a pulse signal through waveform shaping of the signal to detect the object and to measure its relative speed and distance at a processing part according to the pulse signal and the delay time.

Note that “PN” means Pseudo-Random Number. A pseudo-random number is produced by an algorithm so it is not truly random. However, it has the advantage that sequences of pseudo-random numbers can be reproduced. An example of a method of producing pseudo-random numbers is the Linear Feedback Shift Register. A simple Linear Feedback Shift Register can be used to produce white noise for testing audio equipment as taught in the article **Shift Register With Feedback Generates White Noise** by Marc Damashek in the May 27, 1976 issue of Electronics magazine. [*IDS Cite 10*] It has also been used in U.S. Patent 4,159,293 **Random dot generator for raster scan video displays** issued March 25, 1980 to Margolin (the current inventor). [*IDS Cite 11*]

Abstract

> A Linear-Feeback-Shift-Register produces a pseudorandom sequence of bits that are used to produce a stationary random pattern of dots on a standard raster scan video display. The density of dots is adjustable as is their intensity. This dot pattern may be combined with other video sources and thus may serve as a background for the playing of TV video games,

especially those of the "space war" variety. The dot pattern may also be moved as a whole under player control and thus form the basis for a novel type of video game to be described.

[010] Linear-Feedback-Shift-Registers (LFSRs) have also been used to produce pseudo-random sequences of binary signals for use as test signals for transmission paths (U.S. Patent 3,986,168 **Multichannel error signal generator** issued October 12, 1976 Anderson) [*IDS Cite 12*], and as code sequences for encoding information (U.S. Patent 3,515,805 **Data scrambler** issued June 2, 1970 to Fracassi et al.). [*IDS Cite 13*] The theory of Linear-Feedback-Shift-Registers (LFSRs) is covered extensively in "Shift Register Sequences" by Solomon Golomb (Holden-Day Inc., San Francisco, 1967, and Aegean Park Press, 1982) [*IDS Cite 14*].

A very good description of spread spectrum is **The ABCs of Spread Spectrum - A Tutorial** by Randy Roberts, Director of RF/Spread Spectrum Consulting. [*IDS Cite 15*]

[011] The problem with spread spectrum radar is that it might not be undetectable. See **Undetectable Radar? (Probably Not)** by Erik Hundman, Defensetech.org, August 3, 2006. [*IDS Cite 16*]

[012] Any entity that radiates an electromagnetic signal stands a good chance of being detected, even if spread spectrum signals are used. The use of bistatic radar avoids this problem. In bistatic radar the transmitter and the receiver are physically separated by some distance so the location of the receiver cannot be detected by tracking the transmission. Bistatic radar is commonly called passive radar and is the basis for U. S. Patent 5,187,485 previously mentioned which uses the signals from the GPS system as the radiators. Other systems have been proposed using what are called “unintentional radiators.” That doesn’t mean the transmitters are unintentionally radiating, only that they are not radiating for the purpose of providing a signal to be used for bistatic radar. Examples are FM broadcast stations, TV broadcast stations, and cell phone base stations. See **From a Different Perspective: Principles, Practice, and Potential of Bistatic Radar** by H.D. Griffiths. [*IDS Cite 17*]. The problems with these radiators are that:

1. There might not be one where you need it.
2. They cannot be relied upon to always be transmitting.

3. In a combat zone they are prime targets for anti-radiation missiles and other attacks.

[013] UAVs have special problems sensing other aircraft.

1. If the UAV is flown manually by a remote pilot looking at the video produced by a camera mounted in the nose of the aircraft the field of view will be too limited to see other aircraft other than those directly ahead.

2. If the UAV is flown autonomously there is no human pilot. If the flight is supervised by a human operator the problem remains that the field of view from a camera mounted in the nose of the aircraft will be too limited.

3. Military UAVs might not want to use TCAS, ADS-B, or onboard radar because it would allow other aircraft and ground facilities to detect and track them. They want to sense without being sensed.

BACKGROUND OF THE INVENTION – Current Practice in Flying UAVs

[014] The current practice in flying UAVs in civilian airspace is typified by the report **Sensing Requirements for Unmanned Air Vehicles** by AFRL's Air Vehicles Directorate, Control Sciences Division, Systems Development Branch, Wright-Patterson AFB OH, June 2004, which relies on computer-intelligence to use sensors to sense and avoid other aircraft. [*IDS Cite 18*]

[015] According to the presentation entitled **Developing Sense & Avoid Requirements for Meeting an Equivalent Level of Safety** given by Russ Wolfe, Technology IPT Lead, Access 5 Project at UVS Tech 2006 this had not changed as of January 18, 2006. [*IDS Cite 19*] Access 5 was a national project sponsored by NASA and Industry with participation by the FAA and DOD to introduce high altitude long endurance (HALE) remotely operated aircraft (ROA) to routine flights in the National Airspace System (NAS). Access 5 started in May 2004 but when NASA withdrew its support (and funding) the Industry members decided not to spend their own money and Access 5 was dissolved at the end of 2005.

[016] The presentation **Integration into the National Airspace System (NAS)** given by John Timmerman of the FAA's Air Traffic Organization (July 12, 2005) essentially says that under current UAS Operations in the NAS UAVs should not harm other aircraft or the public. (Page 3: "***While ensuring 'no harm' to other NAS customers and public***") [*IDS Cite 20*]

[017] The article **Zone Ready for Drone**, April 7, 2006, on the web site for the FAA's Air Traffic Organization Employees states that [*IDS Cite 21*],

> Since March 29, a temporary flight restriction … has limited access to the airspace along almost 350 miles of the border, expanding an earlier TFR near Nogales. The restriction is in effect nightly from 6 p.m. to 9 a.m., although that time can be expanded by issuance of a Notice to Airmen. Aircraft wishing to fly in the TFR when it is active must receive authorization from air traffic control prior to entry. Once in, pilots are required to maintain two-way communication with ATC and transmit a discrete transponder code.

The reason for the TFR is to enable Predator UAVs to patrol the border. The article quotes Stephen Glowacki, a Systems Safety and Procedures specialist with the FAA's Air Traffic Organization as saying:

> This is an extreme situation that has been presented to us," states Stephen Glowacki, a Systems Safety and Procedures specialist with the FAA's Air Traffic Organization, stressing the nation's security. "We have been working with U.S. Customs and Border Protection to try and answer this situation."
>
> Inserting UASs into the National Airspace System is not a simple feat. According to Glowacki, the technology and certification that will permit unmanned aircraft to "see and avoid" other air traffic is still eight to ten years away. In the mean time, a carefully controlled environment is needed.

[018] From **Quadrennial Roles and Missions Review Report**, Department of Defense, January 2009, page 29 [*IDS Cite 22*]:

> U.S. Joint Forces Command Joint UAS Center of Excellence has identified three areas necessary to ensure access to applicable classes of the National Airspace System: (1) Airworthiness Certification; (2) establishment of standardized basic UAS qualifications consistent with Federal Aviation Administration guidelines for each class of airspace; and (3) development of sense and avoid technology. Working with the Services, the U.S. Joint Forces Command Joint UAS Center of Excellence will ensure these areas are addressed during UAS development.

(Emphasis added.)

OBJECTIVES

[019] Therefore, an objective of the present invention is to improve TCAS so that aircraft equipped with TCAS can detect aircraft not equipped with it (or TCAS is broken or has been deliberately turned off).

Another objective of the invention is to improve ADS-B so that aircraft equipped with ADS-B can detect aircraft not equipped with it (or ADS-B is broken or has been deliberately turned off).

Another objective of the invention is to detect and locate aircraft which are using spread spectrum radar in an attempt to be undetected.

Another objective of the invention is a system to detect and locate aircraft and other objects without itself being detected or located.

A further objective of the invention is an integrated bistatic spread spectrum radar system using a satellite constellation for the radar function as well as for communications.

SUMMARY OF THE INVENTION

[020] TCAS can be improved by using the interrogation signal transmitted from a TCAS unit as a radar transmitter with a receiver to receive reflections. In a first preferred embodiment the standard TCAS antennas are used to receive the reflections of the TCAS signal. Although one of the TCAS antennas is a directional antenna, its directionality is currently limited to 90 degree quadrants. The time delays between the transmitted signal and the reflections are used to determine the range of other aircraft and are used to match the range and number of targets to the TCAS transponder signals normally received. Doppler analysis can be used to confirm the speeds of the targets. In a second preferred embodiment a separate directional receiving antenna is used to give both the range and bearing to aircraft and other objects in the vicinity of the user's aircraft even when other aircraft are not equipped with TCAS.

[021] ADS-B can be improved by using the signal transmitted from an ADS-B unit as a radar transmitter with the ADS-B receiver used to receive reflections. In a third preferred embodiment a standard omni-directional antenna is used to receive the reflections of the ADS-B signal. The time delays between the transmitted signal and the reflections are used to determine the range of other aircraft and match the range and number of targets to the ADS-B signals normally received. Doppler analysis can be used to confirm the speeds of the targets. In a fourth preferred embodiment a directional receive antenna is used to give both the range and bearing to aircraft and other objects in the vicinity of the user's aircraft even when other aircraft are not equipped with ADS-B.

[022] Aircraft using spread spectrum radar can be detected by using two separate receiving systems, each with its own antenna and receiver. Each receiving system is configured to have the same frequency range and bandwidth. The output of each receiver system is digitized to have the same number of samples in a frame of data. A cross-correlation is then performed between the two data frames. The noise produced by each receiver system is completely independent of each other so the internally generated noise is uncorrelated. If there is a correlation between the data frames from two receiver systems it can only have come from an external source, such as a spread spectrum signal.

[023] In a fifth preferred embodiment each receiving system uses an omni-directional antenna, the two receiving systems are spatially separated, and the phase term (time delay) in the cross-correlation function is used to determine the bearing to the target. However, this produces the "Hemisphere Problem" as it is known in the field of Radio Direction Finding (RDF). A target on either side of the line between the two antennas produces the same time delay, and therefore the same angle. One method to determine which side of the line the target is on is to use a third antenna that is not collinear with the first two antennas. The receiving system from the third antenna produces a signal that is cross-correlated with the signal from one of the first two antennas. The other method is to use Doppler from the target to determine the target's velocity along with the change in the User's position. This is used for triangulation of the target. A good place to put the first two antennas are at the ends of the wings, especially in winglets made of non-conducting composites with one antenna in each winglet. The third antenna may be placed either in the nose or the tail. Alternatively, the first two antennas may be placed in the nose and in the tail with the third antenna placed at the end of either wing.

[024] A sixth preferred embodiment adds a second pair of receiving systems using omni-directional antennas. The pair of antennas in the first receiving system are located physically apart from each other and from the first pair of receiving antennas. The bearing produced by the second pair of receiving systems is used for performing triangulation with the first pair of receiving systems to determine the range to the target.

[025] In a seventh preferred embodiment, to improve the Probability of Intercept (POI), two co-located directional antennas are used. In this mode the antennas must be pointed in the same direction. However, this improvement in POI comes at the expense of obtaining range information. Bearing information is produced by the direction of the antennas since it is no longer possible to use the phase information term in the cross-correlation function to determine the bearing to the target.

[026] In an eighth preferred embodiment the two directional antennas are spatially separated. Bearing information is produced by the direction of the antennas and triangulation is used to produce range information. Since a correlated signal is produced only when both antennas are pointed at the target the antenna angles must be coordinated.

[027] In a ninth preferred embodiment a second pair of co-located receiving systems is added, spatially separated from the first pair of co-located receiving systems. Triangulation between the first pair of receiving systems and the second pair of receiving systems is used to determine the range to the target. This has the advantage that each pair of receiving systems may independently search for the presence of a target. When a target is detected by one pair of receiving systems the other pair of receiving systems is brought to bear on it for triangulation to determine its range.

[028] The use of directional antennas requires the ability to aim the antennas. This can be done by physically aiming the antennas (such as when the antennas use parabolic dish reflectors) or by using active electronically scanned arrays. Because each area must be separately scanned the time to detect and locate spread spectrum targets is increased according to the directionality of the antennas. The use of directional antennas reduces the radio frequency noise received that is produced by the Sun, except when the antennas are pointed at the Sun. (The level of the sun's contribution depends on the solar flux.) It also reduces the noise received that is produced by the Earth (about 290K.), except when the antennas are pointed at the Earth.

The technology requirements for performing a reasonably fast digital cross-correlation on two wideband signals are formidable: a fast Analog-to-Digital Converter (ADC) and a fast Digital Signal Processor (DSP). However, fast ADCs are available, such as the AD9481 (8-Bit, 250 MSPS) by Analog Devices Inc. [*IDS Cite 23*]. Fast and inexpensive DSPs are available due to their increasing use in consumer products. An example is the C6713B from Texas Instruments. [*IDS Cite 24*]

> Operating at 300 MHz, the C6713B delivers up to 1800 million floating-point operations per second (MFLOPS), 2400 million instructions per second (MIPS), and with dual fixed-/floating-point multipliers up to 600 million multiply-accumulate operations per second (MMACS).

If additional processing power is required, the cross-correlation function is very amenable to parallel processing.

[029] A system and method for detecting and locating aircraft and other objects without being detected or located will now be described.

As previously discussed, any entity that radiates an electromagnetic signal stands a good chance of being detected and possibly located, even if spread spectrum signals are used. The use of bistatic radar avoids this problem. Systems have been proposed using "unintentional radiators" such as FM broadcast stations, TV broadcast stations, and cell phone base stations. However, these sources cannot be relied upon to always be transmitting, and in a combat zone they are prime targets for anti-radiation missiles and other attacks. Because of the likelihood that any radiator can be detected and probably tracked, the solution is to make the transmitter difficult to attack.

[0030] One or more high-flying aircraft can be used as the transmitting source(s) for a bistatic radar system. One disadvantage of this method is that the technology race between aircraft and anti-aircraft missiles (and directed energy weapons) favors anti-aircraft missiles and directed energy weapons. An example of a directed energy weapon is taught by U.S. Patent 6,377,436 **Microwave Transmission Using a Laser-Generated Plasma Beam Waveguide** issued April 23, 2002 to Margolin (the present inventor). [*IDS Cite 25*] Another disadvantage of using high-flying aircraft is that it requires the close coordination of multiple assets.

[0031] The solution is to go higher and use a permanently orbiting constellation of satellites. It can be called the Global Radar System (GRS). Although this might resemble the method taught in U. S. Patent 5,187,485 **Passive ranging through global positioning system** the purpose of the satellites is different and can be optimized to the mission.

1. GRS satellites will use higher power than GPS.

2. The precise position of each GRS satellite does not need to be known, only the precise range and bearing to the User. The use of GPS should not be a requirement for the operation of the GRS.

3. The GRS satellites will produce a secured spread-spectrum signal. Although GPS also uses a spread-spectrum signal the details are publicly available so manufacturers can make and sell the GPS receivers to the general public.

4. The GPS constellation is in orbital planes approximately 20,200 km above the Earth (Medium Earth Orbit or MEO). The GRS constellation should be in Low Earth Orbit (LEO) in the range of 160 km - 2,000 km.

One of the reasons for using LEO is that it is desirable to keep the existence of GRS a secret and it would be difficult to secretly launch and operate a constellation of satellites. Therefore, the GRS function should be hidden in a satellite constellation that has a non-secret mission. A prime candidate is a new satellite system for providing communications with UAVs around the world. For various reasons, communications with UAVs should have low latency, and a LEO system will have lower latency than a MEO system. The military's increasing use of UAVs and need for dedicated low-latency bandwidth justifies a dedicated satellite system using spread spectrum communications. The function of also providing a spread-spectrum signal for bistatic radar does not have to be publicly revealed. The need to have these "communication" satellites always transmitting can be explained as "continuous monitoring of system health." Indeed, there is value for a User to know that the communications system is working and that a channel is available. It reduces POI by avoiding unnecessary transmissions. POI can also be reduced by using a directional antenna for transmitting and aiming it at an available satellite with the lowest POI. For example, the satellite most directly overhead may have the lowest POI in many situations. This presents the opportunity to provide an integrated bistatic spread spectrum radar system using a satellite constellation for the radar function as well as for communications.

[032] It is desirable to have the capability for GRS satellite-to-satellite communications, preferably using optical links.

[033] The following example is for a 2D system which will be expanded later to a 3D system. A satellite constellation is being used, and each satellite transmits a spread spectrum signal and has its own unique code key. The code key may be a PN key or it may be produced by other means. It is assumed that the User is receiving a signal in straight paths from one or more satellites and that there is a straight path from the satellites to the target and from the target to the User and that the range and bearing from the User to each satellite is known. As a result, the length of the path from each satellite reflected from the target is also known.

[034] The distance from each satellite to the User can be known in several ways. One method is to use GPS for the location of the User and for the satellites to broadcast their GPS positions (regardless of how their positions are determined). Another method is for the User to use GPS, an accurate clock, and an ephemeris that gives the locations of satellites for a period of time in advance. Another method is for the User to have an accurate clock and for the satellites to include the time of transmission in their signals. Another method is for the User to send a signal to the appropriate satellite which responds with a signal that the User can use to get the range and bearing to that satellite. Thereafter, Inertial Navigation may be used. This method has the advantage that it does not use GPS but would be limited to those times when radio silence by the User is not necessary. A further method is to build a simplified form of Global Navigation Satellite System (GNSS) into GRS (and kept secret) as a military backup to GPS. It does not have to be as accurate as GPS because its purpose is to sense other aircraft in order to prevent a collision. It is not necessarily for delivering weapons, which has the opposite goal.

[035] When the User receives a reflected signal from the target a cross correlation is performed using the code keys for the satellites in order to determine which satellite the reflected signal is coming from. The use of an ephemeris would allow the User to test only for those satellites that are visible.

Where the User determines the position of the satellite using GPS, an accurate clock, and an ephemeris it is not necessary for the User to receive a direct signal from the satellite, only the reflection from the target.

[036] At this point the User knows the total length of the path from a first satellite to the target and then to the User and wants to know the length of the path from the target to himself. The User also knows the length of the path from the first satellite to himself. Mathematically, this is the definition of an ellipse. The User and the first satellite are at the foci and the target is somewhere on the ellipse.

[037] When a second satellite is added, a second ellipse is formed. The User is at one of the foci, the second satellite is at the other. The first ellipse and the second ellipse intersect at only two points, with the target at one of the points.

[038] When a third satellite is added, a third ellipse is formed. Again, the User is at one of the foci and the third satellite is at the other. The three ellipses intersect at only one point. That is where the target is.

[039] A 3D system is more complicated because the geometric figure produced between each satellite and the User is not a 2D planar ellipse. Picture an ellipse rotating around the axis between the User and the satellite. The figure that each Satellite produces is an ellipsoid (a prolate spheroid) that looks remarkably like a football (U.S. or Canadian).

[040] Satellite 1 produces an ellipsoid with the User at one of the foci and the satellite at the other. The target is somewhere on the surface of the ellipsoid.

[041] When a second satellite is added, a second ellipsoid is formed. The User is at one of the foci, the second satellite is at the other. The first ellipsoid and the second ellipsoid intersect and produce an ellipse. The reason for this is because they share a common focus. [*IDS Cite 26*]

[042] When a third satellite is added, a third ellipsoid is formed. The User is at one of the foci, the third satellite is at the other. The first and second ellipsoids and the third ellipsoid intersect at two points, with the target at one of the two points.

[043] When a fourth satellite is added, a fourth ellipsoid is formed. The User is at one of the foci, the fourth satellite is at the other. The first three ellipsoids and the fourth ellipsoid intersect at only one point. That is where the target is.

[044] The geometry that has been described might not be obvious to someone versed mainly in GPS geometry. GPS uses only three satellites to determine the User's position in three dimensions. (A fourth satellite is used for time correction.) The reason for this difference is because instead of using only the signal received directly from the satellite, the User is receiving both the direct signal and a signal reflected from the target. A line from the target meets the line from the User to the satellite at a 90 degree angle and forms the radius of a circle. The target can be anywhere on that circle. That is why the additional satellite is needed to determine the position of the target.

[045] There is something to note. Not all ellipses that share a focus point will intersect. However, in this case they must intersect because the ellipses were created by reflections from the same target, and the target cannot be in more than one place at the same time.

[046] The issue of multiple targets will now be discussed. A single target will produce four reflections, one from each satellite. A second target will produce four more reflections unless the geometry of the User and the targets causes one or more of the reflections to coincide. This is unlikely, but possible. A third target produces four more reflections, and so on. A User receiving system using a single omni-directional antenna will have to sort out all these reflections and perform the calculations looking for a single possible solution. To provide better results, Doppler analysis of each reflection can be performed so that the various reflected signals can be matched together. The Doppler shift of each reflected signal is a result of the velocity of the target, the velocity of the satellite producing the signal that is reflected, and the velocity of the User. Another solution is for the User system to use directional antennas.

[047] The geometry shows that several system configurations are possible.

1. System 0 – It is not necessary to receive any signals directly from any satellites. Only the signals reflected from the target are needed. The User tries all of the code keys for all the satellites or uses an ephemeris to try only the code keys for the satellites that are in view. A signal that is detected is subjected to the various treatments described in the previous section on detecting spread spectrum radar. It may be possible to use the radio frequency emanations from the Sun and not use any satellites, but only during daytime.
2. System 1 – The direct and reflected signal from only one satellite is used. This detects the presence of the target but its position can be anywhere on an ellipsoid, which is better than nothing. A directional antenna is used to scan those areas corresponding to the surface of the ellipsoid.
3. System 2 – The direct and reflected signals from two satellites are used. This detects the presence of the target and locates its position to an ellipse. A directional antenna is used to scan the ellipse.
4. System 3 - The direct and reflected signals from three satellites are used. This detects the presence of the target and narrows its position down to only two positions. A directional antenna is used to determine which position the target is in.
5. System 4 – The direct and reflected signals from four satellites are used to detect the presence and position of the target. Only a single omni-directional antenna is needed.

[048] Although it is anticipated that the system will use microwave frequencies, the use of lower frequencies would make it possible to detect stealth aircraft. There are tradeoffs involving the frequency used, the resolution that can be achieved, and the ability to detect stealth aircraft. The lower the frequency the lower the resolution. A lower frequency requires either a larger antenna or an antenna of reduced efficiency. However, a lower frequency increases the ability to detect stealth aircraft. Stealth aircraft commonly employ reflecting surfaces and/or microwave-absorbing surface material. As the wavelength becomes longer and approaches the dimensions of the aircraft, the reflecting surfaces no longer produce localized reflections. And there is a frequency below which energy-absorbing material becomes ineffective depending on the specifics of the material.

[049] In view of the foregoing, a tenth preferred embodiment for sensing aircraft and other objects uses bistatic radar with a spread spectrum signal transmitted from remotely located sources. In an eleventh preferred embodiment an integrated bistatic spread spectrum radar system uses a satellite constellation for the radar function as well as for communications.

[050] In a twelfth preferred embodiment the satellite constellation described above can also be used for long baseline radar interferometry in order to validate the digital terrain elevation database. The distance between satellites provides for a long baseline and the use of multiple satellites simultaneously improves the accuracy of the terrain measurements.

BRIEF DESCRIPTION OF THE DRAWINGS

[051] The invention may best be understood by referring to the following description and accompanying drawings which illustrate the invention. In the drawings:

[052] FIG. 1 is a general illustration showing a TCAS system used as a radar, using standard TCAS antennas.

[053] FIG. 2 is a general illustration showing a TCAS system used as a radar, using a separate directional receiving antenna.

[054] FIG. 3 is a general illustration showing an ADS-B system used as a radar, using omni-directional antennas.

[055] FIG. 4 is a general illustration showing an ADS-B system used as a radar, using a separate directional receiving antenna.

[056] FIG. 5 is a general illustration showing an ADS-B system used as a radar, using a separate directional receiving antenna and a separate receiver.

[057] FIG. 6 is a general illustration showing a method for detecting spread spectrum radar and determining its bearing, using two omni-directional antennas.

[058] FIG. 7 is a general illustration showing why there is a “hemisphere problem” in Radio Direction Finding with two omni-directional antennas.

[059] FIG. 8 is a general illustration showing the addition of an additional antenna to solve the “hemisphere problem” in Radio Direction Finding.

[060] FIG. 9 is a general illustration showing a method for detecting spread spectrum radar, using two pairs of spatially separated omni-directional antennas.

[061] FIG. 10 is a general illustration showing a method for detecting spread spectrum radar, using two co-located directional antennas.

[062] FIG. 11 is a general illustration showing a method for detecting spread spectrum radar and determining its range and bearing, using two spatially separated directional antennas.

[063] FIG. 12 is a general illustration showing a method for detecting spread spectrum radar and determining its range and bearing, using two spatially separated pairs of co-located directional antennas.

[064] FIG. 13 is a general illustration showing a spread spectrum bistatic radar using a satellite constellation as the radar transmitters.

[065] FIG. 14 is a general illustration showing the User equipment suitable for use in a spread spectrum radar using a satellite constellation as the radar transmitters and an omni-directional receive antenna.

[066] FIG. 15 is a general illustration showing another form of User equipment suitable for use in a spread spectrum radar using a satellite constellation as the radar transmitters and an omni-directional receive antenna.

[067] FIG. 16 is a general illustration showing the User equipment suitable for use in a spread spectrum radar system using a satellite constellation as the radar transmitters, a directional receive antenna, and an omni-directional receive antenna.

[068] FIG. 17 is a general illustration showing another form of User equipment suitable for use in a spread spectrum radar system using a satellite constellation as the radar transmitters, a directional receive antenna, and an omni-directional receive antenna.

[069] FIG. 18 is a general illustration showing an integrated bistatic spread spectrum radar system using a satellite constellation for the radar function as well as for communications.

[070] FIG. 19 is a general illustration showing the geometry of a bistatic radar.

[071] FIG. 20 is a general illustration showing that the geometry of a bistatic radar describes an ellipse.

[072] FIG. 21 is a general illustration showing the geometry of an ellipse.

[073] FIG. 22 is a general illustration further showing the geometry of an ellipse.

[074] FIG. 23 is a general illustration further showing the geometry of an ellipse.

[075] FIG. 24 is a general illustration showing a receiver and a first satellite at the foci of a first ellipse.

[076] FIG. 25 is a general illustration showing a receiver and a first satellite at the foci of a first ellipse and the receiver and a second satellite at the foci of a second ellipse.

[077] FIG. 26 is a general illustration showing a receiver and a first satellite at the foci of a first ellipse, the receiver and a second satellite at the foci of a second ellipse, and the receiver and a third satellite at the foci of a third ellipse.

[078] FIG. 27 is a general illustration showing an ellipse that does not intersect another ellipse even though they share a focus.

[079] FIG. 28 is a general illustration showing an ellipse that intersects another ellipse at only one point even though they share a focus.

[080] FIG. 29 is a general illustration showing an ellipsoid.

[081] FIG. 30 is a general illustration showing a cross section of the longitudinal axis of the ellipsoid shown in Fig. 29.

[082] FIG. 31 is a general illustration also showing two ellipsoids with a common focus, meeting end-to-end.

[083] FIG. 32 is a general illustration of two ellipsoids with a common focus, meeting at a first arbitrary angle.

[084] FIG. 33 is a general illustration of two ellipsoids with a common focus, meeting at a second arbitrary angle.

DETAILED DESCRIPTION

[085] In the following description, numerous specific details are set forth to provide a thorough understanding of the invention. However, it is understood that the invention may be practiced without these specific details. In other instances well-known circuits, structures, and techniques have not been shown in detail in order not to obscure the invention.

[086] Figure 1 is a general illustration showing a TCAS system used as a radar, using standard TCAS antennas. TCAS Interrogation Receiver 106 listens for Interrogation signals from other aircraft. When it receives one, TCAS Transponder Transmitter 107 sends out a signal containing the unique ID number of the aircraft and its altitude. TCAS Interrogation Transmitter 105 periodically (and randomly) sends out an Interrogation signal that other TCAS-equipped aircraft respond to. These transponder responses are received by TCAS Transponder Receiver 108. There are at least two antennas: Omni-Directional Antenna 101 and Directional Antenna 102 which is under the control of Antenna Controller 103. Directional Antenna 102 and Antenna Controller 103 may be in the form of several directional antennas which may be selected in turn or used simultaneously. Antenna Diplexer 104 is used to select and/or combine Omni-Directional Antenna 101 and Directional Antenna 102 and route the signals (receiving and transmitting) to the appropriate piece of equipment. The preceding operations are under the control of TCAS Processor 109. The time delay between when the TCAS Interrogation signal is sent out by TCAS Interrogation Transmitter 105 and when a transponder signal from other aircraft is received by TCA Transponder Receiver 108 is used to determine the range to the responding aircraft.

TCAS operation is improved by using the signal produced by TCAS Interrogation Transmitter 105 as a radar with reflected signals received by TCAS Interrogation Receiver 106 under the control of TCAS Processor 109 and Radar Processor 110. The results are displayed on Display 111.

If the number and range of targets reported by radar do not match the number and range of aircraft reported by TCAS then there is an aircraft out there that does not have TCAS or it is broken or has been disabled.

[087] In Figure 2, a separate directional antenna (Antenna 201) is used to receive the reflected signals. The advantage of using a separate antenna for this function is that it can be made to be more directional than the standard Directional Antenna 102 used by TCAS. Directional Antenna 201 is controlled by Antenna Controller 202 under the direction of Radar Processor 210 which also controls the radar function through TCAS Processor 109. Antenna Diplexer 204 is used to select and/or combine Omni-Directional Antenna 101, Directional Antenna 102, and Directional Antenna 201 and route the signals (receiving and transmitting) to the appropriate piece of equipment. Directional Antenna 201 and Antenna Controller 202 may be a system that mechanically aims Directional Antenna 201 or the combination may be an electronically scanned array.

The results are displayed on Display 211.

If the number, range, and bearing to targets reported by radar do not match the number, range, and bearing of aircraft reported by TCAS then there is an aircraft out there that does not have TCAS or it is broken or has been disabled.

[088] Figure 3 is a general illustration showing an ADS-B system used as a radar, using omni-directional antennas. ADS-B Transmitter 303 periodically transmits a message containing the present aircraft's unique ID, GPS coordinates, and other data using Omni-Directional antenna 301. When ADS-B Transmitter 303 is not transmitting, ADS-B Receiver 304 is listening for messages transmitted by other aircraft containing their unique ID, GPS coordinates, and other data. An Antenna Multiplexer (Antenna Mux 302) is used to route the signals from Omni-Directional Antenna 301 to ADS-B Transmitter 303 and ADS-B Receiver 304. Omni-Directional Antenna 306 is used with GPS Receiver 307 to provide the GPS coordinates of the present aircraft. All of this is controlled by ADS-B Processor 305.

ADS-B operation is improved by using the signal produced by ADS-B Transmitter 303 as a radar with reflected signals received by ADS-B Receiver 304 under the control of ADS-B Processor 305 and Radar Processor 308. The results are displayed on Display 309.

If the number and range of targets reported by radar do not match the number and range of aircraft reported by ADS-B then there is an aircraft out there that does not have ADS-B or it is broken or has been disabled.

[089] In Figure 4, a separate directional antenna (Directional Antenna 401) is selected by Antenna Mux 405 to receive the reflected signals. The advantage of using a separate antenna for this function is that it is directional, as opposed to Omni-Directional Antenna 301. Directional Antenna 401 can also be used by ADS-B Transmitter 303 in order to strengthen radar returns from a specific target or to increase the range of the system in a specific direction.

Directional Antenna 401 is controlled by Antenna Controller 402 under the direction of Radar Processor 403 which also controls the radar function through ADS-B Processor 305. Directional Antenna 401 and Antenna Controller 402 may be a system that mechanically aims Directional Antenna 401 or the combination may be an electronically scanned array.

The results are displayed on Display 404.

In Figure 5, as an alternative to sharing ADS-B Receiver 304, Directional Antenna 401 can be used with its own receiver. Antenna Mux 501 routes Directional Antenna 401 to Receiver 502 whose output goes to ADS-B Processor 503 to make it possible to receive and process radar returns without the risk of missing ADS-B messages from other aircraft.

If the number, range, and bearing of targets reported by radar do not match the number, range, and bearing of aircraft reported by ADS-B then there is an aircraft out there that does not have ADS-B or it is broken or has been disabled.

[090] Figure 6 is a general illustration showing a method for detecting spread spectrum radar and determining its bearing using two receiving systems with omni-directional antennas. Omni-Directional Antenna 601 and Receiver 602 make up the first receiving system. Omni-Directional Antenna 603 and Receiver 604 make up the second receiving system. The data from Receiver 602 is stored in Data Buffer 605. The data from Receiver 604 is stored in Data Buffer 606. The data in Data Buffer 605 and Data Buffer 606 are used by Cross-Correlator 607 under control of System Controller 608. The results are displayed on Display 609.

The noise produced by each receiver system is completely independent of each other so the internally generated noise is uncorrelated. If there is a correlation between the data frames from two receiver systems it can only have come from an external source, such as a spread spectrum signal. The phase term (time delay) in the cross-correlation function is used to determine the bearing to the target subject to the “Hemisphere Problem” which occurs because a target on either side of the line between the two antennas produces the same time delay, and therefore the same angle. Referring to Figure 7, Antenna 701 and Antenna 702 both receive Signal 703 from a target. Antenna 702 receives Signal 703 later than Antenna 701. Time translates to distance dt 704 which produces Angle 705. However, Antenna 702 could also receive Signal 706 from a target later than Antenna 701 and with the same delay. Distance dt 707 is the same as distance dt 704 so that Angle 708 is the same as Angle 705.

In Figure 8 a third receiving system is added with Antenna 801 that is not collinear with Antenna 701 and Antenna 702. Signal 703 takes longer to arrive at Antenna 801 than does Signal 706 (distance dt 803 versus distance dt 802). The time delay of the signal received by Antenna 801 is compared to the two calculated values based on the geometry of Antennas 701, 702, and 801. Thus, it is determined whether the signal is Signal 703 or Signal 706.

[091] Figure 9 is a general illustration showing a method for detecting spread spectrum radar, using two pairs of receiving systems where the omni-directional antennas used in each receiving system are spatially separated and the two pairs of receiving systems are spatially separated from each other.

In the first pair of the receiving systems Omni-Directional Antenna 901 and Receiver 902 produce a first signal. The output of Receiver 902 is stored in Data Buffer 905. Omni-Directional Antenna 903 and Receiver 904 produce a second signal. The output of Receiver 904 is stored in Data Buffer 906. The data in Data Buffer 905 and Data Buffer 906 are used by Cross-Correlator 907 which performs a cross-correlation of the signals produced by Receiver 902 and Receiver 904. The noise produced by each receiver system is completely independent of each other so the internally generated noise is uncorrelated. If there is a correlation between the data frames from the two receiver systems it can only have come from an external source, such as a spread spectrum signal. The phase term (time delay) in the cross-correlation function is used to determine a first bearing to the target.

In the second pair of the receiving systems Omni-Directional Antenna 908 and Receiver 909 produce a third signal. Omni-Directional Antenna 910 and Receiver 911 produce a fourth signal. The output of Receiver 909 is stored in Data Buffer 912. The output of Receiver 911 is stored in Data Buffer 913. The data in Data Buffer 912 and Data Buffer 913 are used by Cross-Correlator 914 which performs a cross-correlation of the signals produced by Receiver 909 and Receiver 911. The noise produced by each receiver system is completely independent of each other so the internally generated noise is uncorrelated. If there is a correlation between the data frames from the two receiver systems it can only have come from an external source, such as a spread spectrum signal. The phase term (time delay) in the cross-correlation function is used to determine a second bearing to the target.

System Controller 915 controls the operation of Cross-Correlator 907 and Cross-Correlator 914. It may also control the operation of Receivers 902, 904, 909, and 911.

The distance between the first pair of receiving systems and the second pair of receiving systems is known. The first bearing to the target is determined using the first pair of receiving systems. The second bearing to the target is determined using the second pair of receiving systems. The distance and range to the target are determined using triangulation. The results are displayed on Display 916.

[092] Figure 10 is a general illustration showing a method for detecting spread spectrum radar using two co-located directional antennas. Directional Antenna 1001 and Receiver 1003 make up the first receiving system. The direction of Directional Antenna 1001 is controlled by Antenna Controller 1002. Directional Antenna 1004 and Receiver 1006 make up the second receiving system. The direction of Directional Antenna 1004 is controlled by Antenna Controller 1005. The data output of Receiver 1003 is stored in Data Buffer 1007. The output of Receiver 1006 is stored in Data Buffer 1008. The data in Data Buffer 1007 and Data Buffer 1008 are used by Cross-Correlator 1009 under control of System Controller 1010 which also controls Antenna Controller 1002 and Antenna Controller 1005.

The noise produced by each receiver system is completely independent of each other so the internally generated noise is uncorrelated. If there is a correlation between the data frames from two receiver systems it can only have come from an external source, such as a spread spectrum signal.

Because directional antennas are used, the phase term (time delay) in the cross-correlation function cannot be used to determine the bearing to the target. Directional Antenna 1001 and Directional Antenna 1004 are controlled so they always point in the same direction. The bearing to the target is determined from the direction the antennas are pointing.

Directional Antenna 1001 and Antenna Controller 1002 may be a system that mechanically aims Directional Antenna 1001 or the combination may be an electronically scanned array.

Likewise, Directional Antenna 1004 and Antenna Controller 1005 may be a system that mechanically aims Directional Antenna 1004 or the combination may be an electronically scanned array.

The results are displayed on Display 1011.

[093] Figure 11 is a general illustration showing a method for detecting spread spectrum radar and determining its range and bearing using two spatially separated directional antennas. Directional Antenna 1001 and Receiver 1003 make up the first receiving system. The direction of Directional Antenna 1001 is controlled by Antenna Controller 1002. Directional Antenna 1004 and Receiver 1006 make up the second receiving system. The direction of Directional Antenna 1004 is controlled by Antenna Controller 1005. The output of Receiver 1003 is stored in Data Buffer 1007. The output of Receiver 1006 is stored in Data Buffer 1008. The data in Data Buffer 1007 and Data Buffer 1008 are used by Cross-Correlator 1009 under control of System Controller 1110 which also controls Antenna Controller 1002 and Antenna Controller 1005.

The noise produced by each receiver system is completely independent of each other so the internally generated noise is uncorrelated. If there is a correlation between the data frames from two receiver systems it can only have come from an external source, such as a spread spectrum signal.

Because directional antennas are used, the phase term (time delay) in the cross-correlation function cannot be used to determine the bearing to the target. Directional Antenna 1001 and Directional Antenna 1004 are spatially separate from each other. When a source of correlated noise is found the bearing of Directional Antenna 1001 and the bearing of Directional Antenna 1004 are used, along with the distance between, to triangulate the position and bearing to the external source of correlated noise, namely the target.

Directional Antenna 1001 and Antenna Controller 1002 may be a system that mechanically aims Directional Antenna 1001 or the combination may be an electronically scanned array.

Likewise, Directional Antenna 1004 and Antenna Controller 1005 may be a system that mechanically aims Directional Antenna 1004 or the combination may be an electronically scanned array.

The results are displayed on Display 1111.

[094] Figure 12 is a general illustration showing a method for detecting spread spectrum radar and determining its range and bearing, using two spatially separated pairs of co-located directional antennas.

The first pair of co-located directional antennas are Directional Antenna 1201 and Directional Antenna 1204. Directional Antenna 1201 and Receiver 1203 make up the first receiving system of the pair. The output of Receiver 1203 is stored in Data Buffer 1213. The direction of Directional Antenna 1201 is controlled by Antenna Controller 1202. Directional Antenna 1204 and Receiver 1206 make up the second receiving system of the pair. The output of Receiver 1206 is stored in Data Buffer 1214. The direction of Directional Antenna 1204 is controlled by Antenna Controller 1205. The data in Data Buffer 1213 and Data Buffer 1214 are used by Cross-Correlator 1215 under control of System Controller 1219 which also controls Antenna Controller 1202 and Antenna Controller 1205.

The noise produced by each receiver system is completely independent of each other so the internally generated noise is uncorrelated. If there is a correlation between the data frames from two receiver systems it can only have come from an external source, such as a spread spectrum signal.

Because directional antennas are used, the phase term (time delay) in the cross-correlation function cannot be used to determine the bearing to the target. Directional Antenna 1201 and Directional Antenna 1204 are controlled so they always point in the same direction. The first bearing to the target is determined from the direction the antennas are pointing.

The second pair of co-located directional antennas are Directional Antenna 1207 and Directional Antenna 1210. Directional Antenna 1207 and Receiver 1209 make up the first receiving system of the pair. The output of Receiver 1209 is stored in Data Buffer 1216. The direction of Directional Antenna 1207 is controlled by Antenna Controller 1208. Directional Antenna 1210 and Receiver 1212 make up the second receiving system of the pair. The output of Receiver 1212 is stored in Data Buffer 1217. The direction of Directional Antenna 1210 is controlled by Antenna Controller 1211. The data in Data Buffer 1216 and Data Buffer 1217 are used by Cross-Correlator 1218 under control of System Controller 1219 which also controls Antenna Controller 1208 and Antenna Controller 1211. The noise produced by each receiver system is completely independent of each other so the internally generated noise is uncorrelated. If there is a correlation between the data frames from two receiver systems it can only have come from an external source, such as a spread spectrum signal.

Because directional antennas are used, the phase term (time delay) in the cross-correlation function cannot be used to determine the bearing to the target. Directional Antenna 1207 and Directional Antenna 1210 are controlled so they always point in the same direction. The second bearing to the target is determined from the direction the antennas are pointing.

When a source of correlated noise is found by the first pair of co-located directional antennas the second pair of co-located directional antennas is brought to bear until it also finds the target. The first bearing to the target and the second bearing to the target, along with the distance between the first pair of co-located directional antennas and the second pair of co-located directional antennas, is used to triangulate the position and bearing to the external source of correlated noise, namely the target.

Conversely, when a source of correlated noise is found by the second pair of co-located directional antennas the first pair of co-located directional antennas is brought to bear until it also finds the target. The first bearing to the target and the second bearing to the target, along with the distance between the first pair of co-located directional antennas and the second pair of co-located directional antennas, is used to triangulate the position and bearing to the external source of correlated noise, namely the target.

Directional Antenna 1201 and Antenna Controller 1202 may be a system that mechanically aims Directional Antenna 1201 or the combination may be an electronically scanned array.

Directional Antenna 1204 and Antenna Controller 1205 may be a system that mechanically aims Directional Antenna 1204 or the combination may be an electronically scanned array.

Directional Antenna 1207 and Antenna Controller 1208 may be a system that mechanically aims Directional Antenna 1207 or the combination may be an electronically scanned array.

Directional Antenna 1210 and Antenna Controller 1211 may be a system that mechanically aims Directional Antenna 1210 or the combination may be an electronically scanned array.

The results are displayed on Display 1220.

[095] Figure 13 is a general illustration showing a spread spectrum bistatic radar using a satellite constellation as the radar transmitters. Satellites 1302, 1303, 1304, and 1305 transmit a spread spectrum signal, each having a unique code key. The signal from each satellite is received in a direct path by User 1301. The signal from each satellite is also reflected by Target 1306 and received by User 1301. User 1301 determines his own position and the positions of Satellites 1302, 1303, 1304, and 1305. User 1301 determines the length of the direct path to the satellites and the total length of the signal path from each satellite reflected by Target 1306. By performing the appropriate mathematical calculations User 1301 determines the absolute position of Target 1306.

Alternatively, User 1301 determines the positions of Satellites 1302, 1303, 1304, and 1305 relative to himself. User 1301 determines the length of the direct path to the satellites and the total length of each signal path from each satellite reflected by Target 1306. By using the appropriate mathematical calculations User 1301 determines the relative position of Target 1306.

[096] Figure 14 is a general illustration showing the User equipment suitable for use by spread spectrum radar using a satellite constellation as the radar transmitters. Omni-Directional Antenna 1401 receives the signals transmitted directly from Satellites 1302, 1303, 1304, and

1305 (Figure 13) as well as the satellite signals reflected by Target 1306 (also Figure 13). Omni-Directional Antenna 1401 sends these signals to Receiver 1402. The output of Receiver 1402 is stored in Data Buffer 1403. Under the control of System Controller 1406, Correlator 1404 performs correlations between the data stored in Data Buffer 1403 and a List of Code Keys 1405 which correspond to the Code Keys used by the satellites in the satellite constellation. System Controller 1406 also determines the length of the direct path from each satellite, the length of the path from each satellite reflected by Target 1306 (Figure 13) and performs the calculations to determine the range and bearing to Target 1306. The results are displayed on Display 1407.

[097] Figure 15 is a general illustration showing another form of User equipment suitable for use by spread spectrum radar using a satellite constellation as the radar transmitters. Omni-Directional Antenna 1401 receives the signals transmitted directly from Satellites 1302, 1303, 1304, and 1305 (Figure 13) as well as the satellite signals reflected by Target 1306 (also Figure 13). Omni-Directional Antenna 1401 sends these signals to Receiver 1402. The output of Receiver 1402 is stored in Data Buffer 1403. Under the control of System Controller 1506, Correlator 1404 performs correlations between the data stored in Data Buffer 1403 and a List of Code Keys 1405 which correspond to the Code Keys used by the satellites in the satellite constellation. System Controller 1506 uses GPS Receiver 1507 to determine the User's position. System Controller 1506 also determines the length of the direct path from each satellite, the length of the path from each satellite reflected by Target 1306 (Figure 13) and performs the calculations to determine the range and bearing to Target 1306. The results are displayed on Display 1508.

[098] Figure 16 is a general illustration showing the User equipment suitable for use by spread spectrum radar using a satellite constellation as the radar transmitters. Directional Antenna 1601 receives the signals reflected by Target 1306 (Figure 13) from Satellites 1302, 1303, 1304, and 1305 (Figure 13). Directional Antenna 1601 sends these signals to Receiver 1603. The output of Receiver 1603 is stored in Data Buffer 1604. Under the control of System Controller 1611, Correlator 1605 performs correlations between the data stored in Data Buffer 1604 and a list of Code Keys 1610 which correspond to the Code Keys used by the satellites in the satellite constellation. System Controller 1611 also controls the direction of Directional Antenna 1601 using Antenna Controller 1602.

Omni-Directional Antenna 1606 receives the signals directly sent by Satellites 1302, 1303, 1304, and 1305 (Figure 13). Omni-Directional Antenna 1606 sends these signals to Receiver 1607. The output of Receiver 1607 is stored in Data Buffer 1608. Under the control of System Controller 1611, Correlator 1609 performs correlations between the data stored in Data Buffer 1608 and a List of Code Keys 1610 which correspond to the Code Keys used by the satellites in the satellite constellation. System Controller 1611 also determines the length of the direct path from each satellite and performs the calculations to determine the range and bearing to Target 1306.

Directional Antenna 1601 and Antenna Controller 1602 may be a system that mechanically aims Directional Antenna 1601 or the combination may be an electronically scanned array.

The results are displayed on Display 1612.

[099] Figure 17 is a general illustration showing another form of User equipment suitable for use by spread spectrum radar using a satellite constellation as the radar transmitters. Directional Antenna 1601 receives the signals reflected by Target 1306 (Figure 13) from Satellites 1302, 1303, 1304, and 1305 (Figure 13). Directional Antenna 1601 sends these signals to Receiver 1603. The output of Receiver 1603 is stored in Data Buffer 1604. Under the control of System Controller 1711, Correlator 1605 performs correlations between the data stored in Data Buffer 1604 and a List of Code Keys 1610 which correspond to the Code Keys used by the satellites in the satellite constellation. System Controller 1711 also controls the direction of Directional Antenna 1601 using Antenna Controller 1602.

Omni-Directional Antenna 1606 receives the signals directly sent by Satellites 1302, 1303, 1304, and 1305 (Figure 13). Omni-Directional Antenna 1606 sends these signals to Receiver 1607. The output of Receiver 1607 is stored in Data Buffer 1608. Under the control of System Controller 1711, Correlator 1609 performs correlations between the data stored in Data Buffer 1608 and a List of Code Keys 1610 which correspond to the Code Keys used by the satellites in the satellite constellation. System Controller 1711 also uses GPS Receiver 1712 to determine the length of the direct path from each satellite and performs the calculations to determine the range and bearing to Target 1306.

Directional Antenna 1601 and Antenna Controller 1602 may be a system that mechanically aims Directional Antenna 1601 or the combination may be an electronically scanned array.

The results are displayed on Display 1713.

[100] Figure 18 is a general illustration showing an integrated bistatic spread spectrum radar system using a satellite constellation as the radar as well as for communications. Omni-Directional Antenna 1801 receives the signals transmitted directly from Satellites 1302, 1303, 1304, and 1305 (Figure 13) which contain the communications signals which are also used for bistatic radar. The signals from Omni-Directional Antenna 1801 are sent to Receiver 1802. The output of Receiver 1802 is stored in Data Buffer 1803. Under the control of System Controller 1813, Correlator 1804 performs correlations between the data stored in Data Buffer 1803 and the List of Code Keys 1814 used by the satellites in the satellite constellation shown in Figure 13.

System Controller 1813 uses List of Code Keys 1814 to create a spread spectrum signal and transmits it to the satellites using Transmitter 1807 and Directional Antenna 1805. System Controller 1813 controls the direction of Directional Antenna 1805 using Antenna Controller 1806.

Directional Antenna 1808 is used to receive the satellite signals reflected by Target 1306 (Figure 13). Directional Antenna 1808 sends these signals to Receiver 1810. The output of Receiver 1810 is stored in Data Buffer 1811. Under the control of System Controller 1813, Correlator 1812 performs correlations between the data stored in Data Buffer 1811 and a List of Code Keys 1814 which correspond to the Code Keys used by the satellites in the satellite constellation. System Controller 1813 determines the length of the direct path from each satellite, the length of the path from each satellite reflected by Target 1306 (Figure 13) and performs the calculations to determine the range and bearing to Target 1306. The use of GPS Receiver 1815 in determining the User's position is optional. System Controller 1813 controls the direction of Directional Antenna 1808 using Antenna Controller 1809.

Directional Antenna 1805 and Antenna Controller 1806 may be a system that mechanically aims Directional Antenna 1805 or the combination may be an electronically scanned array.

Directional Antenna 1808 and Antenna Controller 1809 may be a system that mechanically aims Directional Antenna 1808 or the combination may be an electronically scanned array.

The results are displayed on Display 1816.

Geometry

[101] The geometry of a bistatic radar will be discussed, starting with a 2D system which will then be expanded to a 3D system.

Referring to Figure 19, **Receiver 1901** receives a signal directly from **Transmitter 1902** through **Path L 1904**. **Receiver 1901** also receives a signal from **Transmitter 1902** reflected off of **Target 1903** through **Path r1 1905** and **Path r2 1906**.

Receiver 1901 only knows the sum of **Path r1 1905** and **Path r2 1906**. The locus of all points of a plane whose distances to two fixed points add to the same constant is an ellipse. As a result, as shown in Figure 20, **Receiver 1901** only knows that **Target 1903** is somewhere on **Ellipse 2007**. **Receiver 1901** and **Transmitter 1902** are located at the two foci of **Ellipse 2007**.

In the following discussion, the labels are emboldened and omit the drawing figure numbers in order to avoid an unmanageable clutter.

Figure 21 shows an ellipse in standard form. The foci are at **f1** and **f2**. The semi-major axis is **a**. (The major axis is 2 * **a**) The semi-minor axis is **b**. (The minor axis is 2 * **b**)

The two foci are equidistant from the **Y** axis, and are separated by distance **L**.

The sum of **r1** and **r2** is constant so that Point **P** traces out the ellipse.

The parametric equation for an ellipse is:

$$\frac{x^2}{a^2} + \frac{y^2}{b^2} = 1$$

Note that if **a** = **b**:

$$\frac{x^2}{a^2} + \frac{y^2}{a^2} = 1$$

$$\frac{x^2 + y^2}{a^2} = 1$$

$$x^2 + y^2 = a^2$$

If we rename **a** and call it **r**, most engineers will recognize this as the parametric equation for a circle.

$$x^2 + y^2 = r^2$$

An ellipse is also a simple form of Lissajous Figure where:

$x = R * \sin(2\pi t)$ and $y = R * \sin(2\pi t + \delta)$

For more on Lissajous Figures see *IDS Cite 27*.

The ellipse data produced by the present system will be **L** and the sum of **r1** and **r2**. **L** is the distance between the foci **f1** and **f2**. Another way of putting it is that **f1** = -**f2** = **L**/2. We want to determine the semi-major axis (**a**) and the semi-minor axis (**b**).

In Figure 22, Point **P** has been moved to (**a**,0). **r1** and **r2** are not shown because they lie on the **X** axis.

The distance from **f1** to (**a**,0) and from (**a**,0) to **f2** is the sum of **r1** and **r2** because that is the definition of an ellipse.

The distance from **f1** to **f2** is **L**. The distance from **f2** to (**a**,0) is **d**. The distance from (**a**,0) back to **f2** is, again, **d**.

$$r1 + r2 = L + d + d$$

$$2 * d = r1 + r2 - L$$

$$d = (r1 + r2 - L)/2 = (r1 + r2)/2 - L/2$$

Therefore:

$$a = L/2 + d$$

$$= L/2 + (r1 + r2)/2 - L/2$$

$$= (r1 + r2)/2$$

Now that we have found the semi-major axis **a**, let's find the semi-minor axis **b**. Referring to Figure 23, when **P** is located at (0,**b**) the sum of **r1** + **r2** is divided into two equal parts and forms two right triangles with the Origin (0,0) and the foci. Note that in this case **r1** = **r2** and the line from **P** to each focal point is the same length as the semi-major axis (**r1** + **r2**)/2.

$$\mathbf{b}^2 = \left(\frac{\mathbf{(r1 + r2)}}{\mathbf{2}}\right)^2 - \left(\frac{\mathbf{L}}{\mathbf{2}}\right)^2$$

$$\mathbf{b} = \sqrt{\left(\frac{(\mathbf{r1} + \mathbf{r2})}{2}\right)^2 - \left(\frac{\mathbf{L}}{2}\right)^2}$$

Therefore, since the present system measures (**r1** + **r2**) and measures (or calculates) **L** we can calculate **a** and **b** and with that we can calculate any point on the ellipse.

$$\frac{\mathbf{x}^2}{\mathbf{a}^2} + \frac{\mathbf{y}^2}{\mathbf{b}^2} = \mathbf{1}$$

where:

$$a = (r1 + r2)/2$$

$$\mathbf{b} = \sqrt{\left(\frac{(\mathbf{r1} + \mathbf{r2})}{2}\right)^2 - \left(\frac{\mathbf{L}}{2}\right)^2}$$

[102] The general ellipsoid, also called a triaxial ellipsoid, is a quadratic surface which is given in Cartesian coordinates by the parametric equation:

$$\frac{x^2}{a^2} + \frac{y^2}{b^2} + \frac{z^2}{c^2} = 1$$

Note that if **a** = **b** = **c**:

$$\frac{x^2}{a^2} + \frac{y^2}{a^2} + \frac{z^2}{a^2} = 1$$

$$\frac{x^2 + y^2 + z^2}{a^2} = 1$$

$$x^2 + y^2 + z^2 = a^2$$

If we rename **a** and call it **r**, most engineers will recognize this as the parametric equation for a sphere.

$$x^2 + y^2 + z^2 = r^2$$

In the current ellipsoid:

$$\frac{x^2}{a^2} + \frac{y^2}{b^2} + \frac{z^2}{c^2} = 1$$

c = **b** because the target is on the radius of a circle around the axis formed by the two foci. To be precise, this makes our ellipsoid a spheroid and since it is likely that the target will be much closer than any of the satellites **a** will be larger than **b**, making it a prolate spheroid.
In the current ellipsoid:

$$\frac{x^2}{a^2} + \frac{y^2}{b^2} + \frac{z^2}{b^2} = 1$$

$$\frac{x^2}{a^2} + \frac{y^2 + z^2}{b^2} = 1$$

[103] When two ellipsoids having a common focus intersect they produce an ellipse. Figure 31 is a general illustration showing two ellipsoids with a common focus, meeting end-to-end, producing a circle seen edge-on. Figure 31, Figure 32, and Figure 33 were produced by a computer program that modeled an ellipsoid as a segmented prolate spheroid, i.e. a number of circles around a major axis. The radii of the circles vary according to the curve of an ellipse. Projection is orthonormal. In Figure 32 the two ellipsoids are meeting at a first arbitrary angle. In

Figure 33 the two ellipsoids meet at a second arbitrary angle. By inspection it appears that the smaller the angle between the ellipsoids the larger the intersection ellipse. The implication of this is that the closer together the satellites are, the larger the ellipse of intersection becomes. As the satellites become farther apart, the ellipse of intersection becomes smaller.

[104] Starting with the first satellite in Figure 13 (but in 2D) the User knows the total length of the path from a first satellite to the target and then to the User and wants to know the length of the path from the target to himself. The User also knows the length of the path from the first satellite to himself. Mathematically, this is the definition of an ellipse. The User and the first satellite are at the foci and the target is somewhere on the ellipse. See Figure 24.

[105] When a second satellite is added, a second ellipse is formed. The User is at one of the foci, the second satellite is at the other. The first ellipse and the second ellipse intersect at only two points, with the target at one of the two points. See Figure 25.

[106] When a third satellite is added, a third ellipse is formed. Again, the User is at one of the foci and the third satellite is at the other. The three ellipses intersect at only one point. That is where the target is. See Figure 26.

[107] There is something to note. Not all ellipses that share a focus point will intersect. See Figure 27. However, in the present case they must intersect because the ellipses were created by reflections from the same target, and the target cannot be in more than one place at the same time. It is possible that two ellipses that share a focus point will intersect at only one point, but that is a special case. See Figure 28.

[108] A 3D system is more complicated because the geometric figure produced between each satellite and the User is not a 2D planar ellipse. Picture an ellipse rotating around the axis between the User and the satellite. The figure that each Satellite produces is an ellipsoid, more specifically, a prolate spheroid, that looks remarkably like a football (U.S. or Canadian). See Figure 29. That is because a line from the target meets the line from the User to the satellite at a

90 degree angle and forms the radius of a circle. See Figure 30. The target can be anywhere on that circle which means it can be anywhere on the surface of the ellipsoid.

[109] Referring to Figure 13, Satellite 1302 produces an ellipsoid with the User at one foci and the satellite at the other. The target is somewhere on the surface of the ellipsoid.

[110] When a second satellite (Satellite 1303) is added, a second ellipsoid is formed. The User is at one of the foci, the second satellite is at the other. The first ellipsoid and the second ellipsoid intersect and produce an ellipse. The reason the ellipsoids produce an ellipse is because they share a common focus. [*IDS Cite 26*]

[111] When a third satellite (Satellite 1304) is added, a third ellipsoid is formed. The User is at one of the foci, the third satellite is at the other. The first and second ellipsoids and the third ellipsoid intersect with the target at one of two points.

[112] When a fourth satellite (Satellite 1305) is added, a fourth ellipsoid is formed. The User is at one of the foci, the fourth satellite is at the other. The first three ellipsoids and the fourth ellipsoid intersect at only one point. That is where the target is.

[113] The geometry that has been described might not be obvious to someone versed mainly in GPS geometry. GPS uses only three satellites to determine the User's position in three dimensions. (A fourth satellite is used for time correction.) The reason for this difference is because instead of using only the signal received directly from the satellite, the User is receiving both the direct signal and a signal reflected from the target. A line from the target meets the line from the User to the satellite at a 90 degree angle and forms the radius of a circle. The target can be anywhere on that circle. That is why the additional satellite is needed to determine the position of the target.

[114] The geometry shows that several system configurations are possible.

1. System 0 – It is not necessary to receive any signals directly from any satellites. Only the signals reflected from the target are needed. The User tries all of the code keys for all the

satellites or uses an ephemeris to try only the codes for the satellites that are in view. A signal that is detected is subjected to the various treatments described in the previous section on detecting spread spectrum radar. It may be possible to use the radio frequency emanations from the Sun and not use any satellites, but only during daytime.

2. System 1 – The direct and reflected signal from only one satellite is used. This detects the presence of the target but its position can be anywhere on an ellipsoid, which is better than nothing. A directional antenna is used to scan those areas corresponding to the surface of the ellipsoid.
3. System 2 – The direct and reflected signals from two satellites are used. This detects the presence of the target and locates its position to the area of a planar ellipse. A directional antenna is used to scan those areas corresponding the surface of the ellipse.
4. System 3 - The direct and reflected signals from three satellites are used. This detects the presence of the target and narrows its position down to only two positions. A directional antenna is used to determine which position the target is in.
5. System 4 – The direct and reflected signals from four satellites are used to detect the presence and position of the target. Only a single omni-directional antenna is needed.

[115] While preferred embodiments of the present invention have been shown, it is to be expressly understood that modifications and changes may be made thereto.

Electronic Acknowledgement Receipt

EFS ID:	8831879
Application Number:	12910779
International Application Number:	
Confirmation Number:	8875
Title of Invention:	System for sensing aircraft and other objects
First Named Inventor/Applicant Name:	Jed Margolin
Customer Number:	23497
Filer:	Jed Margolin
Filer Authorized By:	
Attorney Docket Number:	
Receipt Date:	13-NOV-2010
Filing Date:	22-OCT-2010
Time Stamp:	03:37:44
Application Type:	Utility under 35 USC 111(a)

Payment information:

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12/910,779	10/22/2010	3662	902		16	7

CONFIRMATION NO. 8875

23497
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FILING RECEIPT

OC000000044366574

Date Mailed: 11/05/2010

Receipt is acknowledged of this non-provisional patent application. The application will be taken up for examination in due course. Applicant will be notified as to the results of the examination. Any correspondence concerning the application must include the following identification information: the U.S. APPLICATION NUMBER, FILING DATE, NAME OF APPLICANT, and TITLE OF INVENTION. Fees transmitted by check or draft are subject to collection. Please verify the accuracy of the data presented on this receipt. **If an error is noted on this Filing Receipt, please submit a written request for a Filing Receipt Correction. Please provide a copy of this Filing Receipt with the changes noted thereon. If you received a "Notice to File Missing Parts" for this application, please submit any corrections to this Filing Receipt with your reply to the Notice. When the USPTO processes the reply to the Notice, the USPTO will generate another Filing Receipt incorporating the requested corrections**

Applicant(s)

Jed Margolin, VC Highlands, NV;

Power of Attorney: None

Domestic Priority data as claimed by applicant

This appln claims benefit of 61/256,765 10/30/2009

Foreign Applications

Permission to Access - A proper **Authorization to Permit Access to Application by Participating Offices** (PTO/SB/39 or its equivalent) has been received by the USPTO.

Projected Publication Date: To Be Determined - pending completion of Corrected Papers

Non-Publication Request: No

Early Publication Request: No

**** SMALL ENTITY ****

Title

System for sensing aircraft and other objects

Preliminary Class

342

PROTECTING YOUR INVENTION OUTSIDE THE UNITED STATES

Since the rights granted by a U.S. patent extend only throughout the territory of the United States and have no effect in a foreign country, an inventor who wishes patent protection in another country must apply for a patent in a specific country or in regional patent offices. Applicants may wish to consider the filing of an international application under the Patent Cooperation Treaty (PCT). An international (PCT) application generally has the same effect as a regular national patent application in each PCT-member country. The PCT process **simplifies** the filing of patent applications on the same invention in member countries, but **does not result** in a grant of "an international patent" and does not eliminate the need of applicants to file additional documents and fees in countries where patent protection is desired.

Almost every country has its own patent law, and a person desiring a patent in a particular country must make an application for patent in that country in accordance with its particular laws. Since the laws of many countries differ in various respects from the patent law of the United States, applicants are advised to seek guidance from specific foreign countries to ensure that patent rights are not lost prematurely.

Applicants also are advised that in the case of inventions made in the United States, the Director of the USPTO must issue a license before applicants can apply for a patent in a foreign country. The filing of a U.S. patent application serves as a request for a foreign filing license. The application's filing receipt contains further information and guidance as to the status of applicant's license for foreign filing.

Applicants may wish to consult the USPTO booklet, "General Information Concerning Patents" (specifically, the section entitled "Treaties and Foreign Patents") for more information on timeframes and deadlines for filing foreign patent applications. The guide is available either by contacting the USPTO Contact Center at 800-786-9199, or it can be viewed on the USPTO website at http://www.uspto.gov/web/offices/pac/doc/general/index.html.

For information on preventing theft of your intellectual property (patents, trademarks and copyrights), you may wish to consult the U.S. Government website, http://www.stopfakes.gov. Part of a Department of Commerce initiative, this website includes self-help "toolkits" giving innovators guidance on how to protect intellectual property in specific countries such as China, Korea and Mexico. For questions regarding patent enforcement issues, applicants may call the U.S. Government hotline at 1-866-999-HALT (1-866-999-4158).

LICENSE FOR FOREIGN FILING UNDER

Title 35, United States Code, Section 184

Title 37, Code of Federal Regulations, 5.11 & 5.15

GRANTED

The applicant has been granted a license under 35 U.S.C. 184, if the phrase "IF REQUIRED, FOREIGN FILING LICENSE GRANTED" followed by a date appears on this form. Such licenses are issued in all applications where the conditions for issuance of a license have been met, regardless of whether or not a license may be required as set forth in 37 CFR 5.15. The scope and limitations of this license are set forth in 37 CFR 5.15(a) unless an earlier license has been issued under 37 CFR 5.15(b). The license is subject to revocation upon written notification. The date indicated is the effective date of the license, unless an earlier license of similar scope has been granted under 37 CFR 5.13 or 5.14.

This license is to be retained by the licensee and may be used at any time on or after the effective date thereof unless it is revoked. This license is automatically transferred to any related applications(s) filed under 37 CFR 1.53(d). This license is not retroactive.

The grant of a license does not in any way lessen the responsibility of a licensee for the security of the subject matter as imposed by any Government contract or the provisions of existing laws relating to espionage and the national security or the export of technical data. Licensees should apprise themselves of current regulations especially with respect to certain countries, of other agencies, particularly the Office of Defense Trade Controls, Department of State (with respect to Arms, Munitions and Implements of War (22 CFR 121-128)); the Bureau of Industry and Security, Department of Commerce (15 CFR parts 730-774); the Office of Foreign AssetsControl, Department of Treasury (31 CFR Parts 500+) and the Department of Energy.

NOT GRANTED

No license under 35 U.S.C. 184 has been granted at this time, if the phrase "IF REQUIRED, FOREIGN FILING LICENSE GRANTED" DOES NOT appear on this form. Applicant may still petition for a license under 37 CFR 5.12, if a license is desired before the expiration of 6 months from the filing date of the application. If 6 months has lapsed from the filing date of this application and the licensee has not received any indication of a secrecy order under 35 U.S.C. 181, the licensee may foreign file the application pursuant to 37 CFR 5.15(b).

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

APPLICATION NUMBER	FILING OR 371(C) DATE	FIRST NAMED APPLICANT	ATTY. DOCKET NO./TITLE
12/910,779	10/22/2010	Jed Margolin	

CONFIRMATION NO. 8875

23497
JED MARGOLIN
1981 EMPIRE ROAD
RENO, NV 89521-7430

FORMALITIES LETTER

OC000000044366575

Date Mailed: 11/05/2010

NOTICE TO FILE CORRECTED APPLICATION PAPERS

Filing Date Granted

An application number and filing date have been accorded to this application. The application is informal since it does not comply with the regulations for the reason(s) indicated below. Applicant is given TWO MONTHS from the date of this Notice within which to correct the informalities indicated below. Extensions of time may be obtained by filing a petition accompanied by the extension fee under the provisions of 37 CFR 1.136(a).

The required item(s) identified below must be timely submitted to avoid abandonment:

- A substitute specification in compliance with 37 CFR 1.52, 1.121(b)(3), and 1.125, is required. The substitute specification must be submitted with markings and be accompanied by a clean version (without markings) as set forth in 37 CFR 1.125(c) and a statement that the substitute specification contains no new matter (see 37 CFR 1.125(b)). The specification, claims, and/or abstract page(s) submitted is not acceptable and cannot be scanned or properly stored because:
  - The line spacing on the specification, claims, and/or abstract is not 1½ or double spaced (see 37 CFR 1.52(b)).

Applicant is cautioned that correction of the above items may cause the specification and drawings page count to exceed 100 pages. If the specification and drawings exceed 100 pages, applicant will need to submit the required application size fee.

Replies should be mailed to:

Mail Stop Missing Parts
Commissioner for Patents
P.O. Box 1450
Alexandria VA 22313-1450

Registered users of EFS-Web may alternatively submit their reply to this notice via EFS-Web.
https://sportal.uspto.gov/authenticate/AuthenticateUserLocalEPF.html

For more information about EFS-Web please call the USPTO Electronic Business Center at **1-866-217-9197** or visit our website at http://www.uspto.gov/ebc.

If you are not using EFS-Web to submit your reply, you must include a copy of this notice.

/nhassani/

Office of Data Management, Application Assistance Unit (571) 272-4000, or (571) 272-4200, or 1-888-786-0101

UTILITY PATENT APPLICATION TRANSMITTAL

(Only for new nonprovisional applications under 37 CFR 1.53(b))

Attorney Docket No.	
First Inventor	Jed Margolin
Title	System for sensing aircraft and other objects
Express Mail Label No.	

APPLICATION ELEMENTS

See MPEP chapter 600 concerning utility patent application contents.

ADDRESS TO: **Commissioner for Patents, P.O. Box 1450, Alexandria VA 22313-1450**

1. ☑ **Fee Transmittal Form** (e.g., PTO/SB/17)
2. ☑ **Applicant claims small entity status.** See 37 CFR 1.27.
3. ☑ **Specification** [*Total Pages* 57]
   Both the claims and abstract must start on a new page
   (For information on the preferred arrangement, see MPEP 608.01(a))
4. ☑ **Drawing(s)** (*35 U.S.C. 113*) [*Total Sheets* 25]
5. **Oath or Declaration** [*Total Sheets* 3]
   a. ☑ Newly executed (original or copy)
   b. ☐ A copy from a prior application (37 CFR 1.63(d))
   (for continuation/divisional with Box 18 completed)
   i. ☐ DELETION OF INVENTOR(S)
   Signed statement attached deleting inventor(s) name in the prior application, see 37 CFR 1.63(d)(2) and 1.33(b).
6. ☐ **Application Data Sheet.** See 37 CFR 1.76
7. ☐ **CD-ROM or CD-R** in duplicate, large table or Computer Program *(Appendix)*
   ☐ Landscape Table on CD
8. **Nucleotide and/or Amino Acid Sequence Submission**
   (if applicable, items a. – c. are required)
   a. ☐ Computer Readable Form (CRF)
   b. Specification Sequence Listing on:
   i. ☐ CD-ROM or CD-R (2 copies); or
   ii. ☐ Paper
   c. ☐ Statements verifying identity of above copies

ACCOMPANYING APPLICATION PARTS

9. ☐ **Assignment Papers** (cover sheet & document(s))
   Name of Assignee ____________________
10. ☐ **37 CFR 3.73(b) Statement** *(when there is an assignee)* ☐ **Power of Attorney**
11. ☐ **English Translation Document** *(if applicable)*
12. ☑ **Information Disclosure Statement** (PTO/SB/08 or PTO-1449)
    ☑ Copies of citations attached
13. ☐ **Preliminary Amendment**
14. ☐ **Return Receipt Postcard** (MPEP 503)
    (Should be specifically itemized)
15. ☐ **Certified Copy of Priority Document(s)**
    (if foreign priority is claimed)
16. ☐ **Nonpublication Request** under 35 U.S.C. 122(b)(2)(B)(i). Applicant must attach form PTO/SB/35 or equivalent.
17. ☐ Other: ____________________

18. If a CONTINUING APPLICATION, *check appropriate box, and supply the requisite information below and in the first sentence of the specification following the title, or in an Application Data Sheet under 37 CFR 1.76:*

☐ Continuation ☐ Divisional ☐ Continuation-in-part (CIP) of prior application No.: ....

Prior application information: *Examiner* ____________ *Art Unit:* ____________

19. CORRESPONDENCE ADDRESS

☑ The address associated with Customer Number: 23497 **OR** ☐ Correspondence address below

Name					
Address					
City		State		Zip Code	
Country		Telephone		Email	

Signature	*Jed Margolin*	Date	10/22/2010
Name (Print/Type)	Jed Margolin	Registration No. (Attorney/Agent)	

DECLARATION FOR UTILITY OR DESIGN PATENT APPLICATION (37 CFR 1.63)

☑ Declaration Submitted With Initial Filing OR ☐ Declaration Submitted After Initial Filing (surcharge (37 CFR 1.16(f)) required)

Attorney Docket Number	
First Named Inventor	Jed Margolin
COMPLETE IF KNOWN	
Application Number	
Filing Date	
Art Unit	
Examiner Name	

I hereby declare that: (1) Each inventor's residence, mailing address, and citizenship are as stated below next to their name; and (2) I believe the inventor(s) named below to be the original and first inventor(s) of the subject matter which is claimed and for which a patent is sought on the invention titled:

System for sensing aircraft and other objects

(Title of the Invention)

the application of which

☑ is attached hereto

OR

☐ was filed on (MM/DD/YYYY) ________________ as United States Application Number or PCT International Application Number ________________ and was amended on (MM/DD/YYYY) ________________ (if applicable).

I hereby state that I have reviewed and understand the contents of the above identified application, including the claims, as amended by any amendment specifically referred to above.

I acknowledge the duty to disclose information which is material to patentability as defined in 37 CFR 1.56, including for continuation-in-part applications, material information which became available between the filing date of the prior application and the national or PCT international filing date of the continuation-in-part application.

Authorization To Permit Access To Application by Participating Offices

☑ If checked, the undersigned hereby grants the USPTO authority to provide the European Patent Office (EPO), the Japan Patent Office (JPO), the Korean Intellectual Property Office (KIPO), the World Intellectual Property Office (WIPO), and any other intellectual property offices in which a foreign application claiming priority to the above-identified patent application is filed access to the above-identified patent application. See 37 CFR 1.14(c) and (h). This box should not be checked if the applicant does not wish the EPO, JPO, KIPO, WIPO, or other intellectual property office in which a foreign application claiming priority to the above-identified patent application is filed to have access to the above-identified patent application.

In accordance with 37 CFR 1.14(h)(3), access will be provided to a copy of the above-identified patent application with respect to: 1) the above-identified patent application-as-filed; 2) any foreign application to which the above-identified patent application claims priority under 35 U.S.C. 119(a)-(d) if a copy of the foreign application that satisfies the certified copy requirement of 37 CFR 1.55 has been filed in the above-identified patent application; and 3) any U.S. application-as-filed from which benefit is sought in the above-identified patent application.

In accordance with 37 CFR 1.14(c), access may be provided to information concerning the date of filing the Authorization to Permit Access to Application by Participating Offices.

DECLARATION — Utility or Design Patent Application

Claim of Foreign Priority Benefits

I hereby claim foreign priority benefits under 35 U.S.C. 119(a)-(d) or (f), or 365(b) of any foreign application(s) for patent, inventor's or plant breeder's rights certificate(s), or 365(a) of any PCT international application which designated at least one country other than the United States of America, listed below and have also identified below, by checking the box, any foreign application for patent, inventor's or plant breeder's rights certificate(s), or any PCT international application having a filing date before that of the application on which priority is claimed.

Prior Foreign Application Number(s)	Country	Foreign Filing Date (MM/DD/YYYY)	Priority Not Claimed	Certified Copy Attached? YES	NO
			☐	☐	☐
			☐	☐	☐
			☐	☐	☐
			☐	☐	☐

☐ Additional foreign application number(s) are listed on a supplemental priority data sheet PTO/SB/02B attached hereto.

DECLARATION — Utility or Design Patent Application

Direct all correspondence to: ☑	The address associated with Customer Number:	23497	OR	☐ Correspondence address below

Name		
Address		
City	State	Zip
Country	Telephone	Email

WARNING:

Petitioner/applicant is cautioned to avoid submitting personal information in documents filed in a patent application that may contribute to identity theft. Personal information such as social security numbers, bank account numbers, or credit card numbers (other than a check or credit card authorization form PTO-2038 submitted for payment purposes) is never required by the USPTO to support a petition or an application. If this type of personal information is included in documents submitted to the USPTO, petitioners/applicants should consider redacting such personal information from the documents before submitting them to the USPTO. Petitioner/applicant is advised that the record of a patent application is available to the public after publication of the application (unless a non-publication request in compliance with 37 CFR 1.213(a) is made in the application) or issuance of a patent. Furthermore, the record from an abandoned application may also be available to the public if the application is referenced in a published application or an issued patent (see 37 CFR 1.14). Checks and credit card authorization forms PTO-2038 submitted for payment purposes are not retained in the application file and therefore are not publicly available. Petitioner/applicant is advised that documents which form the record of a patent application (such as the PTO/SB/01) are placed into the Privacy Act system of records DEPARTMENT OF COMMERCE, COMMERCE-PAT-7, System name: *Patent Application Files*. Documents not retained in an application file (such as the PTO-2038) are placed into the Privacy Act system of COMMERCE/PAT-TM-10, System name: *Deposit Accounts and Electronic Funds Transfer Profiles*.

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under 18 U.S.C. 1001 and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

NAME OF SOLE OR FIRST INVENTOR:	☐ A petition has been filed for this unsigned inventor		
Given Name (first and middle [if any]): Jed	Family Name or Surname: Margolin		
Inventor's Signature: Jed Margolin		Date: 10/22/2010	
Residence: City: VC Highlands	State: NV	Country: USA	Citizenship: USA
Mailing Address: 1981 Empire Rd.			
City: Reno	State: NV	Zip: 89521-7430	Country: USA

☐ Additional inventors or a legal representative are being named on the ______ supplemental sheet(s) PTO/SB/02A or 02LR attached hereto

Effective on 12/08/2004.
Fees pursuant to the Consolidated Appropriations Act, 2005 (H.R. 4818).

FEE TRANSMITTAL
For FY 2009

☑ Applicant claims small entity status. See 37 CFR 1.27

TOTAL AMOUNT OF PAYMENT	($) 985.00

Complete if Known	
Application Number	
Filing Date	
First Named Inventor	Jed Margolin
Examiner Name	
Art Unit	
Attorney Docket No.	

METHOD OF PAYMENT (check all that apply)

☐ Check ☑ Credit Card ☐ Money Order ☐ None ☐ Other (please identify): ____________

☐ Deposit Account Deposit Account Number: ____________ Deposit Account Name: ____________

For the above-identified deposit account, the Director is hereby authorized to: (check all that apply)

☑ Charge fee(s) indicated below ☐ Charge fee(s) indicated below, **except for the filing fee**

☐ Charge any additional fee(s) or underpayments of fee(s) under 37 CFR 1.16 and 1.17 ☐ Credit any overpayments

WARNING: Information on this form may become public. Credit card information should not be included on this form. Provide credit card information and authorization on PTO-2038.

FEE CALCULATION

1. BASIC FILING, SEARCH, AND EXAMINATION FEES

	FILING FEES		SEARCH FEES		EXAMINATION FEES		
Application Type	**Fee ($)**	**Small Entity Fee ($)**	**Fee ($)**	**Small Entity Fee ($)**	**Fee ($)**	**Small Entity Fee ($)**	**Fees Paid ($)**
Utility	330	165	540	270	220	110	545
Design	220	110	100	50	140	70	
Plant	220	110	330	165	170	85	
Reissue	330	165	540	270	650	325	
Provisional	220	110	0	0	0	0	

2. EXCESS CLAIM FEES

Fee Description	**Fee ($)**	**Small Entity Fee ($)**
Each claim over 20 (including Reissues)	52	26
Each independent claim over 3 (including Reissues)	220	110
Multiple dependent claims	390	195

Total Claims 16 - 20 or HP = **Extra Claims** 0 x **Fee ($)** ____ = **Fee Paid ($)** 0

HP = highest number of total claims paid for, if greater than 20.

Indep. Claims 7 - 3 or HP = **Extra Claims** 4 x **Fee ($)** 110 = **Fee Paid ($)** 440

HP = highest number of independent claims paid for, if greater than 3.

Multiple Dependent Claims

Fee ($)	**Fee Paid ($)**
0	0

3. APPLICATION SIZE FEE

If the specification and drawings exceed 100 sheets of paper (excluding electronically filed sequence or computer listings under 37 CFR 1.52(e)), the application size fee due is $270 ($135 for small entity) for each additional 50 sheets or fraction thereof. See 35 U.S.C. 41(a)(1)(G) and 37 CFR 1.16(s).

Total Sheets 82 - 100 = **Extra Sheets** 0 / 50 = **Number of each additional 50 or fraction thereof** 0 (round **up** to a whole number) x **Fee ($)** ____ = **Fee Paid ($)** 0

4. OTHER FEE(S) **Fees Paid ($)**

Non-English Specification, $130 fee (no small entity discount) 0

Other (e.g., late filing surcharge): ____________ 0

SUBMITTED BY

Signature	*Jed Margolin*	Registration No. (Attorney/Agent)		Telephone 775-847-7845
Name (Print/Type)	Jed Margolin			Date 10/22/2010

UNITED STATES PATENT APPLICATION FOR PATENT
FOR

SYSTEM FOR SENSING AIRCRAFT AND OTHER OBJECTS

INVENTOR: JED MARGOLIN

SYSTEM FOR SENSING AIRCRAFT AND OTHER OBJECTS

CROSS REFERENCES TO RELATED APPLICATIONS

[001] This application claims the benefit of U.S. Provisional Application No. 61/256,765 filed on October 30, 2009.

BACKGROUND OF THE INVENTION - Field of Invention

[002] This invention relates to the field of sensing aircraft and other objects and is part of the See and Avoid (SAA) function for manned aircraft and the Detect, Sense and Avoid (DSA) function for remotely piloted vehicles (RPVs) and unmanned aerial vehicles (UAVs). RPV is an older term for UAV. "UCAV" shall mean "Unmanned Combat Aerial Vehicle." UCAV is also sometimes defined as an "Uninhabited Combat Aerial Vehicle." UCAV is a UAV that is intended for use in combat. UAS means "Unmanned Aerial System." UCAS means "Unmanned Combat Air System." The characteristics all these vehicles have in common is that there is no human pilot onboard, and although they may be operated autonomously they can also be controlled by a remotely located operator or pilot. The term UAV shall be used as a generic term for such vehicles. Detect, Sense, and Avoid (DSA) is also commonly called Sense and Avoid (SAA) since "Detect" and "Sense" mostly mean the same thing. This invention is directed to the "See" in "See and Avoid" and the "Sense" in "Sense and Avoid." It may also be used by ground stations to sense aircraft and other objects.

BACKGROUND OF THE INVENTION – Prior Art

[003] In an aircraft with the pilot onboard, Sense and Avoid is called See and Avoid. FAA Regulations do not give much guidance for seeing other aircraft.

Right-of-way rules: Except water operations 14 CFR § 91.113(b) [*IDS Cite 1*]:

> (b) General. When weather conditions permit, regardless of whether an operation is conducted under instrument flight rules or visual flight rules, vigilance shall be maintained by each person operating an aircraft so as to see and avoid other aircraft. When a rule of this section gives another aircraft the right-of-way, the pilot shall give way to that aircraft and may not pass over, under, or ahead of it unless well clear.

Right-of-way rules: Water operations 14 CFR § 91.115(a) [*IDS Cite. 2*]

> (a) *General.* Each person operating an aircraft on the water shall, insofar as possible, keep clear of all vessels and avoid impeding their navigation, and shall give way to any vessel or other aircraft that is given the right-of-way by any rule of this section.

When operating under Visual Flight Rules the idea is to look out small windows providing a limited field of view and hope you see any nearby aircraft in time to avoid a collision. This is made more difficult because of the wide range of aircraft sizes and speeds. (Is it a large aircraft far away or a small aircraft much closer?) This is even more difficult under instrument flight rules where there may be no visibility.

[004] Radar can be used to sense aircraft. Ground-based Radar allows Air Traffic Control (ATC) to direct aircraft in controlled airspace and keep aircraft safely apart. Military aircraft are generally equipped with onboard radar.

[005] One type of collision avoidance system uses **Secondary Surveillance Radar** (**SSR**) where the **Primary Surveillance Radar (PSR)** used in air traffic control (ATC) detects and measures the position of aircraft and a secondary signal is transmitted that triggers a transponder in an aircraft that requests additional information from the aircraft itself such as its identity and altitude. Unlike Primary Surveillance Radar systems, which measure only the range and bearing to targets by detecting reflected radio signals, Secondary Surveillance Radar relies on its targets being equipped with a transponder which replies to each interrogation signal by transmitting its own response containing encoded data. U.S. Patent 4,782,450 **Method and apparatus for passive airborne collision avoidance and navigation** issued November 1, 1988 to Flax teaches that an aircraft can be equipped with a system that monitors the signals from the Secondary Surveillance Radar and the signals produced by each aircraft's transponders to produce its own onboard display of the locations of aircraft in the area. [*IDS Cite 3*]

[006] The **Traffic alert and Collision Avoidance System** (**TCAS**) is an aircraft collision avoidance system designed to reduce the incidence of mid-air collisions between aircraft. It monitors the airspace around an aircraft by interrogating the transponders of other TCAS-equipped aircraft via the 1030 MHz frequency. It then uses the received transponder signals (via the 1090 MHz. frequency) to compute distance, bearing and altitude relative to its own aircraft. This interrogation-and-response cycle may occur several times per second. From the FAA's **Introduction to TCAS II Version 7** [*IDS Cite 4*]

> The TCAS Computer Unit, or TCAS Processor, performs airspace surveillance, intruder tracking, its own aircraft altitude tracking, threat detection, RA maneuver determination and selection, and generation of advisories. The TCAS Processor uses pressure altitude, radar altitude, and discrete aircraft status inputs from its own aircraft to control the collision avoidance logic parameters that determine the protection volume around the TCAS aircraft. If a tracked aircraft is a collision threat, the processor selects an avoidance maneuver that will provide adequate vertical miss distance from the intruder while minimizing the perturbations to the existing flight path. If the threat aircraft is also equipped with TCAS II, the avoidance maneuver will be coordinated with the threat aircraft.

Where TCAS is relied upon to prevent mid-air collisions, an aircraft that does not have the equipment installed (or TCAS is broken or has been deliberately turned off) is a hazard to itself and other aircraft in the vicinity.

[007] The system by which an aircraft periodically transmits its identification, location, altitude, and heading is taught by U.S. Patent 5,153,836 **Universal dynamic navigation, surveillance, emergency location, and collision avoidance system and method** issued October 10, 1992 to Fraughton et al. [*IDS Cite 5*] and was materially adopted by the FAA as Automatic Dependent Surveillance-Broadcast (ADS-B). According to the article **Gulf of Mexico Helo Ops Ready for ADS-B** in Aviation Week & Space Technology (02/26/2007, page 56) [*IDS Cite 6*]:

> By the end of 2010, FAA expects to have the ADS-B system tested and operationally acceptable for the NAS, with Houston Center providing services in the Gulf region. By 2013, all of the U.S. is scheduled to be covered with ground infrastructure.

As with TCAS, where ADS-B is relied upon to prevent mid-air collisions, an aircraft that does not have the equipment installed (or ADS-B is broken or has been deliberately turned off) is a hazard to itself and other aircraft in the vicinity. ADS-B also comes with the risk that terrorists can use it to identify and track targets.

[008] A passive radar system is taught by U. S. Patent 5,187,485 **Passive ranging through global positioning system** issued February 16, 1993 to Tsui, et al. [*IDS Cite 7*] The patent teaches a method for determining the distance from a target to an observation station, using four GPS satellites as radiation sources, and a GPS receiver at the observation station to form a bistatic radar system, wherein an angle of arrival (AOA) of the target to the observation station has been measured first. Because the signal level from the GPS satellites is already low, the signal reflected from various objects is very low, requiring the use of a large antenna or more-powerful GPS satellites. See **Test Results from a Novel Passive Bistatic GPS Radar Using a Phased Sensor Array** by Alison Brown and Ben Mathews, NAVSYS Corporation. [*IDS Cite 8*]

[009] There are other types of radar that attempt to keep the presence and location of the emitter from being detected. Examples are Spread Spectrum, Frequency Hopping, Ultra Wideband, and Noise Radar. Although there are differences between them, what they have in common is that they are designed to transmit a signal that cannot be detected except by the originating entity. As a result, target echoes also cannot be detected except by the originating entity. They generally do this by using a much wider bandwidth than a standard radar.

Spread Spectrum will be used here as an example. An example of Spread Spectrum Radar is taught by U.S. Patent 5,724,041 **Spread spectrum radar device using pseudorandom noise signal for detection of an object** issued March 3, 1998 to Inoue, et al. [*IDS Cite 9*].

Abstract

A radar device transmits by a transmitting part a wave whose band is spread by a PN code from a PN generator, receives at a receiving part a reflected wave from an object based on the wave and detects the object by detecting correlation between the received signal and the PN code. In this radar device, the received signal which is spread to a wide range is converted to a low-frequency band which is easy to be measured by a down converter so that a signal is generated when correlation is made by a delay of the PN code from a delay circuit, and generates a pulse signal through waveform shaping of the signal to detect the object and to measure its relative speed and distance at a processing part according to the pulse signal and the delay time.

Note that "PN" means Pseudo-Random Number. A pseudo-random number is produced by an algorithm so it is not truly random. However, it has the advantage that sequences of pseudo-random numbers can be reproduced. An example of a method of producing pseudo-random numbers is the Linear Feedback Shift Register. A simple Linear Feedback Shift Register can be used to produce white noise for testing audio equipment as taught in the article **Shift Register With Feedback Generates White Noise** by Marc Damashek in the May 27, 1976 issue of Electronics magazine. [*IDS Cite 10*] It has also been used in U.S. Patent 4,159,293 **Random dot generator for raster scan video displays** issued March 25, 1980 to Margolin (the current inventor). [*IDS Cite 11*]

Abstract

A Linear-Feeback-Shift-Register produces a pseudorandom sequence of bits that are used to produce a stationary random pattern of dots on a standard raster scan video display. The density of dots is adjustable as is their intensity. This dot pattern may be combined with other video sources and thus may serve as a background for the playing of TV video games, especially those of the "space war" variety. The dot pattern may also be moved as a whole under player control and thus form the basis for a novel type of video game to be described.

[010] Linear-Feedback-Shift-Registers (LFSRs) have also been used to produce pseudo-random sequences of binary signals for use as test signals for transmission paths (U.S. Patent 3,986,168 **Multichannel error signal generator** issued October 12, 1976 Anderson) [*IDS Cite 12*], and as code sequences for encoding information (U.S. Patent 3,515,805 **Data scrambler** issued June 2, 1970 to Fracassi et al.). [*IDS Cite 13*] The theory of Linear-Feedback-Shift-Registers (LFSRs) is covered extensively in "Shift Register Sequences" by Solomon Golomb (Holden-Day Inc., San Francisco, 1967, and Aegean Park Press, 1982) [*IDS Cite 14*].

A very good description of spread spectrum is **The ABCs of Spread Spectrum - A Tutorial** by Randy Roberts, Director of RF/Spread Spectrum Consulting. [*IDS Cite 15*]

[011] The problem with spread spectrum radar is that it might not be undetectable. See **Undetectable Radar? (Probably Not)** by Erik Hundman, Defensetech.org, August 3, 2006. [*IDS Cite 16*]

[012] Any entity that radiates an electromagnetic signal stands a good chance of being detected, even if spread spectrum signals are used. The use of bistatic radar avoids this problem. In bistatic radar the transmitter and the receiver are physically separated by some distance so the location of the receiver cannot be detected by tracking the transmission. Bistatic radar is commonly called passive radar and is the basis for U. S. Patent 5,187,485 previously mentioned which uses the signals from the GPS system as the radiators. Other systems have been proposed using what are called "unintentional radiators." That doesn't mean the transmitters are unintentionally radiating, only that they are not radiating for the purpose of providing a signal to be used for bistatic radar. Examples are FM broadcast stations, TV broadcast stations, and cell phone base stations. See **From a Different Perspective: Principles, Practice, and Potential of Bistatic Radar** by H.D. Griffiths. [*IDS Cite 17*]. The problems with these radiators are that:

1. There might not be one where you need it.
2. They cannot be relied upon to always be transmitting.
3. In a combat zone they are prime targets for anti-radiation missiles and other attacks.

[013] UAVs have special problems sensing other aircraft.

1. If the UAV is flown manually by a remote pilot looking at the video produced by a camera mounted in the nose of the aircraft the field of view will be too limited to see other aircraft other than those directly ahead.

2. If the UAV is flown autonomously there is no human pilot. If the flight is supervised by a human operator the problem remains that the field of view from a camera mounted in the nose of the aircraft will be too limited.

3. Military UAVs might not want to use TCAS, ADS-B, or onboard radar because it would allow other aircraft and ground facilities to detect and track them. They want to sense without being sensed.

BACKGROUND OF THE INVENTION – Current Practice in Flying UAVs

[014] The current practice in flying UAVs in civilian airspace is typified by the report **Sensing Requirements for Unmanned Air Vehicles** by AFRL's Air Vehicles Directorate, Control Sciences Division, Systems Development Branch, Wright-Patterson AFB OH, June 2004, which relies on computer-intelligence to use sensors to sense and avoid other aircraft. [*IDS Cite 18*]

[015] According to the presentation entitled **Developing Sense & Avoid Requirements for Meeting an Equivalent Level of Safety** given by Russ Wolfe, Technology IPT Lead, Access 5 Project at UVS Tech 2006 this had not changed as of January 18, 2006. [*IDS Cite 19*] Access 5 was a national project sponsored by NASA and Industry with participation by the FAA and DOD to introduce high altitude long endurance (HALE) remotely operated aircraft (ROA) to routine flights in the National Airspace System (NAS). Access 5 started in May 2004 but when NASA withdrew its support (and funding) the Industry members decided not to spend their own money and Access 5 was dissolved at the end of 2005.

[016] The presentation **Integration into the National Airspace System (NAS)** given by John Timmerman of the FAA's Air Traffic Organization (July 12, 2005) essentially says that under current UAS Operations in the NAS UAVs should not harm other aircraft or the public. (Page 3: "***While ensuring 'no harm' to other NAS customers and public***") [*IDS Cite 20*]

[017] The article **Zone Ready for Drone**, April 7, 2006, on the web site for the FAA's Air Traffic Organization Employees states that [*IDS Cite 21*],

> Since March 29, a temporary flight restriction … has limited access to the airspace along almost 350 miles of the border, expanding an earlier TFR near Nogales. The restriction is in effect nightly from 6 p.m. to 9 a.m., although that time can be expanded by issuance of a Notice to Airmen. Aircraft wishing to fly in the TFR when it is active

> must receive authorization from air traffic control prior to entry. Once in, pilots are required to maintain two-way communication with ATC and transmit a discrete transponder code.

The reason for the TFR is to enable Predator UAVs to patrol the border. The article quotes Stephen Glowacki, a Systems Safety and Procedures specialist with the FAA's Air Traffic Organization as saying:

> This is an extreme situation that has been presented to us," states Stephen Glowacki, a Systems Safety and Procedures specialist with the FAA's Air Traffic Organization, stressing the nation's security. "We have been working with U.S. Customs and Border Protection to try and answer this situation."
>
> Inserting UASs into the National Airspace System is not a simple feat. According to Glowacki, the technology and certification that will permit unmanned aircraft to "see and avoid" other air traffic is still eight to ten years away. In the mean time, a carefully controlled environment is needed.

[018] From **Quadrennial Roles and Missions Review Report**, Department of Defense, January 2009, page 29 [*IDS Cite 22*]:

> <u>U.S. Joint Forces Command Joint UAS Center of Excellence has identified three areas necessary to ensure access to applicable classes of the National Airspace System:</u> (1) Airworthiness Certification; (2) establishment of standardized basic UAS qualifications consistent with Federal Aviation Administration guidelines for each class of airspace; and <u>(3) development of sense and avoid technology</u>. Working with the Services, the U.S. Joint Forces Command Joint UAS Center of Excellence will ensure these areas are addressed during UAS development.

(Emphasis added.)

OBJECTIVES

[019] Therefore, an objective of the present invention is to improve TCAS so that aircraft equipped with TCAS can detect aircraft not equipped with it (or TCAS is broken or has been deliberately turned off).

Another objective of the invention is to improve ADS-B so that aircraft equipped with ADS-B can detect aircraft not equipped with it (or ADS-B is broken or has been deliberately turned off).

Another objective of the invention is to detect and locate aircraft which are using spread spectrum radar in an attempt to be undetected.

Another objective of the invention is a system to detect and locate aircraft and other objects without itself being detected or located.

A further objective of the invention is an integrated bistatic spread spectrum radar system using a satellite constellation for the radar function as well as for communications.

SUMMARY OF THE INVENTION

[020] TCAS can be improved by using the interrogation signal transmitted from a TCAS unit as a radar transmitter with a receiver to receive reflections. In a first preferred embodiment the standard TCAS antennas are used to receive the reflections of the TCAS signal. Although one of the TCAS antennas is a directional antenna, its directionality is currently limited to 90 degree quadrants. The time delays between the transmitted signal and the reflections are used to determine the range of other aircraft and are used to match the range and number of targets to the TCAS transponder signals normally received. Doppler analysis can be used to confirm the speeds of the targets. In a second preferred embodiment a separate directional receiving antenna is used to give both the range and bearing to aircraft and other objects in the vicinity of the user's aircraft even when other aircraft are not equipped with TCAS.

[021] ADS-B can be improved by using the signal transmitted from an ADS-B unit as a radar transmitter with the ADS-B receiver used to receive reflections. In a third preferred embodiment a standard omni-directional antenna is used to receive the reflections of the ADS-B signal. The time delays between the transmitted signal and the reflections are used to determine the range of other aircraft and match the range and number of targets to the ADS-B signals normally received. Doppler analysis can be used to confirm the speeds of the targets. In a fourth preferred embodiment a directional receive antenna is used to give both the range and bearing to aircraft and other objects in the vicinity of the user's aircraft even when other aircraft are not equipped with ADS-B.

[022] Aircraft using spread spectrum radar can be detected by using two separate receiving systems, each with its own antenna and receiver. Each receiving system is configured to have the same frequency range and bandwidth. The output of each receiver system is digitized to have the same number of samples in a frame of data. A cross-correlation is then performed between the two data frames. The noise produced by each receiver system is completely independent of each other so the internally generated noise is uncorrelated. If there is a correlation between the data frames from two receiver systems it can only have come from an external source, such as a spread spectrum signal.

[023] In a fifth preferred embodiment each receiving system uses an omni-directional antenna, the two receiving systems are spatially separated, and the phase term (time delay) in the cross-correlation function is used to determine the bearing to the target. However, this produces the "Hemisphere Problem" as it is known in the field of Radio Direction Finding (RDF). A target on either side of the line between the two antennas produces the same time delay, and therefore the same angle. One method to determine which side of the line the target is on is to use a third antenna that is not collinear with the first two antennas. The receiving system from the third antenna produces a signal that is cross-correlated with the signal from one of the first two antennas. The other method is to use Doppler from the target to determine the target's velocity along with the change in the User's position. This is used for triangulation of the target. A good place to put the first two antennas are at the ends of the wings, especially in winglets made of non-conducting composites with one antenna in each winglet. The third antenna may be placed either in the nose or the tail. Alternatively, the first two antennas may be placed in the nose and in the tail with the third antenna placed at the end of either wing.

[024] A sixth preferred embodiment adds a second pair of receiving systems using omni-directional antennas. The pair of antennas in the first receiving system are located physically apart from each other and from the first pair of receiving antennas. The bearing produced by the second pair of receiving systems is used for performing triangulation with the first pair of receiving systems to determine the range to the target.

[025] In a seventh preferred embodiment, to improve the Probability of Intercept (POI), two co-located directional antennas are used. In this mode the antennas must be pointed in the same direction. However, this improvement in POI comes at the expense of obtaining range information. Bearing information is produced by the direction of the antennas since it is no longer possible to use the phase information term in the cross-correlation function to determine the bearing to the target.

[026] In an eighth preferred embodiment the two directional antennas are spatially separated. Bearing information is produced by the direction of the antennas and triangulation is used to produce range information. Since a correlated signal is produced only when both antennas are pointed at the target the antenna angles must be coordinated.

[027] In a ninth preferred embodiment a second pair of co-located receiving systems is added, spatially separated from the first pair of co-located receiving systems. Triangulation between the first pair of receiving systems and the second pair of receiving systems is used to determine the range to the target. This has the advantage that each pair of receiving systems may independently search for the presence of a target. When a target is detected by one pair of receiving systems the other pair of receiving systems is brought to bear on it for triangulation to determine its range.

[028] The use of directional antennas requires the ability to aim the antennas. This can be done by physically aiming the antennas (such as when the antennas use parabolic dish reflectors) or by using active electronically scanned arrays. Because each area must be separately scanned the time to detect and locate spread spectrum targets is increased according to the directionality of the antennas. The use of directional antennas reduces the radio frequency noise received that is produced by the Sun, except when the antennas are pointed at the Sun. (The level of the sun's contribution depends on the solar flux.) It also reduces the noise received that is produced by the Earth (about 290K.), except when the antennas are pointed at the Earth.

The technology requirements for performing a reasonably fast digital cross-correlation on two wideband signals are formidable: a fast Analog-to-Digital Converter (ADC) and a fast Digital Signal Processor (DSP). However, fast ADCs are available, such as the AD9481 (8-Bit, 250 MSPS) by Analog Devices Inc. [*IDS Cite 23*]. Fast and inexpensive DSPs are available due to their increasing use in consumer products. An example is the C6713B from Texas Instruments. [*IDS Cite 24*]

> Operating at 300 MHz, the C6713B delivers up to 1800 million floating-point operations per second (MFLOPS), 2400 million instructions per second (MIPS), and with dual fixed-/floating-point multipliers up to 600 million multiply-accumulate operations per second (MMACS).

If additional processing power is required, the cross-correlation function is very amenable to parallel processing.

[029] A system and method for detecting and locating aircraft and other objects without being detected or located will now be described.

As previously discussed, any entity that radiates an electromagnetic signal stands a good chance of being detected and possibly located, even if spread spectrum signals are used. The use of bistatic radar avoids this problem. Systems have been proposed using “unintentional radiators” such as FM broadcast stations, TV broadcast stations, and cell phone base stations. However, these sources cannot be relied upon to always be transmitting, and in a combat zone they are prime targets for anti-radiation missiles and other attacks. Because of the likelihood that any radiator can be detected and probably tracked, the solution is to make the transmitter difficult to attack.

[0030] One or more high-flying aircraft can be used as the transmitting source(s) for a bistatic radar system. One disadvantage of this method is that the technology race between aircraft and anti-aircraft missiles (and directed energy weapons) favors anti-aircraft missiles and directed energy weapons. An example of a directed energy weapon is taught by U.S. Patent 6,377,436 **Microwave Transmission Using a Laser-Generated Plasma Beam Waveguide**

issued April 23, 2002 to Margolin (the present inventor). [*IDS Cite 25*] Another disadvantage of using high-flying aircraft is that it requires the close coordination of multiple assets.

[0031] The solution is to go higher and use a permanently orbiting constellation of satellites. It can be called the Global Radar System (GRS). Although this might resemble the method taught in U. S. Patent 5,187,485 **Passive ranging through global positioning system** the purpose of the satellites is different and can be optimized to the mission.

1. GRS satellites will use higher power than GPS.

2. The precise position of each GRS satellite does not need to be known, only the precise range and bearing to the User. The use of GPS should not be a requirement for the operation of the GRS.

3. The GRS satellites will produce a secured spread-spectrum signal. Although GPS also uses a spread-spectrum signal the details are publicly available so manufacturers can make and sell the GPS receivers to the general public.

4. The GPS constellation is in orbital planes approximately 20,200 km above the Earth (Medium Earth Orbit or MEO). The GRS constellation should be in Low Earth Orbit (LEO) in the range of 160 km - 2,000 km.

One of the reasons for using LEO is that it is desirable to keep the existence of GRS a secret and it would be difficult to secretly launch and operate a constellation of satellites. Therefore, the GRS function should be hidden in a satellite constellation that has a non-secret mission. A prime candidate is a new satellite system for providing communications with UAVs around the world. For various reasons, communications with UAVs should have low latency, and a LEO system will have lower latency than a MEO system. The military's increasing use of UAVs and need for dedicated low-latency bandwidth justifies a dedicated satellite system using spread spectrum communications. The function of also providing a spread-spectrum signal for bistatic radar does not have to be publicly revealed. The need to have these "communication" satellites always transmitting can be explained as "continuous monitoring of system health." Indeed, there is value for a User to know that the communications system is working and that a channel is available. It reduces POI by avoiding unnecessary transmissions. POI can also be reduced by using a directional antenna for transmitting and aiming it at an available satellite with the lowest POI. For example, the satellite most directly overhead may have the lowest POI in many situations. This presents the opportunity to provide an integrated bistatic spread spectrum radar system using a satellite constellation for the radar function as well as for communications.

[032] It is desirable to have the capability for GRS satellite-to-satellite communications, preferably using optical links.

[033] The following example is for a 2D system which will be expanded later to a 3D system. A satellite constellation is being used, and each satellite transmits a spread spectrum signal and has its own unique code key. The code key may be a PN key or it may be produced by other means. It is assumed that the User is receiving a signal in straight paths from one or more satellites and that there is a straight path from the satellites to the target and from the target to the User and that the range and bearing from the User to each satellite is known. As a result, the length of the path from each satellite reflected from the target is also known.

[034] The distance from each satellite to the User can be known in several ways. One method is to use GPS for the location of the User and for the satellites to broadcast their GPS positions (regardless of how their positions are determined). Another method is for the User to use GPS, an accurate clock, and an ephemeris that gives the locations of satellites for a period of time in advance. Another method is for the User to have an accurate clock and for the satellites to include the time of transmission in their signals. Another method is for the User to send a signal to the appropriate satellite which responds with a signal that the User can use to get the range and bearing to that satellite. Thereafter, Inertial Navigation may be used. This method has the advantage that it does not use GPS but would be limited to those times when radio silence by the User is not necessary. A further method is to build a simplified form of Global Navigation Satellite System (GNSS) into GRS (and kept secret) as a military backup to GPS. It does not have to be as accurate as GPS because its purpose is to sense other aircraft in order to prevent a collision. It is not necessarily for delivering weapons, which has the opposite goal.

[035] When the User receives a reflected signal from the target a cross correlation is performed using the code keys for the satellites in order to determine which satellite the reflected signal is coming from. The use of an ephemeris would allow the User to test only for those satellites that are visible.

Where the User determines the position of the satellite using GPS, an accurate clock, and an ephemeris it is not necessary for the User to receive a direct signal from the satellite, only the reflection from the target.

[036] At this point the User knows the total length of the path from a first satellite to the target and then to the User and wants to know the length of the path from the target to himself. The User also knows the length of the path from the first satellite to himself. Mathematically, this is the definition of an ellipse. The User and the first satellite are at the foci and the target is somewhere on the ellipse.

[037] When a second satellite is added, a second ellipse is formed. The User is at one of the foci, the second satellite is at the other. The first ellipse and the second ellipse intersect at only two points, with the target at one of the points.

[038] When a third satellite is added, a third ellipse is formed. Again, the User is at one of the foci and the third satellite is at the other. The three ellipses intersect at only one point. That is where the target is.

[039] A 3D system is more complicated because the geometric figure produced between each satellite and the User is not a 2D planar ellipse. Picture an ellipse rotating around the axis between the User and the satellite. The figure that each Satellite produces is an ellipsoid (a prolate spheroid) that looks remarkably like a football (U.S. or Canadian).

[040] Satellite 1 produces an ellipsoid with the User at one of the foci and the satellite at the other. The target is somewhere on the surface of the ellipsoid.

[041] When a second satellite is added, a second ellipsoid is formed. The User is at one of the foci, the second satellite is at the other. The first ellipsoid and the second ellipsoid intersect and produce an ellipse. The reason for this is because they share a common focus. [*IDS Cite 26*]

[042] When a third satellite is added, a third ellipsoid is formed. The User is at one of the foci, the third satellite is at the other. The first and second ellipsoids and the third ellipsoid intersect at two points, with the target at one of the two points.

[043] When a fourth satellite is added, a fourth ellipsoid is formed. The User is at one of the foci, the fourth satellite is at the other. The first three ellipsoids and the fourth ellipsoid intersect at only one point. That is where the target is.

[044] The geometry that has been described might not be obvious to someone versed mainly in GPS geometry. GPS uses only three satellites to determine the User's position in three dimensions. (A fourth satellite is used for time correction.) The reason for this difference is because instead of using only the signal received directly from the satellite, the User is receiving both the direct signal and a signal reflected from the target. A line from the target meets the line from the User to the satellite at a 90 degree angle and forms the radius of a circle. The target can be anywhere on that circle. That is why the additional satellite is needed to determine the position of the target.

[045] There is something to note. Not all ellipses that share a focus point will intersect. However, in this case they must intersect because the ellipses were created by reflections from the same target, and the target cannot be in more than one place at the same time.

[046] The issue of multiple targets will now be discussed. A single target will produce four reflections, one from each satellite. A second target will produce four more reflections unless the geometry of the User and the targets causes one or more of the reflections to coincide. This is unlikely, but possible. A third target produces four more reflections, and so on. A User receiving system using a single omni-directional antenna will have to sort out all these reflections and perform the calculations looking for a single possible solution. To provide better results, Doppler analysis of each reflection can be performed so that the various reflected signals can be matched together. The Doppler shift of each reflected signal is a result of the velocity of the target, the velocity of the satellite producing the signal that is reflected, and the velocity of the User. Another solution is for the User system to use directional antennas.

[047] The geometry shows that several system configurations are possible.

1. System 0 – It is not necessary to receive any signals directly from any satellites. Only the signals reflected from the target are needed. The User tries all of the code keys for all the satellites or uses an ephemeris to try only the code keys for the satellites that are in view. A signal that is detected is subjected to the various treatments described in the previous section on detecting spread spectrum radar. It may be possible to use the radio frequency emanations from the Sun and not use any satellites, but only during daytime.
2. System 1 – The direct and reflected signal from only one satellite is used. This detects the presence of the target but its position can be anywhere on an ellipsoid, which is better than nothing. A directional antenna is used to scan those areas corresponding to the surface of the ellipsoid.
3. System 2 – The direct and reflected signals from two satellites are used. This detects the presence of the target and locates its position to an ellipse. A directional antenna is used to scan the ellipse.
4. System 3 - The direct and reflected signals from three satellites are used. This detects the presence of the target and narrows its position down to only two positions. A directional antenna is used to determine which position the target is in.
5. System 4 – The direct and reflected signals from four satellites are used to detect the presence and position of the target. Only a single omni-directional antenna is needed.

[048] Although it is anticipated that the system will use microwave frequencies, the use of lower frequencies would make it possible to detect stealth aircraft. There are tradeoffs involving the frequency used, the resolution that can be achieved, and the ability to detect stealth aircraft. The lower the frequency the lower the resolution. A lower frequency requires either a larger antenna or an antenna of reduced efficiency. However, a lower frequency increases the ability to detect stealth aircraft. Stealth aircraft commonly employ reflecting surfaces and/or microwave-absorbing surface material. As the wavelength becomes longer and approaches the dimensions of the aircraft, the reflecting surfaces no longer produce localized reflections. And there is a frequency below which energy-absorbing material becomes ineffective depending on the specifics of the material.

[049] In view of the foregoing, a tenth preferred embodiment for sensing aircraft and other objects uses bistatic radar with a spread spectrum signal transmitted from remotely located sources. In an eleventh preferred embodiment an integrated bistatic spread spectrum radar system uses a satellite constellation for the radar function as well as for communications.

[050] In a twelfth preferred embodiment the satellite constellation described above can also be used for long baseline radar interferometry in order to validate the digital terrain elevation database. The distance between satellites provides for a long baseline and the use of multiple satellites simultaneously improves the accuracy of the terrain measurements.

BRIEF DESCRIPTION OF THE DRAWINGS

[051] The invention may best be understood by referring to the following description and accompanying drawings which illustrate the invention. In the drawings:

[052] FIG. 1 is a general illustration showing a TCAS system used as a radar, using standard TCAS antennas.

[053] FIG. 2 is a general illustration showing a TCAS system used as a radar, using a separate directional receiving antenna.

[054] FIG. 3 is a general illustration showing an ADS-B system used as a radar, using omni-directional antennas.

[055] FIG. 4 is a general illustration showing an ADS-B system used as a radar, using a separate directional receiving antenna.

[056] FIG. 5 is a general illustration showing an ADS-B system used as a radar, using a separate directional receiving antenna and a separate receiver.

[057] FIG. 6 is a general illustration showing a method for detecting spread spectrum radar and determining its bearing, using two omni-directional antennas.

[058] FIG. 7 is a general illustration showing why there is a "hemisphere problem" in Radio Direction Finding with two omni-directional antennas.

[059] FIG. 8 is a general illustration showing the addition of an additional antenna to solve the "hemisphere problem" in Radio Direction Finding.

[060] FIG. 9 is a general illustration showing a method for detecting spread spectrum radar, using two pairs of spatially separated omni-directional antennas.

[061] FIG. 10 is a general illustration showing a method for detecting spread spectrum radar, using two co-located directional antennas.

[062] FIG. 11 is a general illustration showing a method for detecting spread spectrum radar and determining its range and bearing, using two spatially separated directional antennas.

[063] FIG. 12 is a general illustration showing a method for detecting spread spectrum radar and determining its range and bearing, using two spatially separated pairs of co-located directional antennas.

[064] FIG. 13 is a general illustration showing a spread spectrum bistatic radar using a satellite constellation as the radar transmitters.

[065] FIG. 14 is a general illustration showing the User equipment suitable for use in a spread spectrum radar using a satellite constellation as the radar transmitters and an omni-directional receive antenna.

[066] FIG. 15 is a general illustration showing another form of User equipment suitable for use in a spread spectrum radar using a satellite constellation as the radar transmitters and an omni-directional receive antenna.

[067] FIG. 16 is a general illustration showing the User equipment suitable for use in a spread spectrum radar system using a satellite constellation as the radar transmitters, a directional receive antenna, and an omni-directional receive antenna.

[068] FIG. 17 is a general illustration showing another form of User equipment suitable for use in a spread spectrum radar system using a satellite constellation as the radar transmitters, a directional receive antenna, and an omni-directional receive antenna.

[069] FIG. 18 is a general illustration showing an integrated bistatic spread spectrum radar system using a satellite constellation for the radar function as well as for communications.

[070] FIG. 19 is a general illustration showing the geometry of a bistatic radar.

[071] FIG. 20 is a general illustration showing that the geometry of a bistatic radar describes an ellipse.

[072] FIG. 21 is a general illustration showing the geometry of an ellipse.

[073] FIG. 22 is a general illustration further showing the geometry of an ellipse.

[074] FIG. 23 is a general illustration further showing the geometry of an ellipse.

[075] FIG. 24 is a general illustration showing a receiver and a first satellite at the foci of a first ellipse.

[076] FIG. 25 is a general illustration showing a receiver and a first satellite at the foci of a first ellipse and the receiver and a second satellite at the foci of a second ellipse.

[077] FIG. 26 is a general illustration showing a receiver and a first satellite at the foci of a first ellipse, the receiver and a second satellite at the foci of a second ellipse, and the receiver and a third satellite at the foci of a third ellipse.

[078] FIG. 27 is a general illustration showing an ellipse that does not intersect another ellipse even though they share a focus.

[079] FIG. 28 is a general illustration showing an ellipse that intersects another ellipse at only one point even though they share a focus.

[080] FIG. 29 is a general illustration showing an ellipsoid.

[081] FIG. 30 is a general illustration showing a cross section of the longitudinal axis of the ellipsoid shown in Fig. 29.

[082] FIG. 31 is a general illustration also showing two ellipsoids with a common focus, meeting end-to-end.

[083] FIG. 32 is a general illustration of two ellipsoids with a common focus, meeting at a first arbitrary angle.

[084] FIG. 33 is a general illustration of two ellipsoids with a common focus, meeting at a second arbitrary angle.

DETAILED DESCRIPTION

[085] In the following description, numerous specific details are set forth to provide a thorough understanding of the invention. However, it is understood that the invention may be practiced without these specific details. In other instances well-known circuits, structures, and techniques have not been shown in detail in order not to obscure the invention.

[086] Figure 1 is a general illustration showing a TCAS system used as a radar, using standard TCAS antennas. TCAS Interrogation Receiver 106 listens for Interrogation signals from other aircraft. When it receives one, TCAS Transponder Transmitter 107 sends out a signal containing the unique ID number of the aircraft and its altitude. TCAS Interrogation Transmitter 105 periodically (and randomly) sends out an Interrogation signal that other TCAS-equipped aircraft respond to. These transponder responses are received by TCAS Transponder Receiver 108. There are at least two antennas: Omni-Directional Antenna 101 and Directional Antenna 102 which is under the control of Antenna Controller 103. Directional Antenna 102 and Antenna Controller 103 may be in the form of several directional antennas which may be selected in turn or used simultaneously. Antenna Diplexer 104 is used to select and/or combine Omni-Directional Antenna 101 and Directional Antenna 102 and route the signals (receiving and transmitting) to the appropriate piece of equipment. The preceding operations are under the control of TCAS Processor 109. The time delay between when the TCAS Interrogation signal is sent out by TCAS Interrogation Transmitter 105 and when a transponder signal from other aircraft is received by TCA Transponder Receiver 108 is used to determine the range to the responding aircraft.

TCAS operation is improved by using the signal produced by TCAS Interrogation Transmitter 105 as a radar with reflected signals received by TCAS Interrogation Receiver 106 under the control of TCAS Processor 109 and Radar Processor 110. The results are displayed on Display 111.

If the number and range of targets reported by radar do not match the number and range of aircraft reported by TCAS then there is an aircraft out there that does not have TCAS or it is broken or has been disabled.

[087] In Figure 2, a separate directional antenna (Antenna 201) is used to receive the reflected signals. The advantage of using a separate antenna for this function is that it can be made to be more directional than the standard Directional Antenna 102 used by TCAS. Directional Antenna 201 is controlled by Antenna Controller 202 under the direction of Radar Processor 210 which also controls the radar function through TCAS Processor 109. Antenna Diplexer 204 is used to select and/or combine Omni-Directional Antenna 101, Directional Antenna 102, and Directional Antenna 201 and route the signals (receiving and transmitting) to the appropriate piece of equipment. Directional Antenna 201 and Antenna Controller 202 may be a system that mechanically aims Directional Antenna 201 or the combination may be an electronically scanned array.

The results are displayed on Display 211.

If the number, range, and bearing to targets reported by radar do not match the number, range, and bearing of aircraft reported by TCAS then there is an aircraft out there that does not have TCAS or it is broken or has been disabled.

[088] Figure 3 is a general illustration showing an ADS-B system used as a radar, using omni-directional antennas. ADS-B Transmitter 303 periodically transmits a message containing the present aircraft's unique ID, GPS coordinates, and other data using Omni-Directional antenna 301. When ADS-B Transmitter 303 is not transmitting, ADS-B Receiver 304 is listening for messages transmitted by other aircraft containing their unique ID, GPS coordinates, and other data. An Antenna Multiplexer (Antenna Mux 302) is used to route the signals from Omni-Directional Antenna 301 to ADS-B Transmitter 303 and ADS-B Receiver 304. Omni-Directional Antenna 306 is used with GPS Receiver 307 to provide the GPS coordinates of the present aircraft. All of this is controlled by ADS-B Processor 305.

ADS-B operation is improved by using the signal produced by ADS-B Transmitter 303 as a radar with reflected signals received by ADS-B Receiver 304 under the control of ADS-B Processor 305 and Radar Processor 308. The results are displayed on Display 309.

If the number and range of targets reported by radar do not match the number and range of aircraft reported by ADS-B then there is an aircraft out there that does not have ADS-B or it is broken or has been disabled.

[089] In Figure 4, a separate directional antenna (Directional Antenna 401) is selected by Antenna Mux 405 to receive the reflected signals. The advantage of using a separate antenna for this function is that it is directional, as opposed to Omni-Directional Antenna 301.

Directional Antenna 401 can also be used by ADS-B Transmitter 303 in order to strengthen radar returns from a specific target or to increase the range of the system in a specific direction.

Directional Antenna 401 is controlled by Antenna Controller 402 under the direction of Radar Processor 403 which also controls the radar function through ADS-B Processor 305. Directional Antenna 401 and Antenna Controller 402 may be a system that mechanically aims Directional Antenna 401 or the combination may be an electronically scanned array.

The results are displayed on Display 404.

In Figure 5, as an alternative to sharing ADS-B Receiver 304, Directional Antenna 401 can be used with its own receiver. Antenna Mux 501 routes Directional Antenna 401 to Receiver 502 whose output goes to ADS-B Processor 503 to make it possible to receive and process radar returns without the risk of missing ADS-B messages from other aircraft.

If the number, range, and bearing of targets reported by radar do not match the number, range, and bearing of aircraft reported by ADS-B then there is an aircraft out there that does not have ADS-B or it is broken or has been disabled.

[090] Figure 6 is a general illustration showing a method for detecting spread spectrum radar and determining its bearing using two receiving systems with omni-directional antennas. Omni-Directional Antenna 601 and Receiver 602 make up the first receiving system. Omni-Directional Antenna 603 and Receiver 604 make up the second receiving system. The data from Receiver 602 is stored in Data Buffer 605. The data from Receiver 604 is stored in Data Buffer 606. The data in Data Buffer 605 and Data Buffer 606 are used by Cross-Correlator 607 under control of System Controller 608. The results are displayed on Display 609.

The noise produced by each receiver system is completely independent of each other so the internally generated noise is uncorrelated. If there is a correlation between the data frames from two receiver systems it can only have come from an external source, such as a spread spectrum signal. The phase term (time delay) in the cross-correlation function is used to determine the bearing to the target subject to the "Hemisphere Problem" which occurs because a target on either side of the line between the two antennas produces the same time delay, and therefore the same angle. Referring to Figure 7, Antenna 701 and Antenna 702 both receive Signal 703 from a target. Antenna 702 receives Signal 703 later than Antenna 701. Time translates to distance dt 704 which produces Angle 705. However, Antenna 702 could also receive Signal 706 from a target later than Antenna 701 and with the same delay. Distance dt 707 is the same as distance dt 704 so that Angle 708 is the same as Angle 705.

In Figure 8 a third receiving system is added with Antenna 801 that is not collinear with Antenna 701 and Antenna 702. Signal 703 takes longer to arrive at Antenna 801 than does Signal 706 (distance dt 803 versus distance dt 802). The time delay of the signal received by Antenna 801 is compared to the two calculated values based on the geometry of Antennas 701, 702, and 801. Thus, it is determined whether the signal is Signal 703 or Signal 706.

[091] Figure 9 is a general illustration showing a method for detecting spread spectrum radar, using two pairs of receiving systems where the omni-directional antennas used in each receiving system are spatially separated and the two pairs of receiving systems are spatially separated from each other.

In the first pair of the receiving systems Omni-Directional Antenna 901 and Receiver 902 produce a first signal. The output of Receiver 902 is stored in Data Buffer 905. Omni-Directional Antenna 903 and Receiver 904 produce a second signal. The output of Receiver 904 is stored in Data Buffer 906. The data in Data Buffer 905 and Data Buffer 906 are used by Cross-Correlator 907 which performs a cross-correlation of the signals produced by Receiver 902 and Receiver 904. The noise produced by each receiver system is completely independent of each other so the internally generated noise is uncorrelated. If there is a correlation between the data frames from the two receiver systems it can only have come from an external source, such as a spread spectrum signal. The phase term (time delay) in the cross-correlation function is used to determine a first bearing to the target.

In the second pair of the receiving systems Omni-Directional Antenna 908 and Receiver 909 produce a third signal. Omni-Directional Antenna 910 and Receiver 911 produce a fourth signal. The output of Receiver 909 is stored in Data Buffer 912. The output of Receiver 911 is stored in Data Buffer 913. The data in Data Buffer 912 and Data Buffer 913 are used by Cross-Correlator 914 which performs a cross-correlation of the signals produced by Receiver 909 and Receiver 911. The noise produced by each receiver system is completely independent of each other so the internally generated noise is uncorrelated. If there is a correlation between the data frames from the two receiver systems it can only have come from an external source, such as a spread spectrum signal. The phase term (time delay) in the cross-correlation function is used to determine a second bearing to the target.

System Controller 915 controls the operation of Cross-Correlator 907 and Cross-Correlator 914. It may also control the operation of Receivers 902, 904, 909, and 911.

The distance between the first pair of receiving systems and the second pair of receiving systems is known. The first bearing to the target is determined using the first pair of receiving systems. The second bearing to the target is determined using the second pair of receiving systems. The distance and range to the target are determined using triangulation. The results are displayed on Display 916.

[092] Figure 10 is a general illustration showing a method for detecting spread spectrum radar using two co-located directional antennas. Directional Antenna 1001 and Receiver 1003 make up the first receiving system. The direction of Directional Antenna 1001 is controlled by Antenna Controller 1002. Directional Antenna 1004 and Receiver 1006 make up the second receiving system. The direction of Directional Antenna 1004 is controlled by Antenna Controller 1005. The data output of Receiver 1003 is stored in Data Buffer 1007. The output of Receiver 1006 is stored in Data Buffer 1008. The data in Data Buffer 1007 and Data Buffer 1008 are used by Cross-Correlator 1009 under control of System Controller 1010 which also controls Antenna Controller 1002 and Antenna Controller 1005.

The noise produced by each receiver system is completely independent of each other so the internally generated noise is uncorrelated. If there is a correlation between the data frames from two receiver systems it can only have come from an external source, such as a spread spectrum signal.

Because directional antennas are used, the phase term (time delay) in the cross-correlation function cannot be used to determine the bearing to the target. Directional Antenna 1001 and Directional Antenna 1004 are controlled so they always point in the same direction. The bearing to the target is determined from the direction the antennas are pointing.

Directional Antenna 1001 and Antenna Controller 1002 may be a system that mechanically aims Directional Antenna 1001 or the combination may be an electronically scanned array.

Likewise, Directional Antenna 1004 and Antenna Controller 1005 may be a system that mechanically aims Directional Antenna 1004 or the combination may be an electronically scanned array.

The results are displayed on Display 1011.

[093] Figure 11 is a general illustration showing a method for detecting spread spectrum radar and determining its range and bearing using two spatially separated directional antennas. Directional Antenna 1001 and Receiver 1003 make up the first receiving system. The direction of Directional Antenna 1001 is controlled by Antenna Controller 1002. Directional Antenna 1004 and Receiver 1006 make up the second receiving system. The direction of Directional Antenna 1004 is controlled by Antenna Controller 1005. The output of Receiver 1003 is stored in Data Buffer 1007. The output of Receiver 1006 is stored in Data Buffer 1008. The data in Data Buffer 1007 and Data Buffer 1008 are used by Cross-Correlator 1009 under control of System Controller 1110 which also controls Antenna Controller 1002 and Antenna Controller 1005.

The noise produced by each receiver system is completely independent of each other so the internally generated noise is uncorrelated. If there is a correlation between the data frames from two receiver systems it can only have come from an external source, such as a spread spectrum signal.

Because directional antennas are used, the phase term (time delay) in the cross-correlation function cannot be used to determine the bearing to the target. Directional Antenna 1001 and Directional Antenna 1004 are spatially separate from each other. When a source of correlated noise is found the bearing of Directional Antenna 1001 and the bearing of Directional Antenna 1004 are used, along with the distance between, to triangulate the position and bearing to the external source of correlated noise, namely the target.

Directional Antenna 1001 and Antenna Controller 1002 may be a system that mechanically aims Directional Antenna 1001 or the combination may be an electronically scanned array.

Likewise, Directional Antenna 1004 and Antenna Controller 1005 may be a system that mechanically aims Directional Antenna 1004 or the combination may be an electronically scanned array.

The results are displayed on Display 1111.

[094] Figure 12 is a general illustration showing a method for detecting spread spectrum radar and determining its range and bearing, using two spatially separated pairs of co-located directional antennas.

The first pair of co-located directional antennas are Directional Antenna 1201 and Directional Antenna 1204. Directional Antenna 1201 and Receiver 1203 make up the first receiving system of the pair. The output of Receiver 1203 is stored in Data Buffer 1213. The direction of Directional Antenna 1201 is controlled by Antenna Controller 1202. Directional Antenna 1204 and Receiver 1206 make up the second receiving system of the pair. The output of Receiver 1206 is stored in Data Buffer 1214. The direction of Directional Antenna 1204 is controlled by Antenna Controller 1205. The data in Data Buffer 1213 and Data Buffer 1214 are used by Cross-Correlator 1215 under control of System Controller 1219 which also controls Antenna Controller 1202 and Antenna Controller 1205.

The noise produced by each receiver system is completely independent of each other so the internally generated noise is uncorrelated. If there is a correlation between the data frames from two receiver systems it can only have come from an external source, such as a spread spectrum signal.

Because directional antennas are used, the phase term (time delay) in the cross-correlation function cannot be used to determine the bearing to the target. Directional Antenna 1201 and Directional Antenna 1204 are controlled so they always point in the same direction. The first bearing to the target is determined from the direction the antennas are pointing.

The second pair of co-located directional antennas are Directional Antenna 1207 and Directional Antenna 1210. Directional Antenna 1207 and Receiver 1209 make up the first receiving system of the pair. The output of Receiver 1209 is stored in Data Buffer 1216. The direction of Directional Antenna 1207 is controlled by Antenna Controller 1208. Directional Antenna 1210 and Receiver 1212 make up the second receiving system of the pair. The output of Receiver 1212 is stored in Data Buffer 1217. The direction of Directional Antenna 1210 is controlled by Antenna Controller 1211. The data in Data Buffer 1216 and Data Buffer 1217 are used by Cross-Correlator 1218 under control of System Controller 1219 which also controls Antenna Controller 1208 and Antenna Controller 1211. The noise produced by each receiver system is completely independent of each other so the internally generated noise is uncorrelated. If there is a correlation between the data frames from two receiver systems it can only have come from an external source, such as a spread spectrum signal.

Because directional antennas are used, the phase term (time delay) in the cross-correlation function cannot be used to determine the bearing to the target. Directional Antenna 1207 and Directional Antenna 1210 are controlled so they always point in the same direction. The second bearing to the target is determined from the direction the antennas are pointing.

When a source of correlated noise is found by the first pair of co-located directional antennas the second pair of co-located directional antennas is brought to bear until it also finds the target. The first bearing to the target and the second bearing to the target, along with the distance between the first pair of co-located directional antennas and the second pair of co-located directional antennas, is used to triangulate the position and bearing to the external source of correlated noise, namely the target.

Conversely, when a source of correlated noise is found by the second pair of co-located directional antennas the first pair of co-located directional antennas is brought to bear until it also finds the target. The first bearing to the target and the second bearing to the target, along with the distance between the first pair of co-located directional antennas and the second pair of co-located directional antennas, is used to triangulate the position and bearing to the external source of correlated noise, namely the target.

Directional Antenna 1201 and Antenna Controller 1202 may be a system that mechanically aims Directional Antenna 1201 or the combination may be an electronically scanned array.

Directional Antenna 1204 and Antenna Controller 1205 may be a system that mechanically aims Directional Antenna 1204 or the combination may be an electronically scanned array.

Directional Antenna 1207 and Antenna Controller 1208 may be a system that mechanically aims Directional Antenna 1207 or the combination may be an electronically scanned array.

Directional Antenna 1210 and Antenna Controller 1211 may be a system that mechanically aims Directional Antenna 1210 or the combination may be an electronically scanned array.

The results are displayed on Display 1220.

[095] Figure 13 is a general illustration showing a spread spectrum bistatic radar using a satellite constellation as the radar transmitters. Satellites 1302, 1303, 1304, and 1305 transmit a spread spectrum signal, each having a unique code key. The signal from each satellite is received in a direct path by User 1301. The signal from each satellite is also reflected by Target 1306 and received by User 1301. User 1301 determines his own position and the positions of Satellites 1302, 1303, 1304, and 1305. User 1301 determines the length of the direct path to the satellites and the total length of the signal path from each satellite reflected by Target 1306. By performing the appropriate mathematical calculations User 1301 determines the absolute position of Target 1306.

Alternatively, User 1301 determines the positions of Satellites 1302, 1303, 1304, and 1305 relative to himself. User 1301 determines the length of the direct path to the satellites and the total length of each signal path from each satellite reflected by Target 1306. By using the appropriate mathematical calculations User 1301 determines the relative position of Target 1306.

[096] Figure 14 is a general illustration showing the User equipment suitable for use by spread spectrum radar using a satellite constellation as the radar transmitters. Omni-Directional Antenna 1401 receives the signals transmitted directly from Satellites 1302, 1303, 1304, and 1305 (Figure 13) as well as the satellite signals reflected by Target 1306 (also Figure 13). Omni-Directional Antenna 1401 sends these signals to Receiver 1402. The output of Receiver 1402 is stored in Data Buffer 1403. Under the control of System Controller 1406, Correlator 1404 performs correlations between the data stored in Data Buffer 1403 and a List of Code Keys 1405 which correspond to the Code Keys used by the satellites in the satellite constellation. System Controller 1406 also determines the length of the direct path from each satellite, the length of the path from each satellite reflected by Target 1306 (Figure 13) and performs the calculations to determine the range and bearing to Target 1306. The results are displayed on Display 1407.

[097] Figure 15 is a general illustration showing another form of User equipment suitable for use by spread spectrum radar using a satellite constellation as the radar transmitters. Omni-Directional Antenna 1401 receives the signals transmitted directly from Satellites 1302, 1303, 1304, and 1305 (Figure 13) as well as the satellite signals reflected by Target 1306 (also Figure 13). Omni-Directional Antenna 1401 sends these signals to Receiver 1402. The output of Receiver 1402 is stored in Data Buffer 1403. Under the control of System Controller 1506, Correlator 1404 performs correlations between the data stored in Data Buffer 1403 and a List of Code Keys 1405 which correspond to the Code Keys used by the satellites in the satellite constellation. System Controller 1506 uses GPS Receiver 1507 to determine the User's position. System Controller 1506 also determines the length of the direct path from each satellite, the length of the path from each satellite reflected by Target 1306 (Figure 13) and performs the calculations to determine the range and bearing to Target 1306. The results are displayed on Display 1508.

[098] Figure 16 is a general illustration showing the User equipment suitable for use by spread spectrum radar using a satellite constellation as the radar transmitters. Directional Antenna 1601 receives the signals reflected by Target 1306 (Figure 13) from Satellites 1302, 1303, 1304, and 1305 (Figure 13). Directional Antenna 1601 sends these signals to Receiver 1603. The output of Receiver 1603 is stored in Data Buffer 1604. Under the control of System Controller 1611, Correlator 1605 performs correlations between the data stored in Data Buffer 1604 and a list of Code Keys 1610 which correspond to the Code Keys used by the satellites in the satellite constellation. System Controller 1611 also controls the direction of Directional Antenna 1601 using Antenna Controller 1602.

Omni-Directional Antenna 1606 receives the signals directly sent by Satellites 1302, 1303, 1304, and 1305 (Figure 13). Omni-Directional Antenna 1606 sends these signals to Receiver 1607. The output of Receiver 1607 is stored in Data Buffer 1608. Under the control of System Controller 1611, Correlator 1609 performs correlations between the data stored in Data Buffer 1608 and a List of Code Keys 1610 which correspond to the Code Keys used by the satellites in the satellite constellation. System Controller 1611 also determines the length of the direct path from each satellite and performs the calculations to determine the range and bearing to Target 1306.

Directional Antenna 1601 and Antenna Controller 1602 may be a system that mechanically aims Directional Antenna 1601 or the combination may be an electronically scanned array.

The results are displayed on Display 1612.

[099] Figure 17 is a general illustration showing another form of User equipment suitable for use by spread spectrum radar using a satellite constellation as the radar transmitters. Directional Antenna 1601 receives the signals reflected by Target 1306 (Figure 13) from Satellites 1302, 1303, 1304, and 1305 (Figure 13). Directional Antenna 1601 sends these signals to Receiver 1603. The output of Receiver 1603 is stored in Data Buffer 1604. Under the control of System Controller 1711, Correlator 1605 performs correlations between the data stored in Data Buffer 1604 and a List of Code Keys 1610 which correspond to the Code Keys used by the satellites in the satellite constellation. System Controller 1711 also controls the direction of Directional Antenna 1601 using Antenna Controller 1602.

Omni-Directional Antenna 1606 receives the signals directly sent by Satellites 1302, 1303, 1304, and 1305 (Figure 13). Omni-Directional Antenna 1606 sends these signals to Receiver 1607. The output of Receiver 1607 is stored in Data Buffer 1608. Under the control of System Controller 1711, Correlator 1609 performs correlations between the data stored in Data Buffer 1608 and a List of Code Keys 1610 which correspond to the Code Keys used by the satellites in the satellite constellation. System Controller 1711 also uses GPS Receiver 1712 to determine the length of the direct path from each satellite and performs the calculations to determine the range and bearing to Target 1306.

Directional Antenna 1601 and Antenna Controller 1602 may be a system that mechanically aims Directional Antenna 1601 or the combination may be an electronically scanned array.

The results are displayed on Display 1713.

[100] Figure 18 is a general illustration showing an integrated bistatic spread spectrum radar system using a satellite constellation as the radar as well as for communications. Omni-Directional Antenna 1801 receives the signals transmitted directly from Satellites 1302, 1303, 1304, and 1305 (Figure 13) which contain the communications signals which are also used for bistatic radar. The signals from Omni-Directional Antenna 1801 are sent to Receiver 1802. The output of Receiver 1802 is stored in Data Buffer 1803. Under the control of System Controller 1813, Correlator 1804 performs correlations between the data stored in Data Buffer 1803 and the List of Code Keys 1814 used by the satellites in the satellite constellation shown in Figure 13.

System Controller 1813 uses List of Code Keys 1814 to create a spread spectrum signal and transmits it to the satellites using Transmitter 1807 and Directional Antenna 1805. System

Controller 1813 controls the direction of Directional Antenna 1805 using Antenna Controller 1806.

Directional Antenna 1808 is used to receive the satellite signals reflected by Target 1306 (Figure 13). Directional Antenna 1808 sends these signals to Receiver 1810. The output of Receiver 1810 is stored in Data Buffer 1811. Under the control of System Controller 1813, Correlator 1812 performs correlations between the data stored in Data Buffer 1811 and a List of Code Keys 1814 which correspond to the Code Keys used by the satellites in the satellite constellation. System Controller 1813 determines the length of the direct path from each satellite, the length of the path from each satellite reflected by Target 1306 (Figure 13) and performs the calculations to determine the range and bearing to Target 1306. The use of GPS Receiver 1815 in determining the User's position is optional. System Controller 1813 controls the direction of Directional Antenna 1808 using Antenna Controller 1809.

Directional Antenna 1805 and Antenna Controller 1806 may be a system that mechanically aims Directional Antenna 1805 or the combination may be an electronically scanned array.

Directional Antenna 1808 and Antenna Controller 1809 may be a system that mechanically aims Directional Antenna 1808 or the combination may be an electronically scanned array.

The results are displayed on Display 1816.

Geometry

[101] The geometry of a bistatic radar will be discussed, starting with a 2D system which will then be expanded to a 3D system.

Referring to Figure 19, **Receiver 1901** receives a signal directly from **Transmitter 1902** through **Path L 1904**. **Receiver 1901** also receives a signal from **Transmitter 1902** reflected off of **Target 1903** through **Path r1 1905** and **Path r2 1906**.

Receiver 1901 only knows the sum of **Path r1 1905** and **Path r2 1906**. The locus of all points of a plane whose distances to two fixed points add to the same constant is an ellipse. As a result, as shown in Figure 20, **Receiver 1901** only knows that **Target 1903** is somewhere on **Ellipse 2007**. **Receiver 1901** and **Transmitter 1902** are located at the two foci of **Ellipse 2007**.

In the following discussion, the labels are emboldened and omit the drawing figure numbers in order to avoid an unmanageable clutter.

Figure 21 shows an ellipse in standard form. The foci are at **f1** and **f2**. The semi-major axis is **a**. (The major axis is 2 * **a**) The semi-minor axis is **b**. (The minor axis is 2 * **b**)

The two foci are equidistant from the **Y** axis, and are separated by distance **L**.

The sum of **r1** and **r2** is constant so that Point **P** traces out the ellipse.

The parametric equation for an ellipse is:

$$\frac{x^2}{a^2} + \frac{y^2}{b^2} = 1$$

Note that if **a** = **b**:

$$\frac{x^2}{a^2} + \frac{y^2}{a^2} = 1$$

$$\frac{x^2 + y^2}{a^2} = 1$$

$$x^2 + y^2 = a^2$$

If we rename **a** and call it **r**, most engineers will recognize this as the parametric equation for a circle.

$$x^2 + y^2 = r^2$$

An ellipse is also a simple form of Lissajous Figure where:

$x = R * \sin(2\pi t)$ and $y = R * \sin(2\pi t + \delta)$

For more on Lissajous Figures see *IDS Cite 27.*

The ellipse data produced by the present system will be **L** and the sum of **r1** and **r2**. **L** is the distance between the foci **f1** and **f2**. Another way of putting it is that **f1** = -**f2** = **L**/2. We want to determine the semi-major axis (**a**) and the semi-minor axis (**b**).

In Figure 22, Point **P** has been moved to (**a**,0). **r1** and **r2** are not shown because they lie on the **X** axis.

The distance from **f1** to (**a**,0) and from (**a**,0) to **f2** is the sum of **r1** and **r2** because that is the definition of an ellipse.

The distance from **f1** to **f2** is **L**. The distance from **f2** to (**a**,0) is **d**. The distance from (**a**,0) back to **f2** is, again, **d**.

$$r1 + r2 = L + d + d$$

$$2 * d = r1 + r2 - L$$

$$d = (r1 + r2 - L)/2 = (r1 + r2)/2 - L/2$$

Therefore:

$$a = L/2 + d$$

$$= L/2 + (r1 + r2)/2 - L/2$$

$$= (r1 + r2)/2$$

Now that we have found the semi-major axis **a**, let's find the semi-minor axis **b**. Referring to Figure 23, when **P** is located at (0,**b**) the sum of **r1** + **r2** is divided into two equal parts and forms two right triangles with the Origin (0,0) and the foci. Note that in this case **r1** = **r2** and the line from **P** to each focal point is the same length as the semi-major axis (**r1** + **r2**)/2.

$$\mathbf{b^2 = \left(\frac{(r1 + r2)}{2}\right)^2 - \left(\frac{L}{2}\right)^2}$$

$$\mathbf{b = \sqrt{\left(\frac{(r1 + r2)}{2}\right)^2 - \left(\frac{L}{2}\right)^2}}$$

Therefore, since the present system measures (**r1** + **r2**) and measures (or calculates) **L** we can calculate **a** and **b** and with that we can calculate any point on the ellipse.

$$\mathbf{\frac{x^2}{a^2} + \frac{y^2}{b^2} = 1}$$

where:

$$a = (r1 + r2)/2$$

$$\mathbf{b} = \sqrt{\left(\frac{\mathbf{(r1 + r2)}}{\mathbf{2}}\right)^{\mathbf{2}} - \left(\frac{\mathbf{L}}{\mathbf{2}}\right)^{\mathbf{2}}}$$

[102] The general ellipsoid, also called a triaxial ellipsoid, is a quadratic surface which is given in Cartesian coordinates by the parametric equation:

$$\frac{x^2}{a^2} + \frac{y^2}{b^2} + \frac{z^2}{c^2} = 1$$

Note that if **a** = **b** = **c**:

$$\frac{x^2}{a^2} + \frac{y^2}{a^2} + \frac{z^2}{a^2} = 1$$

$$\frac{x^2 + y^2 + z^2}{a^2} = 1$$

$$x^2 + y^2 + z^2 = a^2$$

If we rename **a** and call it **r**, most engineers will recognize this as the parametric equation for a sphere.

$$x^2 + y^2 + z^2 = r^2$$

In the current ellipsoid:

$$\frac{x^2}{a^2} + \frac{y^2}{b^2} + \frac{z^2}{c^2} = 1$$

c = **b** because the target is on the radius of a circle around the axis formed by the two foci. To be precise, this makes our ellipsoid a spheroid and since it is likely that the target will be much closer than any of the satellites **a** will be larger than **b**, making it a prolate spheroid.

In the current ellipsoid:

$$\frac{x^2}{a^2} + \frac{y^2}{b^2} + \frac{z^2}{b^2} = 1$$

$$\frac{x^2}{a^2} + \frac{y^2 + z^2}{b^2} = 1$$

[103] When two ellipsoids having a common focus intersect they produce an ellipse. Figure 31 is a general illustration showing two ellipsoids with a common focus, meeting end-to-end, producing a circle seen edge-on. Figure 31, Figure 32, and Figure 33 were produced by a computer program that modeled an ellipsoid as a segmented prolate spheroid, i.e. a number of circles around a major axis. The radii of the circles vary according to the curve of an ellipse. Projection is orthonormal. In Figure 32 the two ellipsoids are meeting at a first arbitrary angle. In Figure 33 the two ellipsoids meet at a second arbitrary angle. By inspection it appears that the smaller the angle between the ellipsoids the larger the intersection ellipse. The implication of this is that the closer together the satellites are, the larger the ellipse of intersection becomes. As the satellites become farther apart, the ellipse of intersection becomes smaller.

[104] Starting with the first satellite in Figure 13 (but in 2D) the User knows the total length of the path from a first satellite to the target and then to the User and wants to know the length of the path from the target to himself. The User also knows the length of the path from the first satellite to himself. Mathematically, this is the definition of an ellipse. The User and the first satellite are at the foci and the target is somewhere on the ellipse. See Figure 24.

[105] When a second satellite is added, a second ellipse is formed. The User is at one of the foci, the second satellite is at the other. The first ellipse and the second ellipse intersect at only two points, with the target at one of the two points. See Figure 25.

[106] When a third satellite is added, a third ellipse is formed. Again, the User is at one of the foci and the third satellite is at the other. The three ellipses intersect at only one point. That is where the target is. See Figure 26.

[107] There is something to note. Not all ellipses that share a focus point will intersect. See Figure 27. However, in the present case they must intersect because the ellipses were created by reflections from the same target, and the target cannot be in more than one place at the same time. It is possible that two ellipses that share a focus point will intersect at only one point, but that is a special case. See Figure 28.

[108] A 3D system is more complicated because the geometric figure produced between each satellite and the User is not a 2D planar ellipse. Picture an ellipse rotating around the axis between the User and the satellite. The figure that each Satellite produces is an ellipsoid, more specifically, a prolate spheroid, that looks remarkably like a football (U.S. or Canadian). See Figure 29. That is because a line from the target meets the line from the User to the satellite at a 90 degree angle and forms the radius of a circle. See Figure 30. The target can be anywhere on that circle which means it can be anywhere on the surface of the ellipsoid.

[109] Referring to Figure 13, Satellite 1302 produces an ellipsoid with the User at one foci and the satellite at the other. The target is somewhere on the surface of the ellipsoid.

[110] When a second satellite (Satellite 1303) is added, a second ellipsoid is formed. The User is at one of the foci, the second satellite is at the other. The first ellipsoid and the second ellipsoid intersect and produce an ellipse. The reason the ellipsoids produce an ellipse is because they share a common focus. [*IDS Cite 26*]

[111] When a third satellite (Satellite 1304) is added, a third ellipsoid is formed. The User is at one of the foci, the third satellite is at the other. The first and second ellipsoids and the third ellipsoid intersect with the target at one of two points.

[112] When a fourth satellite (Satellite 1305) is added, a fourth ellipsoid is formed. The User is at one of the foci, the fourth satellite is at the other. The first three ellipsoids and the fourth ellipsoid intersect at only one point. That is where the target is.

[113] The geometry that has been described might not be obvious to someone versed mainly in GPS geometry. GPS uses only three satellites to determine the User's position in three dimensions. (A fourth satellite is used for time correction.) The reason for this difference is because instead of using only the signal received directly from the satellite, the User is receiving both the direct signal and a signal reflected from the target. A line from the target meets the line from the User to the satellite at a 90 degree angle and forms the radius of a circle. The target can be anywhere on that circle. That is why the additional satellite is needed to determine the position of the target.

[114] The geometry shows that several system configurations are possible.

1. System 0 – It is not necessary to receive any signals directly from any satellites. Only the signals reflected from the target are needed. The User tries all of the code keys for all the satellites or uses an ephemeris to try only the codes for the satellites that are in view. A signal that is detected is subjected to the various treatments described in the previous section on detecting spread spectrum radar. It may be possible to use the radio frequency emanations from the Sun and not use any satellites, but only during daytime.
2. System 1 – The direct and reflected signal from only one satellite is used. This detects the presence of the target but its position can be anywhere on an ellipsoid, which is better than nothing. A directional antenna is used to scan those areas corresponding to the surface of the ellipsoid.
3. System 2 – The direct and reflected signals from two satellites are used. This detects the presence of the target and locates its position to the area of a planar ellipse. A directional antenna is used to scan those areas corresponding the surface of the ellipse.

4. System 3 - The direct and reflected signals from three satellites are used. This detects the presence of the target and narrows its position down to only two positions. A directional antenna is used to determine which position the target is in.
5. System 4 – The direct and reflected signals from four satellites are used to detect the presence and position of the target. Only a single omni-directional antenna is needed.

[115] While preferred embodiments of the present invention have been shown, it is to be expressly understood that modifications and changes may be made thereto.

CLAIMS

I claim:

1. A system for sensing aircraft and other objects comprising:

(a) an ADS-B transmitter;

(b) an ADS-B receiver;

(c) an ADS-B antenna;

(d) an ADS-B antenna multiplexer;

(e) an ADS-B processor;

(f) a radar processor;

(g) a display;

whereby

(a) said ADS-B antenna multiplexer is controlled by said ADS-B processor and allows said ADS-B antenna to be used by either said ADS-B transmitter or said ADS-B receiver,

(b) said ADS-B processor and said radar processor work together,

(c) said ADS-B processor periodically causes said ADS-B transmitter to emit a transmitted signal through said ADS-B antenna,

(d) said transmitted signal is reflected by a target producing a reflected signal,

(e) said reflected signal is received by said ADS-B antenna and sent to said ADS-B receiver,

(f) said radar processor processes said reflected signal from said ADS-B receiver and said transmitted signal from said ADS-B transmitter to determine a range to said target, and

(g) displays said range on said display.

2. The system of claim 1 wherein said radar processor is incorporated into said ADS-B processor.

3. A system for sensing aircraft and other objects comprising:

(a) an ADS-B transmitter;

(b) an ADS-B receiver;

(c) an ADS-B antenna;

(d) an ADS-B antenna multiplexer;

(e) an ADS-B processor;

(f) a radar processor;

(g) a second antenna;

(h) an antenna controller;

(i) a second receiver;

(j) a display;

whereby

(a) said second antenna is directional and the direction of said second antenna is controlled by said antenna controller under control of said radar processor,

(b) said ADS-B antenna multiplexer is controlled by said ADS-B processor and allows said ADS-B transmitter to use either said ADS-B antenna or said second antenna and also allows said ADS-B receiver to use either said ADS-B antenna or said second antenna,

(c) said ADS-B processor and said radar processor work together,

(d) said ADS-B processor periodically causes said ADS-B transmitter to emit a transmitted signal through either said ADS-B antenna or said second antenna through said ADS-B antenna multiplexer,

(e) said transmitted signal is reflected by a target producing a reflected signal,

(f) said reflected signal is received by either said ADS-B antenna or said second antenna through said ADS-B antenna multiplexer, which sends said reflected signal to said second receiver,

(g) said radar processor processes said reflected signal from said second receiver and said transmitted signal from said ADS-B transmitter to determine a range to said target,

(h) said radar processor uses the direction of said second antenna to determine a bearing to said target, and

(i) displays said range and said bearing on said display.

4. The system of claim 3 wherein said radar processor is incorporated into said ADS-B processor.

5. A system for sensing aircraft and other objects comprising:

(a) a TCAS Interrogation transmitter;

(b) a TCAS Interrogation Receiver;

(c) a first TCAS antenna;

(d) a second TCAS antenna;

(e) an antenna controller;

(f) a TCAS antenna diplexer;

(g) a TCAS processor;

(h) a radar processor;

(i) a display;

whereby

(a) said second TCAS antenna is directional and is controlled by said TCAS processor using said antenna controller,

(b) said TCAS processor and said radar processor work together,

(c) said TCAS antenna diplexer is controlled by said TCAS processor and allows said first TCAS antenna to be used by either said TCAS interrogation transmitter or said TCAS interrogation receiver and also allows said second TCAS antenna to be used by either said TCAS interrogation transmitter or said TCAS interrogation receiver,

(d) said TCAS processor periodically causes said TCAS interrogation transmitter to emit a transmitted signal through either said first TCAS antenna or said second TCAS antenna,

(e) said transmitted signal is reflected by a target producing a reflected signal,

(f) said reflected signal is received by either said first TCAS antenna or by said second TCAS antenna and sent to said TCAS interrogation receiver,

(g) said radar processor processes said reflected signal from said TCAS interrogation receiver and said transmitted signal from said TCAS interrogation transmitter to determine a range to said target,

(h) said radar processor uses the direction of said antenna controller to determine a bearing to said target, and

(i) displays said range and said bearing on said display.

6. The system of claim 5 wherein said radar processor is incorporated into said TCAS processor.

7. A system for sensing spread-spectrum signals comprising:

(a) a first antenna;

(b) a first receiver for receiving spread-spectrum signals;

(c) a first data buffer;

(d) a second antenna;

(e) a second receiver for receiving spread-spectrum signals;

(f) a second data buffer;

(g) a cross-correlator with two inputs and one or more outputs;

(h) a system controller;

(i) a display;

whereby

(a) said first antenna is connected to said first receiver,

(b) said first receiver provides data for said first data buffer,

(c) said second antenna is connected to said second receiver,

(d) said second receiver provides data for said second data buffer,

(e) the output of said first data buffer is connected to a first input of said two inputs to said cross-correlator,

(f) the output of said second data buffer is connected to a second input of said two inputs to said cross-correleator,

(g) under the direction of said system controller said cross-correlator performs a cross-correlation between said first input and said second input and produces an output, said output indicating the magnitude of the cross-correlation between a spread-spectrum signal received by both said first receiver and said second receiver,

(h) said one or more outputs of said cross-correlator is displayed on said display,

whereby a high cross-correlation between said first receiver and said second receiver indicates the presence of a spread-spectrum signal.

8. The system of claim 7 further comprising a distance between said first antenna and said second antenna whereby under the direction of said system controller said cross-correlator performs a cross-correlation between said first input and said second input and produces a second output, said second output indicating the phase of the cross-correlation between a spread-spectrum signal received by both said first receiver and said second receiver, and whereby said phase indicates a bearing to the location of said spread-spectrum signal, and said bearing is displayed on said display.

9. The system of claim 7 further comprising:

(a) a distance between said first antenna and said second antenna;

(b) a first antenna controller for said first antenna;

(c) a second antenna controller for said second antenna;

whereby

(a) said first antenna is a directional antenna,

(b) said second antenna is a directional antenna,

(c) said system controller uses said first antenna controller to control the direction of said first antenna,

(d) said system controller uses said second antenna controller to control the direction of said second antenna,

(e) said system controller coordinates the direction of said first directional antenna with the direction of said second directional antenna to triangulate the source of said spread-spectrum signal to determine a range and a bearing to said spread-spectrum signal, and

(f) said range and said bearing to said spread-spectrum signal are displayed on said display.

10. A system for sensing aircraft and other objects comprising:

(a) four or more orbiting satellites;

(b) an antenna;

(c) a receiver;

(d) a data buffer;

(e) a cross-correlator with two or more inputs and one or more outputs;

(f) a system controller;

(g) a list of code keys;

(h) a display;

wherein

(a) each of said four or more orbiting satellites transmits a signal encoded by a unique code key selected from said list of code keys,

(b) said antenna is connected to said receiver,

(c) the output of said receiver is connected to the input of said data buffer,

(d) the output of said data buffer is connected to a first of said two or more inputs of said cross-correlator,

(e) said system controller provides a second of said two or more inputs of said cross-correlator,

(f) said system controller receives an output of said one or more outputs of said cross-correleator,

and whereby

(a) said system controller uses said signal transmitted by each of said four or more orbiting satellites, said list of code keys, and said cross-correlator to uniquely identify each of said four or more orbiting satellites,

(b) said system controller determines a distance and a direction to each uniquely identified satellite,

(c) said signal from said each uniquely identified satellite is reflected by a target producing a uniquely identifiable reflected signal,

(d) each said uniquely identifiable reflected signal is received by said antenna, which is connected to said receiver, which is connected to said data buffer, which is connected to said first of said two or more inputs of said cross-correlator,

(e) said system controller uses said list of code keys and said cross-correlator to identify each said uniquely identifiable reflected signal,

(f) said system controller uses each said uniquely identifiable reflected signal and said range and said direction to said each uniquely identified satellite to determine a range and a bearing to said target, and

(g) displays said range and said bearing on said display,

and wherein

(a) the range and direction to a first of said four or more orbiting satellites and the signal from said first of said four or more orbiting satellites reflected from said target produce a first ellipsoid with said first of said four or more orbiting satellites at one focal point of said first ellipsoid, said antenna at the other focal point of said first ellipsoid, and said target on the surface of said first ellipsoid,

(b) the range and direction to a second of said four or more orbiting satellites and the signal from said second of said four or more orbiting satellites reflected from said target produce a second ellipsoid with said second of said four or more orbiting satellites at one focal point of said second ellipsoid, said antenna at the other focal point of said second ellipsoid, and said target on the surface of said second ellipsoid,

(c) the range and direction to a third of said four or more orbiting satellites and the signal from said third of said four or more orbiting satellites reflected from said target produce a third ellipsoid with said third of said four or more orbiting satellites at one focal point of said third ellipsoid, said antenna at the other focal point of said third ellipsoid, and said target on the surface of said third ellipsoid,

(d) the range and direction to a fourth of said four or more orbiting satellites and the signal from said fourth of said four or more orbiting satellites reflected from said target produce a fourth ellipsoid with said fourth of said four or more orbiting satellites at one focal point of said fourth ellipsoid, said antenna at the other focal point of said fourth ellipsoid, and said target on the surface of said fourth ellipsoid,

(e) said first ellipsoid and said second ellipsoid intersect in an ellipse with said target located on said ellipse,

(f) said third ellipsoid and said ellipse intersect at two points with said target located at one of said two points,

(g) said fourth ellipsoid intersects with only one of said two points with said target located at said only one of said two points.

11. The system of claim 10 further comprising communications links between each of said four or more orbiting satellites.

12. The system of claim 10 wherein at least one of said four or more orbiting satellites is located in low earth orbit.

13. The system of claim 10 further comprising:

(a) a receiver in each of said four or more orbiting satellites;

(b) a transmitter;

whereby said receiver in each of said four or more orbiting satellites and said transmitter are used to send transmissions to at least one of said four or more orbiting satellites in order to provide two-way communications through said at least one of said four or more orbiting satellites.

14. The system of claim 11 further comprising a satellite receiver in at least two or more of said four or more orbiting satellites whereby a signal transmitted by said at least two or more of said four or more orbiting satellites and said satellite receiver are used to perform long baseline radar interferometric measurements of terrain elevations.

15. A system for sensing aircraft and other objects comprising:

(a) one or more orbiting satellites;

(b) a first antenna;

(c) a second antenna;

(d) a controller for said second antenna;

(e) an antenna multiplexer;

(f) a receiver;

(g) a data buffer;

(h) a cross-correlator with two or more inputs and one or more outputs;

(i) a system controller;

(j) a list of code keys;

(k) a display;

wherein

(a) said antenna multiplexer selects between said first antenna and said second antenna under control of said system controller,

(b) the output of said antenna multiplexer is connected to the input of said receiver,

(c) said second antenna is directional and is controlled by said antenna controller under control of said system controller,

(d) the output of said receiver is connected to the input of said data buffer,

(e) the output of said data buffer is connected to a first of said two or more inputs of said cross-correlator,

(f) said system controller provides a second of said two or more inputs of said cross-correlator,

(g) said system controller receives an output of said one or more outputs of said cross-correleator,

and whereby

(a) said first antenna is selected by said system controller,

(b) said one or more orbiting satellites transmits a signal encoded by a unique code key selected from said list of code keys,

(c) said system controller uses said signal transmitted by said one or more orbiting satellites, said list of code keys, and said cross-correlator to uniquely identify said one or more orbiting satellites,

(d) said system controller determines a distance to a uniquely identified satellite,

(e) said signal from said uniquely identified satellite is reflected by a target producing a uniquely identifiable reflected signal,

(f) said uniquely identifiable reflected signal is received by said second antenna, which is connected to said receiver, which is connected to said data buffer, which is connected to said first of said two or more inputs of said cross-correlator,

(g) said system controller uses said list of code keys and said cross-correlator to identify said uniquely identifiable reflected signal,

(h) said system controller uses said antenna controller to direct said second antenna at the source of said uniquely identifiable reflected signal to produce a bearing to said uniquely identifiable reflected signal,

(i) said system controller uses said uniquely identifiable reflected signal and said range to said uniquely identified satellite to determine a range and a bearing to said target, and

(j) displays said range and said bearing on said display,

and wherein

(a) the range and direction to said one or more orbiting satellites and the signal from said one or more orbiting satellites reflected from said target produces an ellipsoid with said one or more orbiting satellites at one focal point of said ellipsoid, said antenna at the other focal point of said ellipsoid, and said target on the surface of said ellipsoid,

(b) said second antenna is aimed to receive said signal from said one or more orbiting satellites reflected from said target, and

(c) the direction of said second antenna is used to determine the location of said target on said ellipsoid.

16. A system for sensing aircraft and other objects during daytime comprising:

(a) a first directional antenna;

(b) a first antenna controller;

(c) a first receiver;

(d) a first data buffer;

(e) a second directional antenna;

(f) a second antenna controller;

(g) a second receiver;

(h) a second data buffer;

(i) a cross-correlator;

(j) a system controller;

(k) a display;

whereby

(a) the position of said first directional antenna is controlled by said first antenna controller under the control of said system controller,

(b) the position of said second directional antenna is controlled by said second antenna controller under the control of said system controller,

(c) said cross-correlator has two inputs and one output,

(d) said first directional antenna is connected to the input of said first receiver,

(e) the output of said first receiver is connected to the input of said first data buffer,

(f) the output of said first data buffer is connected to a first input of said cross-correlator under control of said system controller,

(g) said second directional antenna is connected to the input of said second receiver,

(h) the output of said second receiver is connected to the input of said second data buffer,

(i) the output of said second data buffer is connected to a second input of said cross-correlator under control of said system controller,

(j) said system controller directs said first antenna controller to point said first directional antenna at the Sun to produce a first signal,

(k) said system controller directs said cross-correlator to perform a cross-correlation between said first signal received from said first directional antenna which is stored in said first data buffer and a second signal received from said second directional antenna which is stored in said second data buffer,

(l) said system controller directs said second antenna controller to point said second directional antenna to produce said second signal to maximize said output of said cross-correlator where said second directional antenna is not pointed at said Sun,

whereas

(a) said second signal is a reflection of said first signal produced by said Sun, said reflection being produced by a target,

(b) a time delay between said first signal and said second signal is used to determine an ellipsoid with said first directional antenna located at one focal point of said ellipsoid, said Sun located at the other focal point of said ellipsoid and said target on the surface of said ellipsoid,

(c) the direction of said second directional antenna is used to determine the location of said target on said ellipsoid,

(d) said system controller uses said location of said target on said ellipsoid to produce a range and a bearing to said target, and

(e) displays said range and said bearing on said display.

ABSTRACT OF THE DISCLOSURE

A system for sensing aircraft and other objects uses bistatic radar with spread-spectrum signals transmitted from remotely located sources such as aircraft flying at very high altitudes or from a satellite constellation. A bistatic spread spectrum radar system using a satellite constellation can be integrated with a communications system and/or with a system using long baseline radar interferometry to validate the digital terrain elevation database. The reliability and safety of TCAS and ADS-B are improved by using the signals transmitted from a TCAS or ADS-B unit as a radar transmitter with a receiver used to receive reflections. Aircraft and other objects using spread spectrum radar are detected by using two separate receiving systems. Cross-Correlation between the outputs of the two receiving systems reveals whether a noise signal is produced by the receiving systems themselves or is coming from the outside.

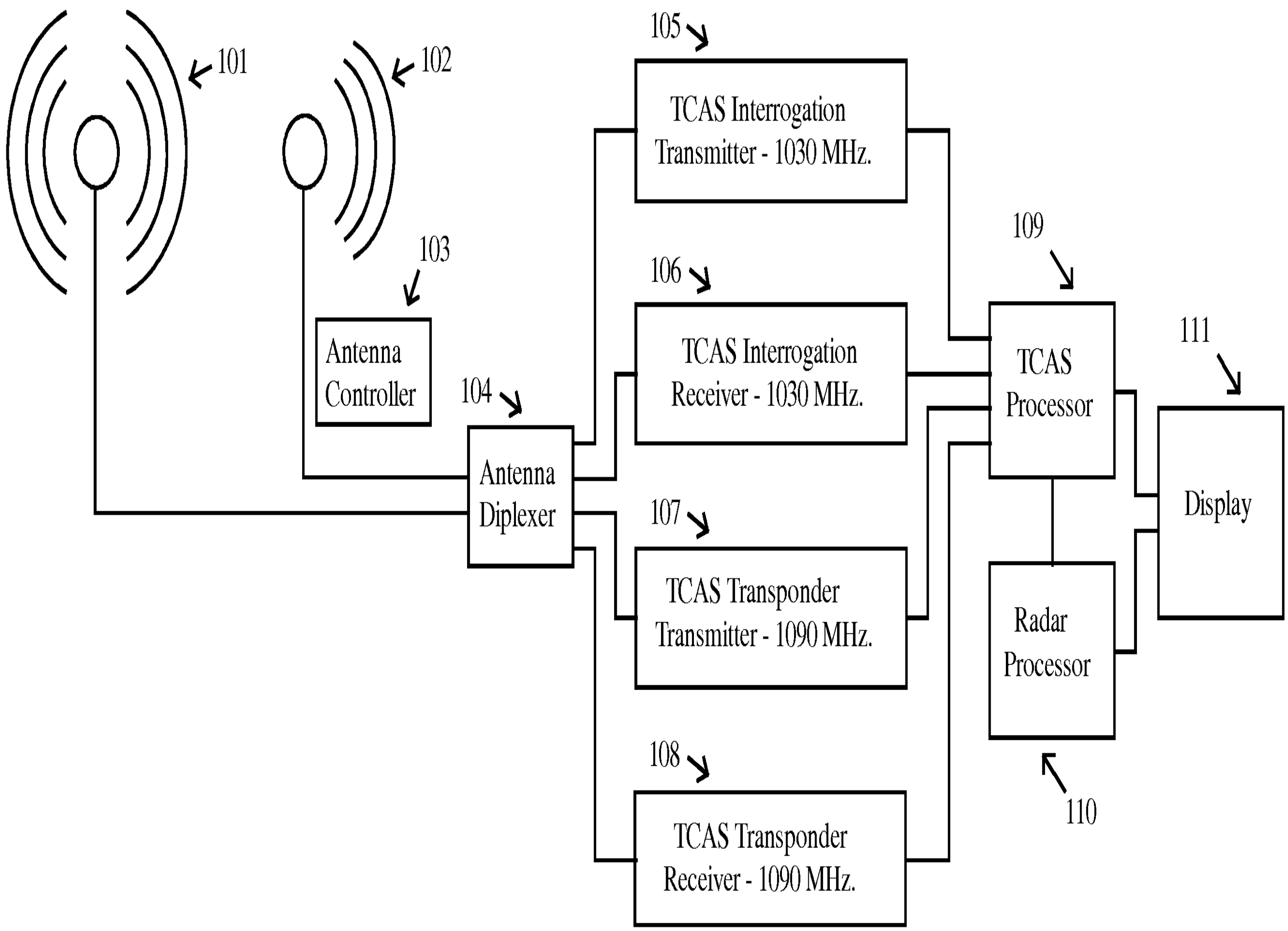
101
102
103
Antenna Controller
104
Antenna Diplexer
105
TCAS Interrogation Transmitter - 1030 MHz.
106
TCAS Interrogation Receiver - 1030 MHz.
107
TCAS Transponder Transmitter - 1090 MHz.
108
TCAS Transponder Receiver - 1090 MHz.
109
TCAS Processor
110
Radar Processor
111
Display

Fig. 1

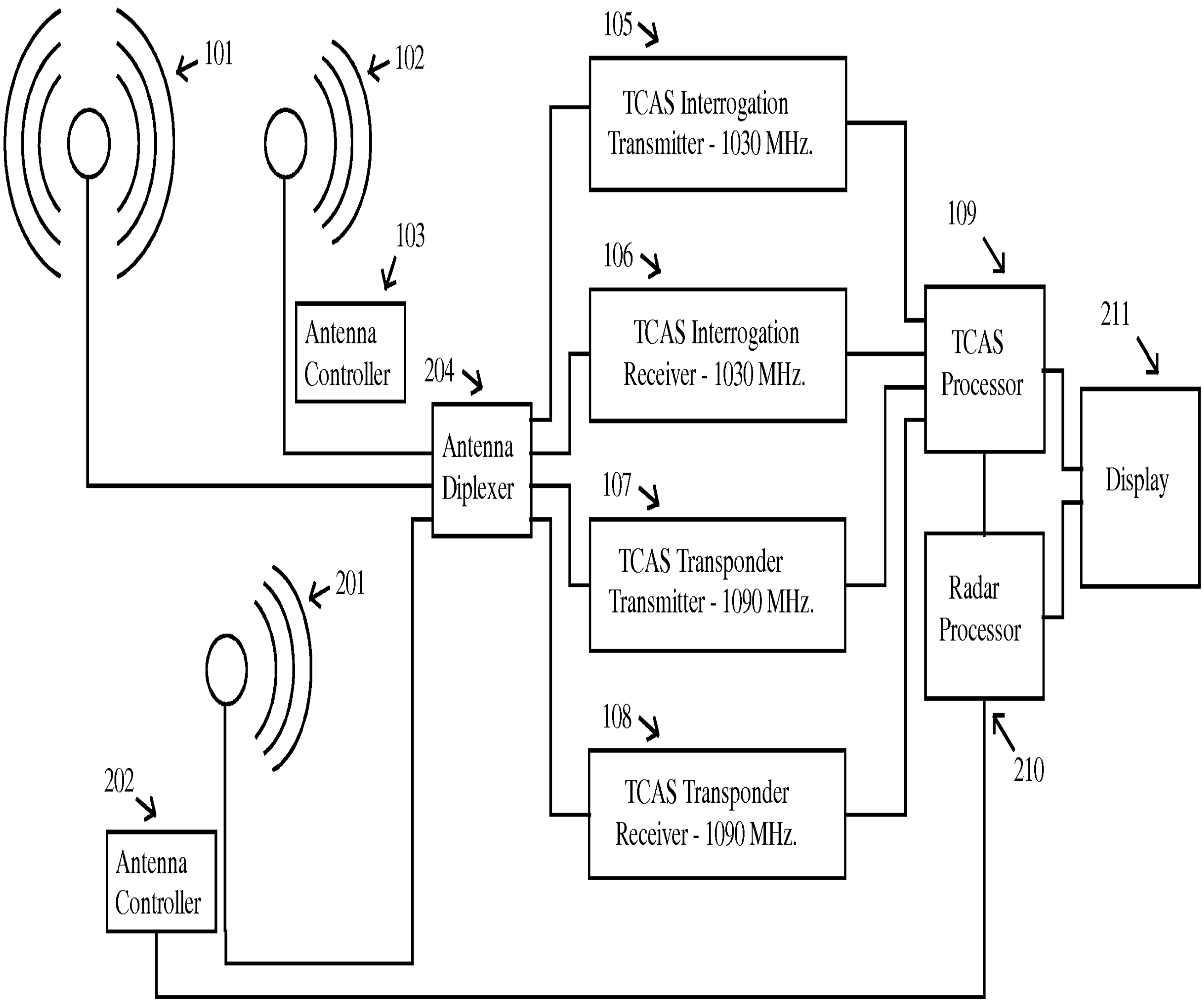
101
102
103
Antenna Controller
204
Antenna Diplexer
201
202
Antenna Controller
105
TCAS Interrogation Transmitter - 1030 MHz.
106
TCAS Interrogation Receiver - 1030 MHz.
107
TCAS Transponder Transmitter - 1090 MHz.
108
TCAS Transponder Receiver - 1090 MHz.
109
TCAS Processor
Radar Processor
210
211
Display

Fig. 2

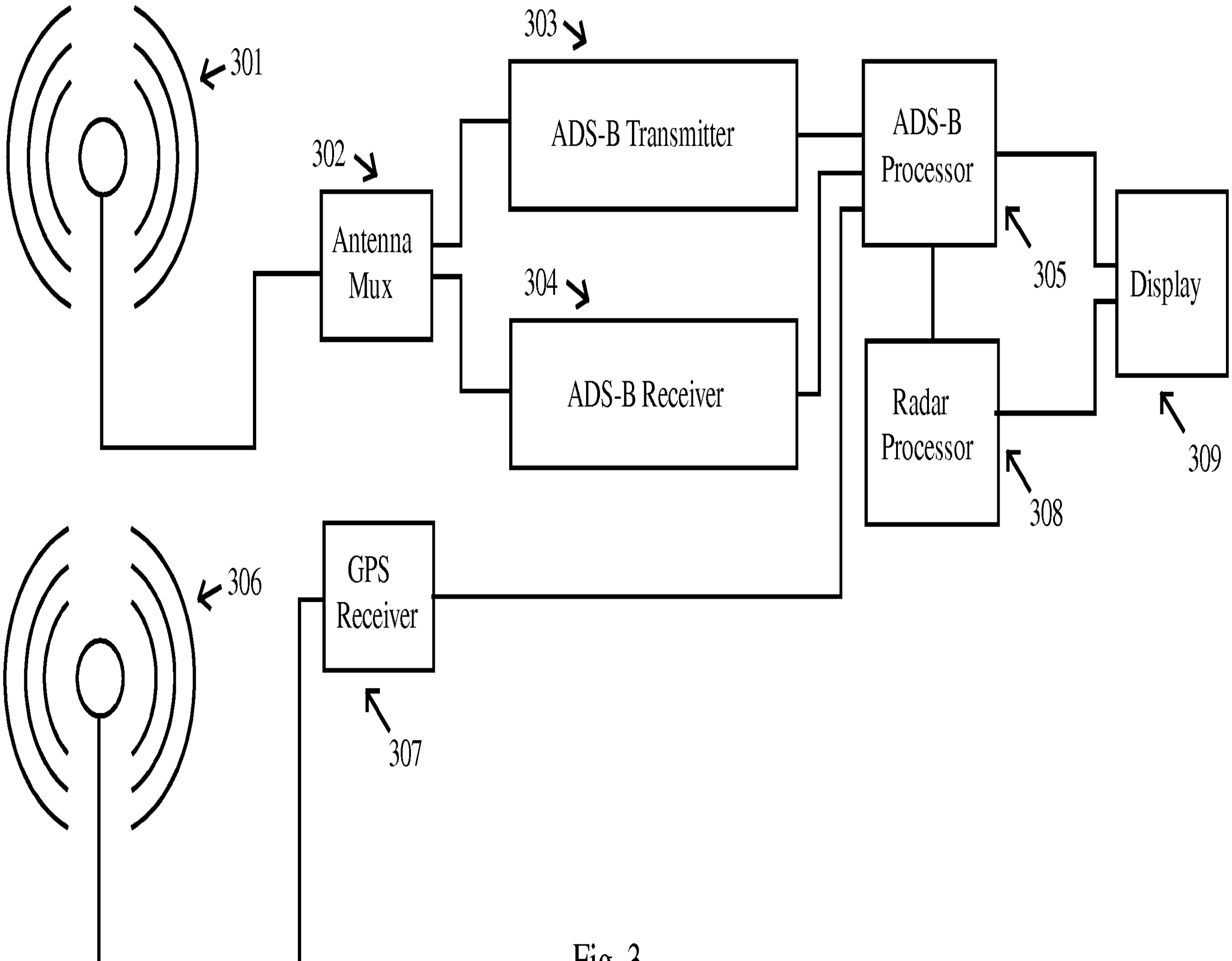
301
302
303
304
305
306
307
308
309
Antenna Mux
ADS-B Transmitter
ADS-B Receiver
ADS-B Processor
Radar Processor
Display
GPS Receiver

Fig. 3

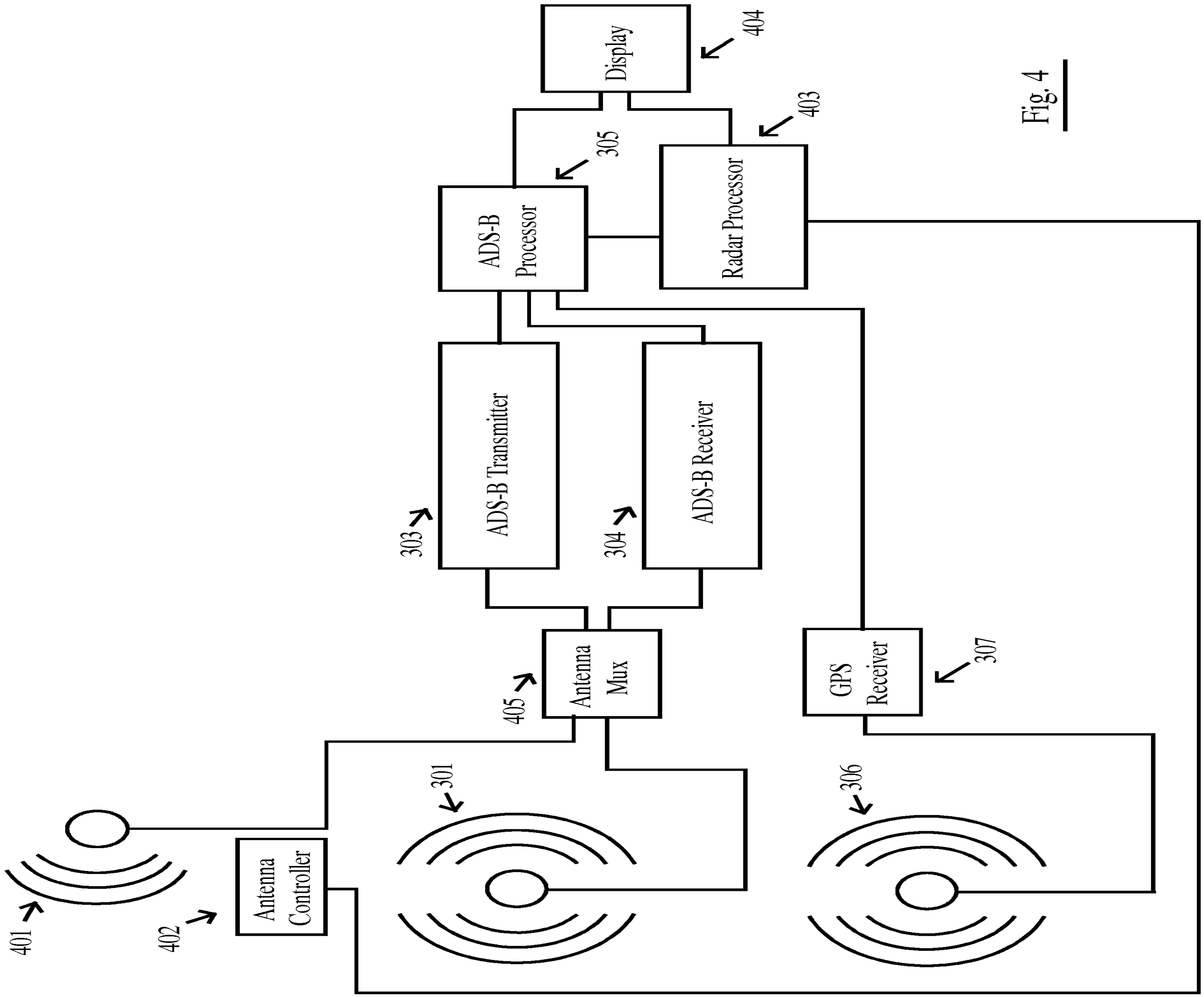
Display
404
403
305
ADS-B Processor
Radar Processor
ADS-B Transmitter
ADS-B Receiver
303
304
Antenna Mux
405
GPS Receiver
307
301
306
401
402
Antenna Controller

Fig. 4

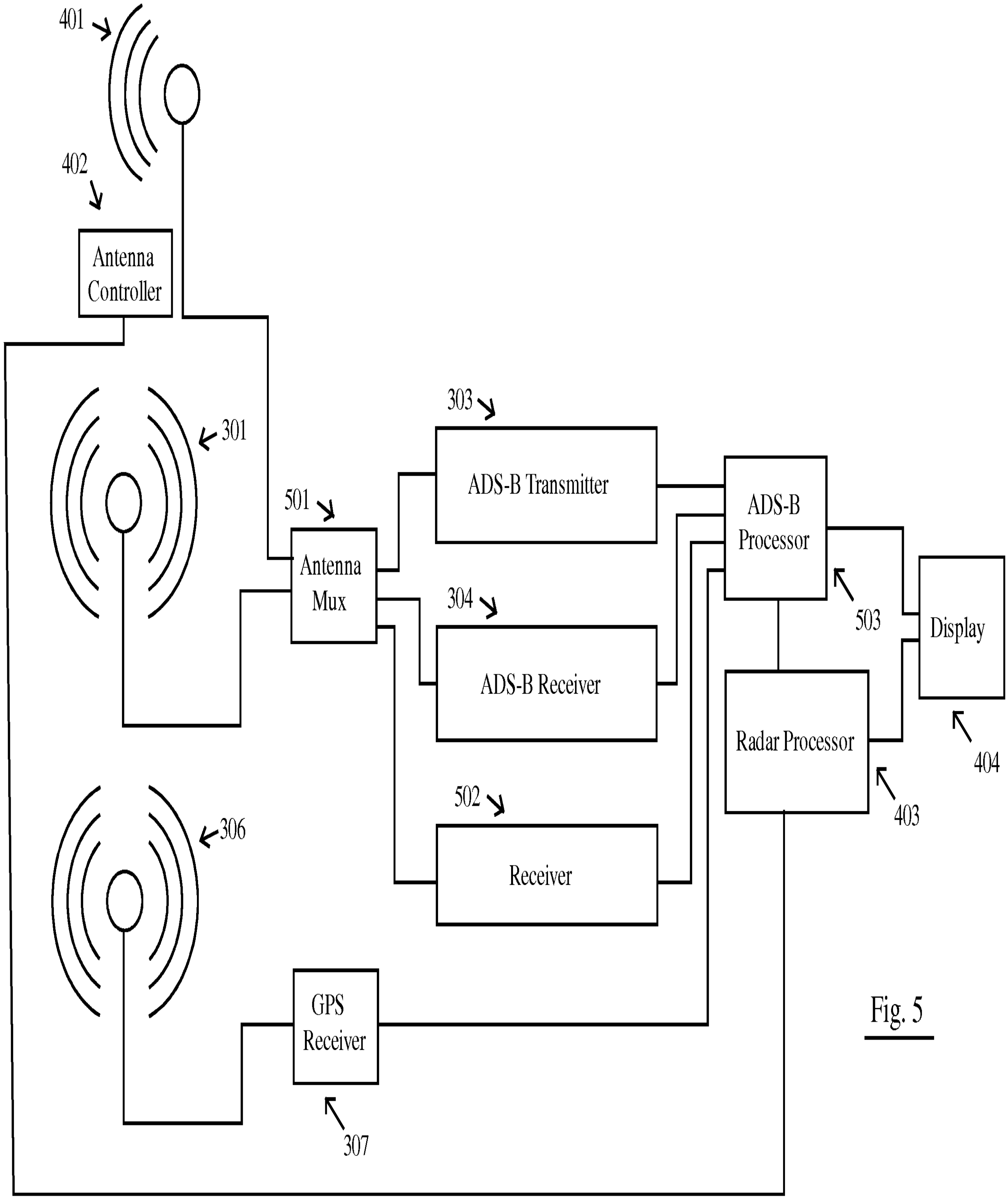
401
402
Antenna Controller
301
303
501
Antenna Mux
ADS-B Transmitter
ADS-B Processor
304
ADS-B Receiver
503
Display
Radar Processor
404
403
306
502
Receiver
GPS Receiver
307

Fig. 5

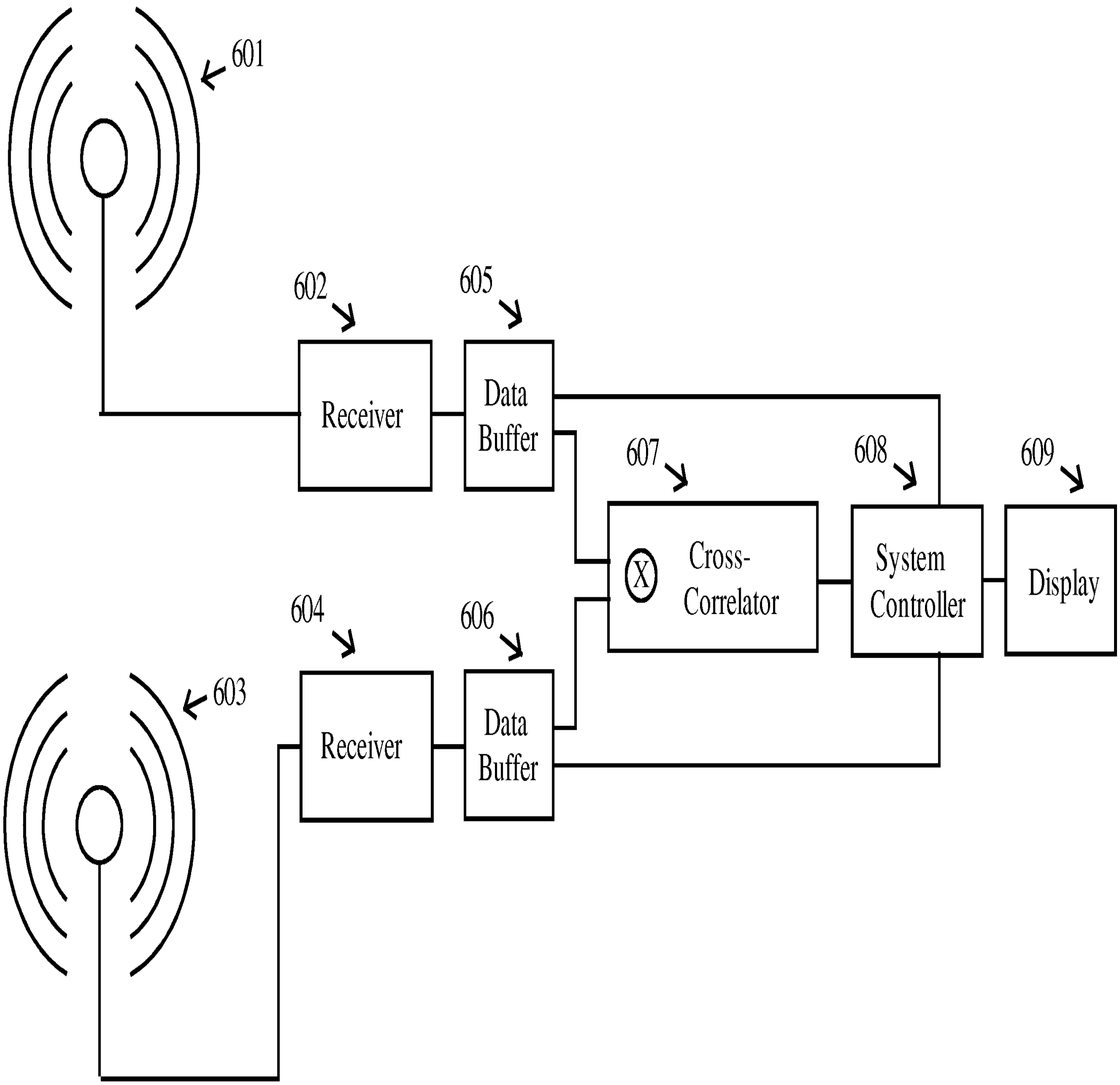
601
602
605
Receiver
Data
Buffer
607
608
609
Cross-
Correlator
System
Controller
Display
604
606
603
Receiver
Data
Buffer

Fig. 6

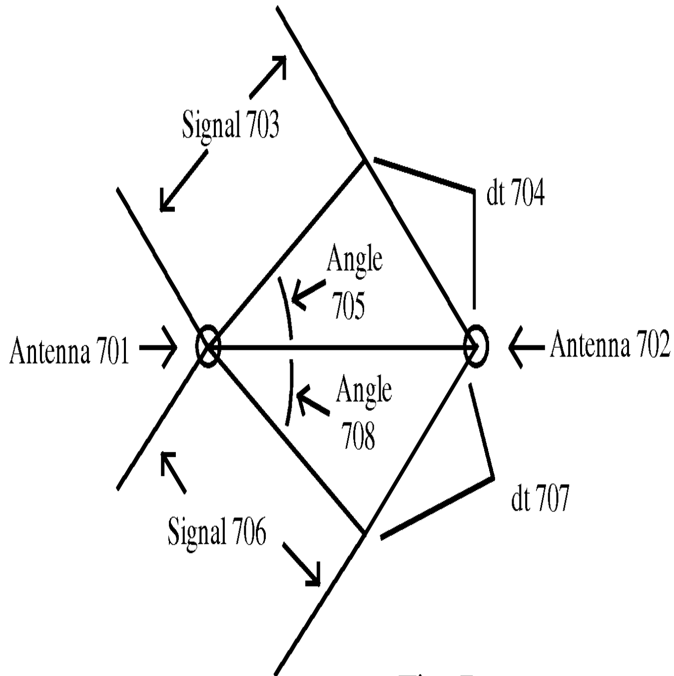
Signal 703
dt 704
Angle 705
Antenna 701
Antenna 702
Angle 708
dt 707
Signal 706

Fig. 7

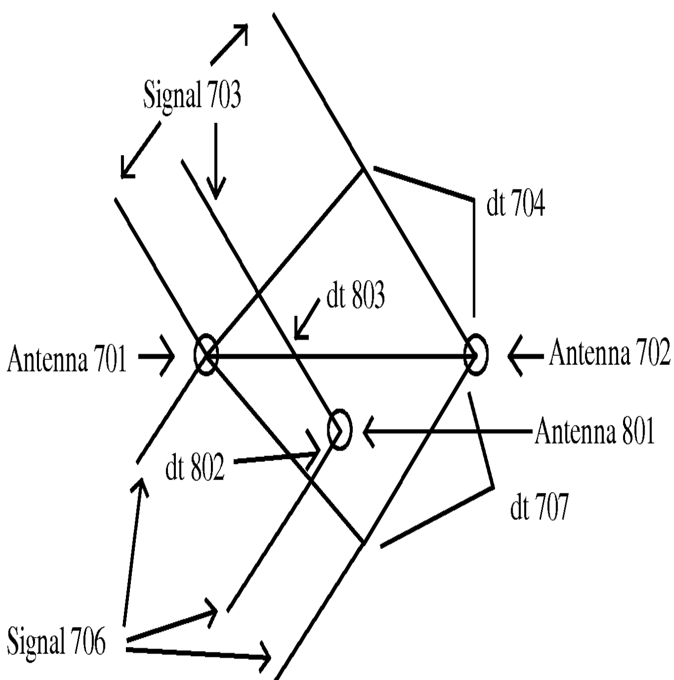
Signal 703
dt 704
dt 803
Antenna 701
Antenna 702
Antenna 801
dt 802
dt 707
Signal 706

Fig. 8

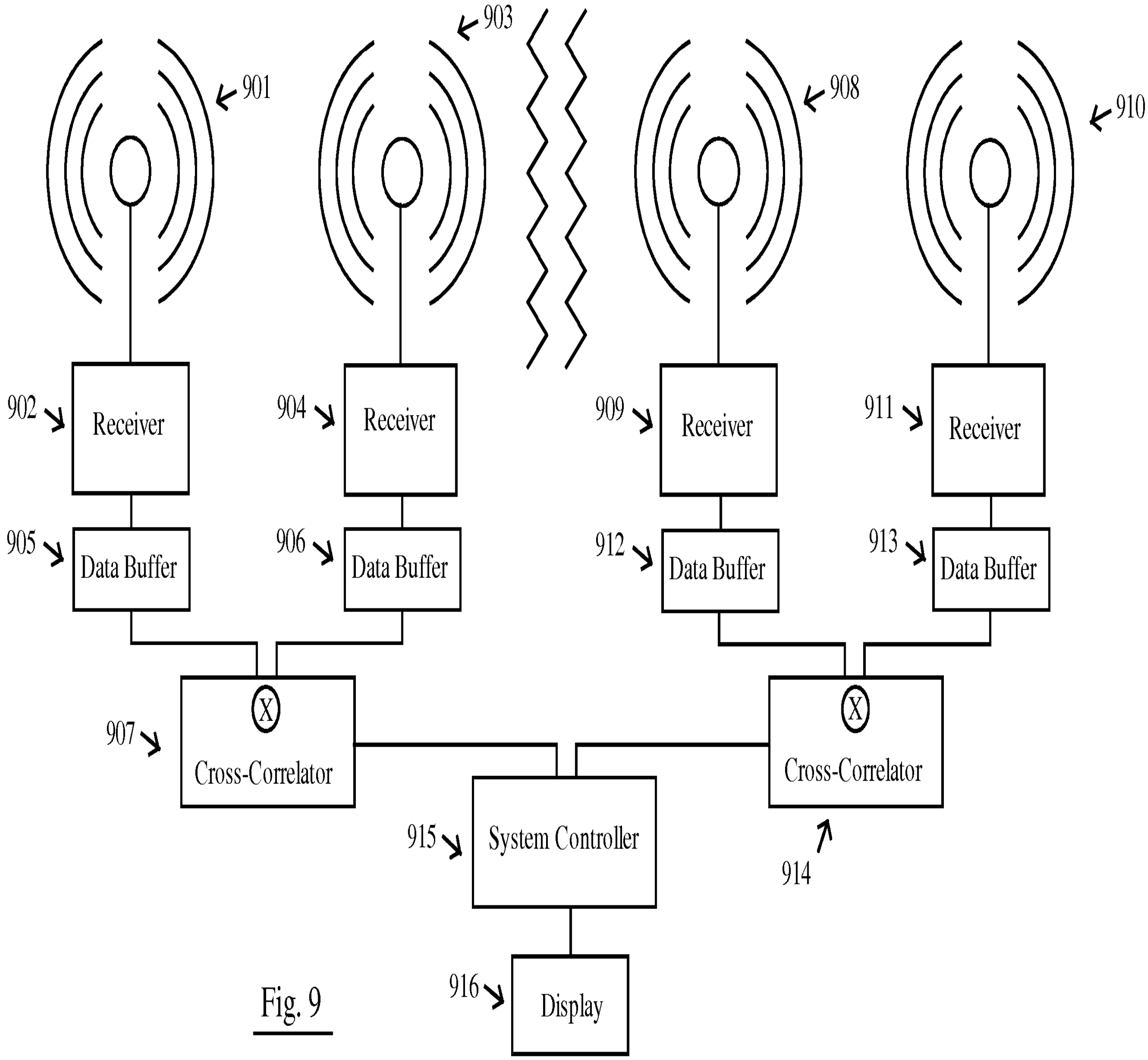
901
902
Receiver
903
904
Receiver
905
Data Buffer
906
Data Buffer
907
Cross-Correlator
X
908
909
Receiver
910
911
Receiver
912
Data Buffer
913
Data Buffer
914
Cross-Correlator
X
915
System Controller
916
Display

Fig. 9

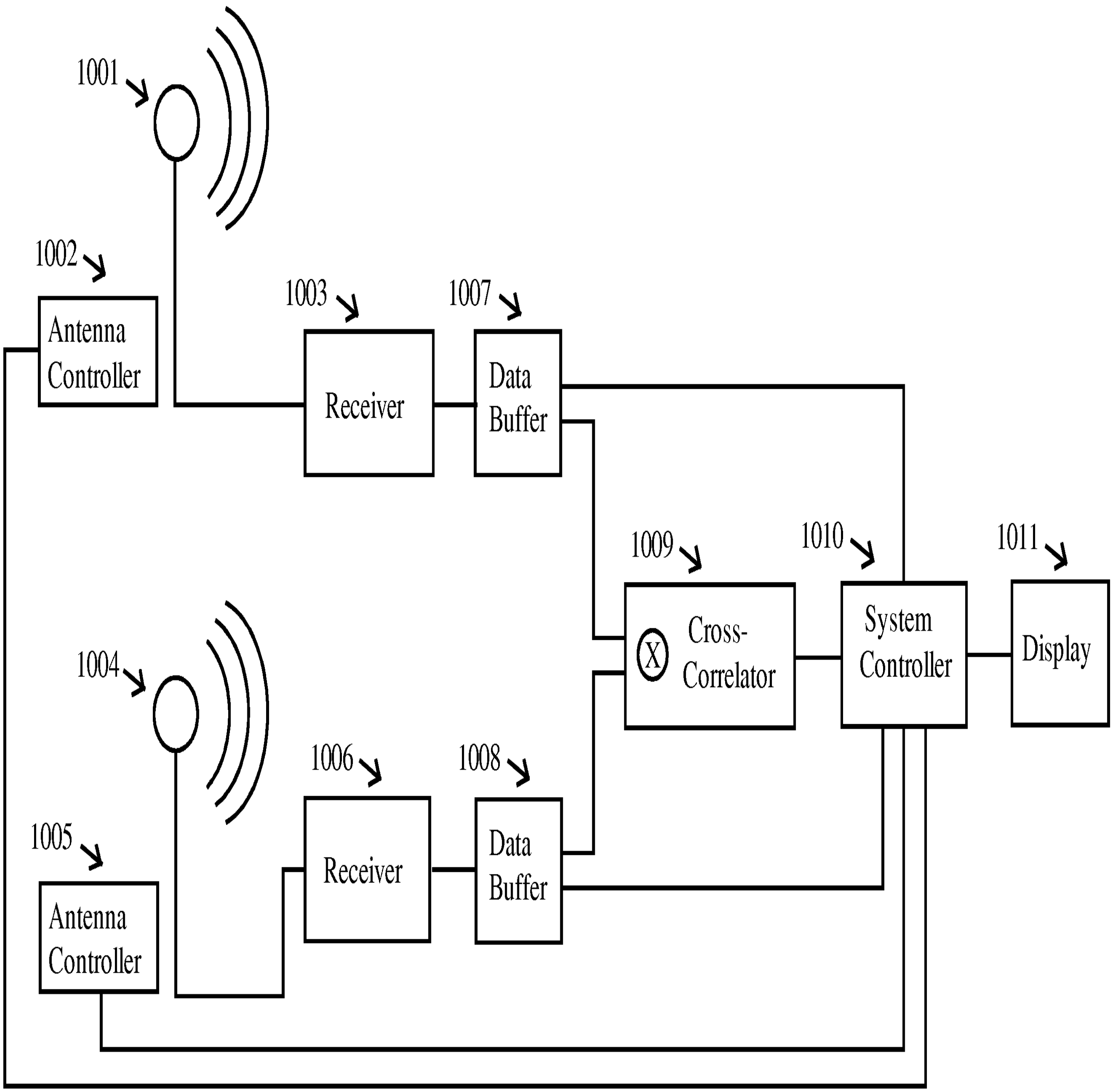
1001
1002
Antenna Controller
1003
Receiver
1007
Data Buffer
1009
Cross-Correlator
X
1010
System Controller
1011
Display
1004
1005
Antenna Controller
1006
Receiver
1008
Data Buffer

Fig. 10

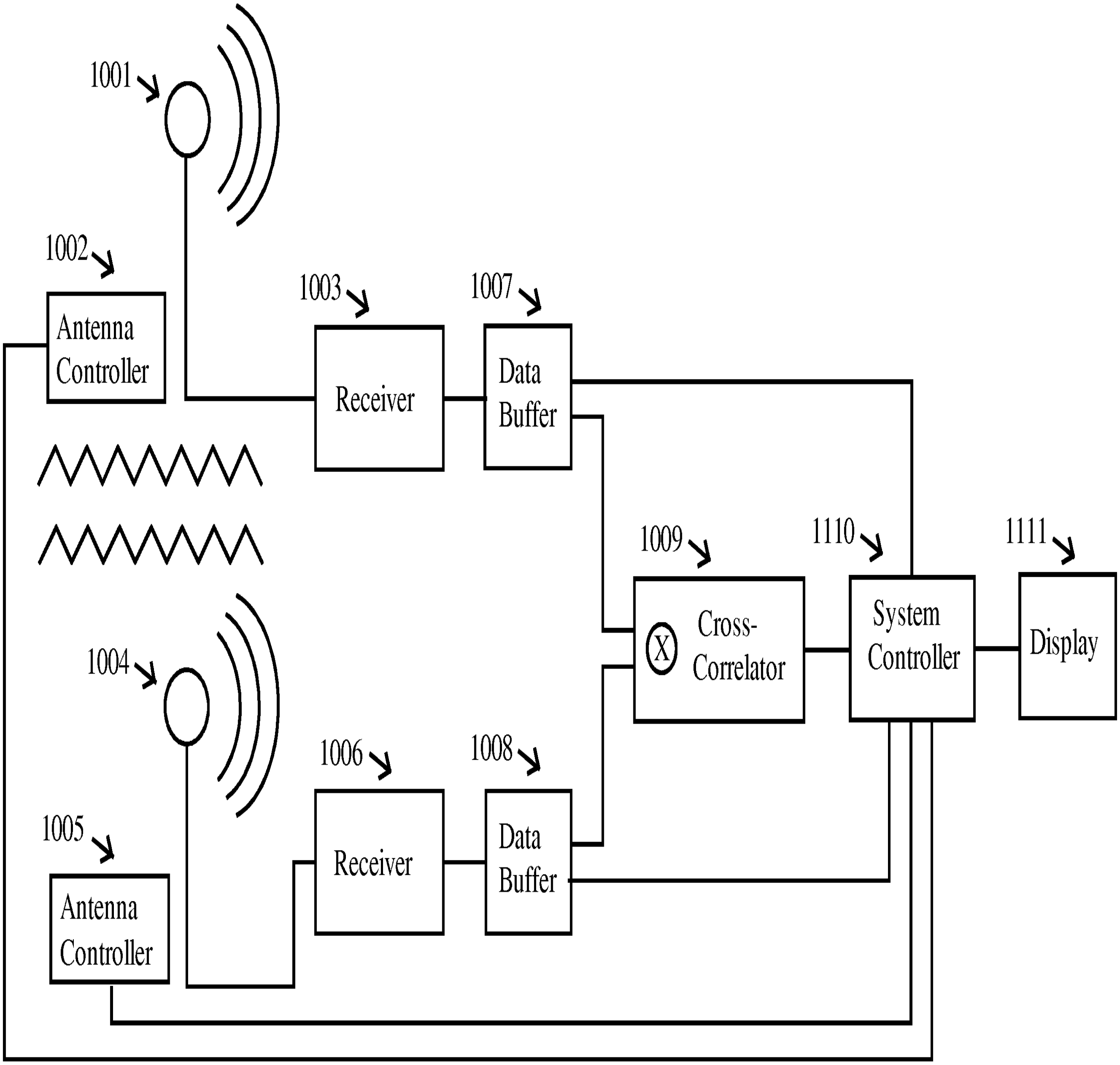
1001
1002
Antenna Controller
1003
Receiver
1007
Data Buffer
1004
1005
Antenna Controller
1006
Receiver
1008
Data Buffer
1009
X
Cross-Correlator
1110
System Controller
1111
Display

Fig. 11

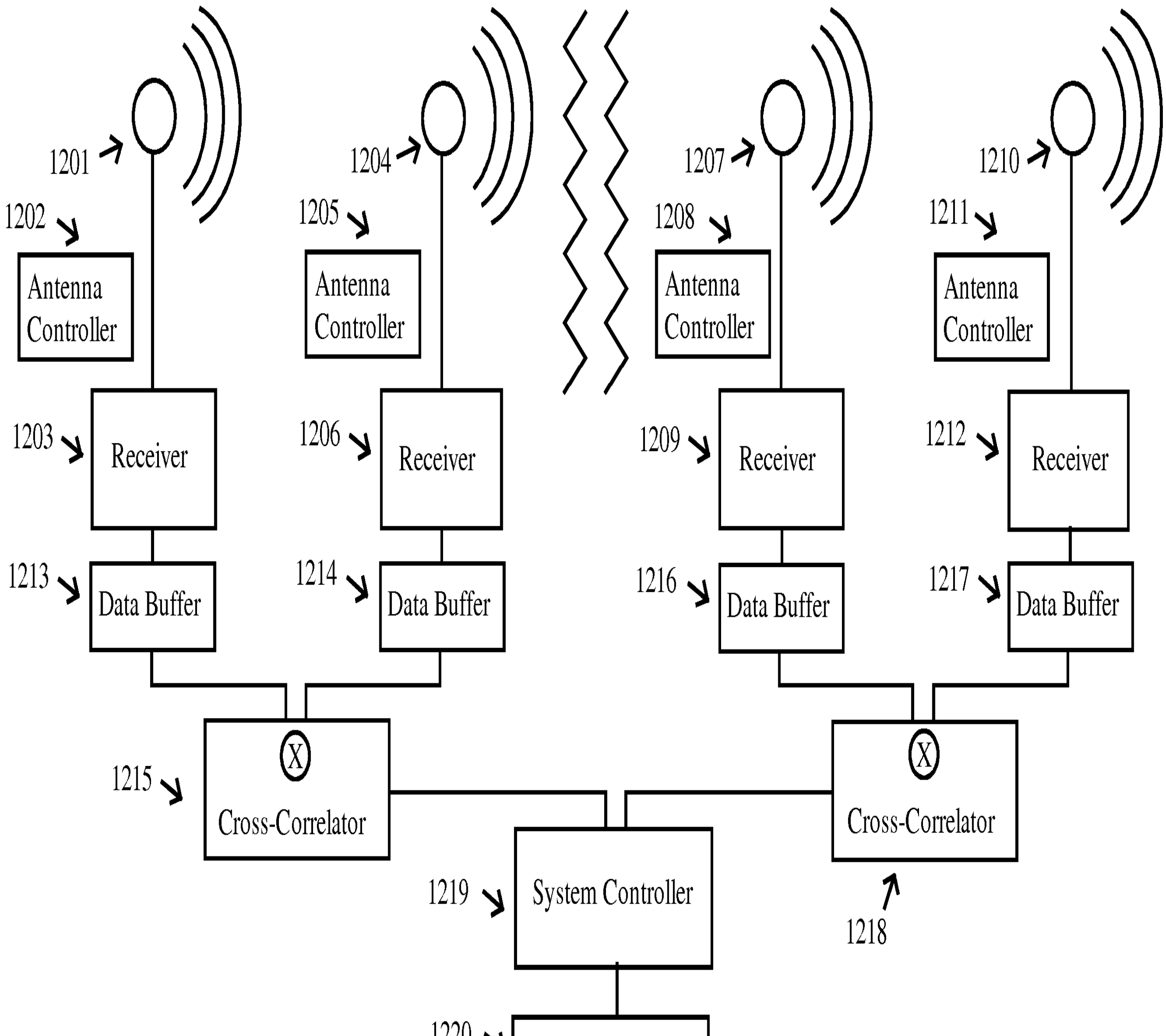
1201
1202
Antenna Controller
1203
Receiver
1213
Data Buffer
1204
1205
Antenna Controller
1206
Receiver
1214
Data Buffer
1207
1208
Antenna Controller
1209
Receiver
1216
Data Buffer
1210
1211
Antenna Controller
1212
Receiver
1217
Data Buffer
1215
X
Cross-Correlator
X
Cross-Correlator
1218
1219
System Controller
1220
Display

Fig. 12

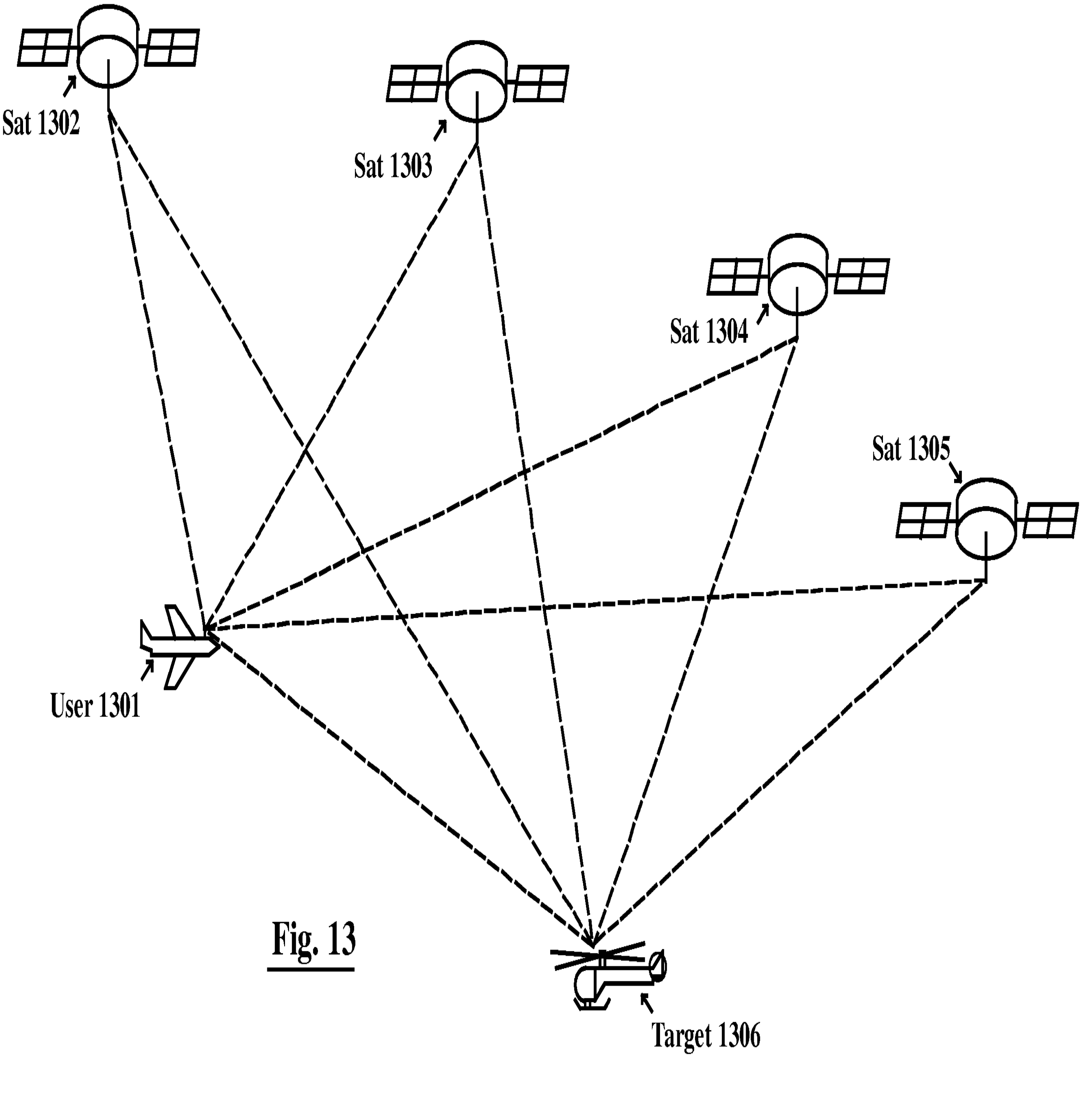

Fig. 13

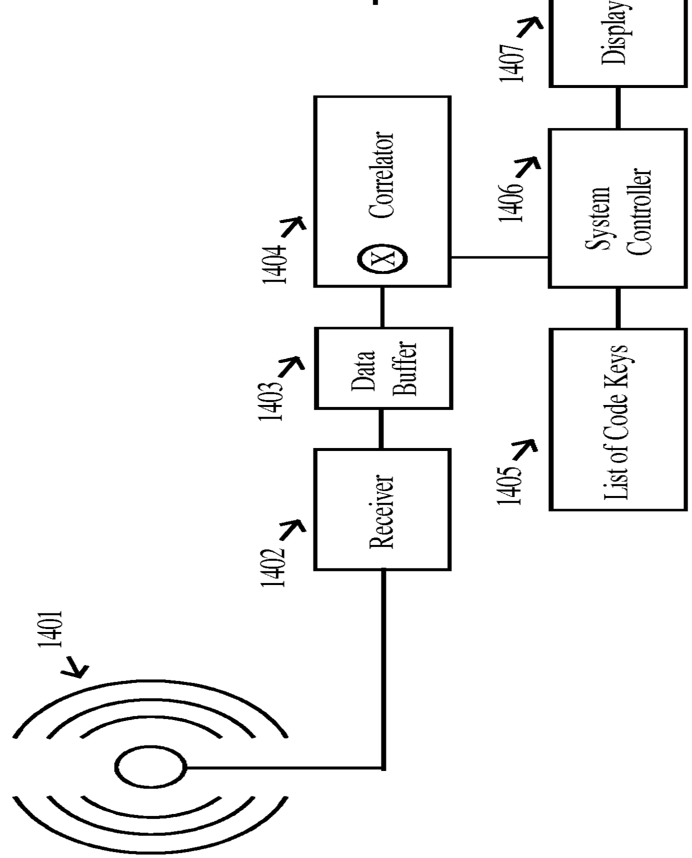
1401
1402
Receiver
1403
Data
Buffer
1404
X
Correlator
1405
List of Code Keys
1406
System
Controller
1407
Display

Fig. 14

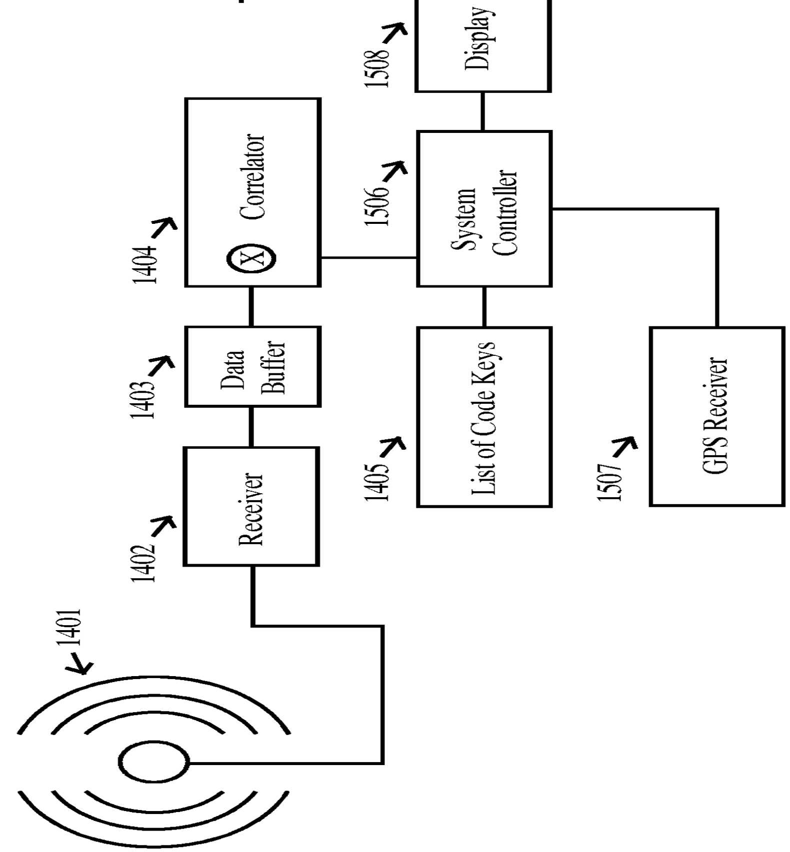
1401
1402
Receiver
1403
Data
Buffer
1404
X
Correlator
1405
List of Code Keys
1506
System
Controller
1508
Display
1507
GPS Receiver

Fig. 15

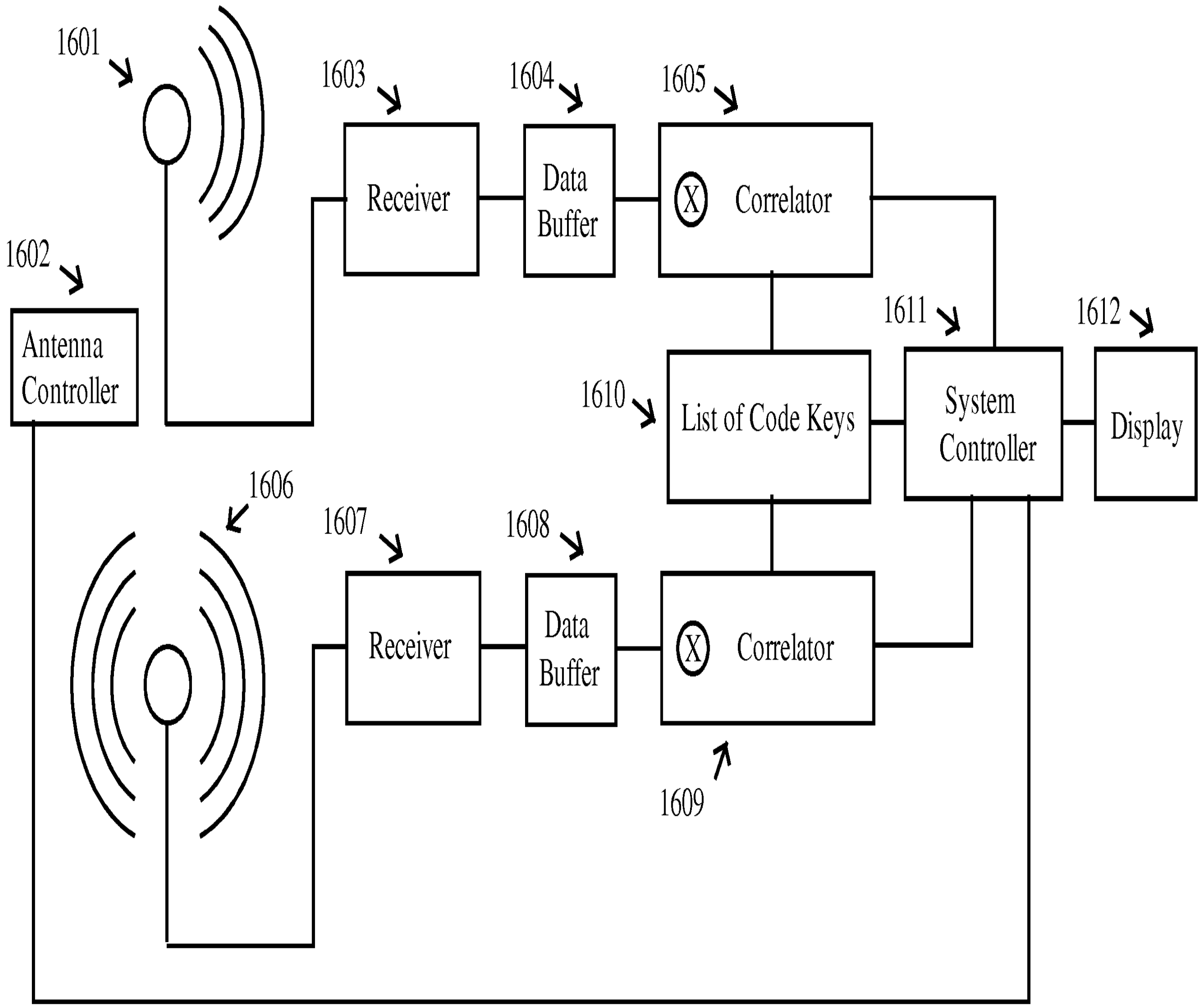
1601
1602
Antenna Controller
1603
Receiver
1604
Data Buffer
1605
X
Correlator
1610
List of Code Keys
1611
System Controller
1612
Display
1606
1607
Receiver
1608
Data Buffer
X
Correlator
1609

Fig. 16

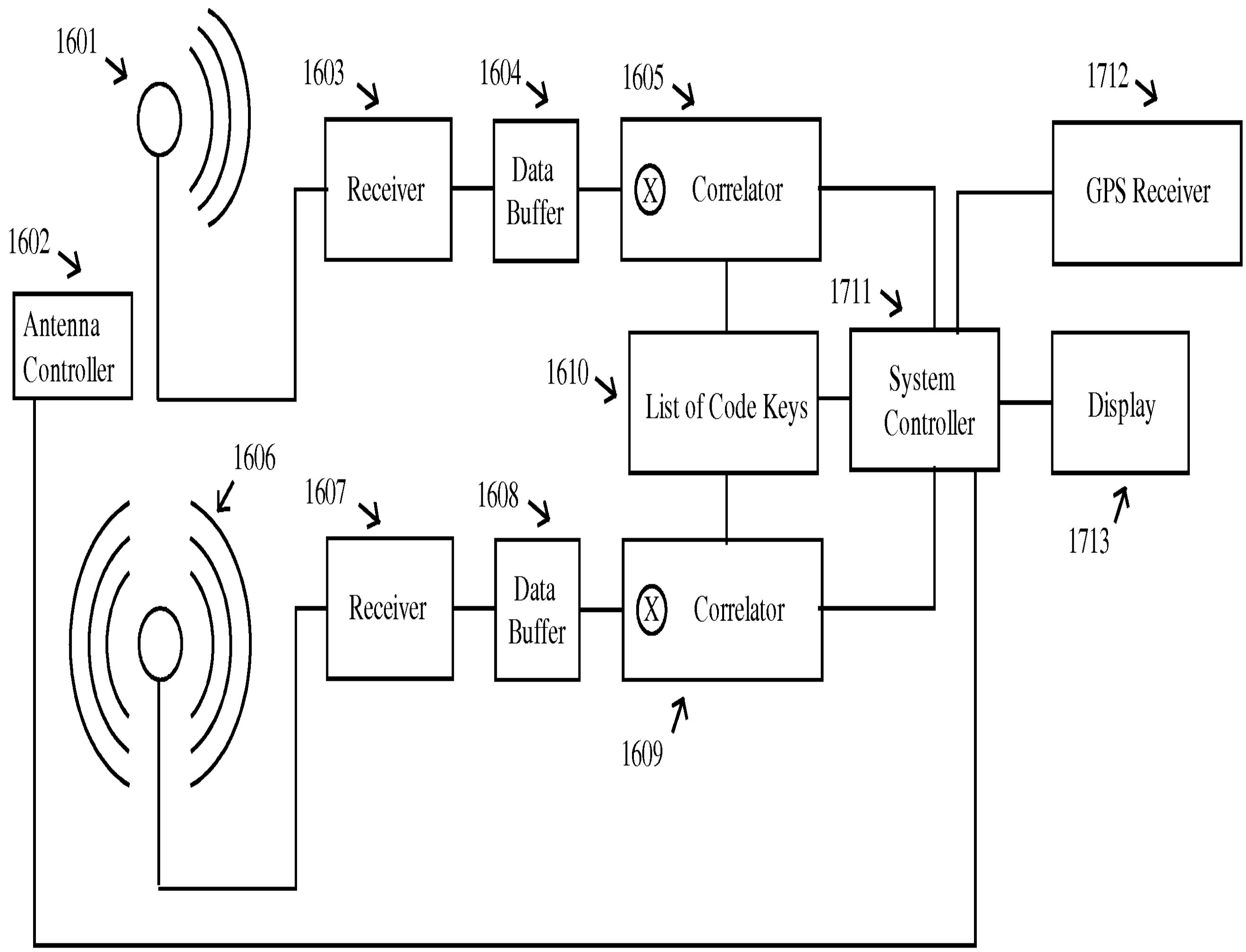
1601
1602
Antenna Controller
1603
Receiver
1604
Data Buffer
1605
X
Correlator
1712
GPS Receiver
1711
System Controller
1610
List of Code Keys
Display
1713
1606
1607
Receiver
1608
Data Buffer
X
Correlator
1609

Fig. 17

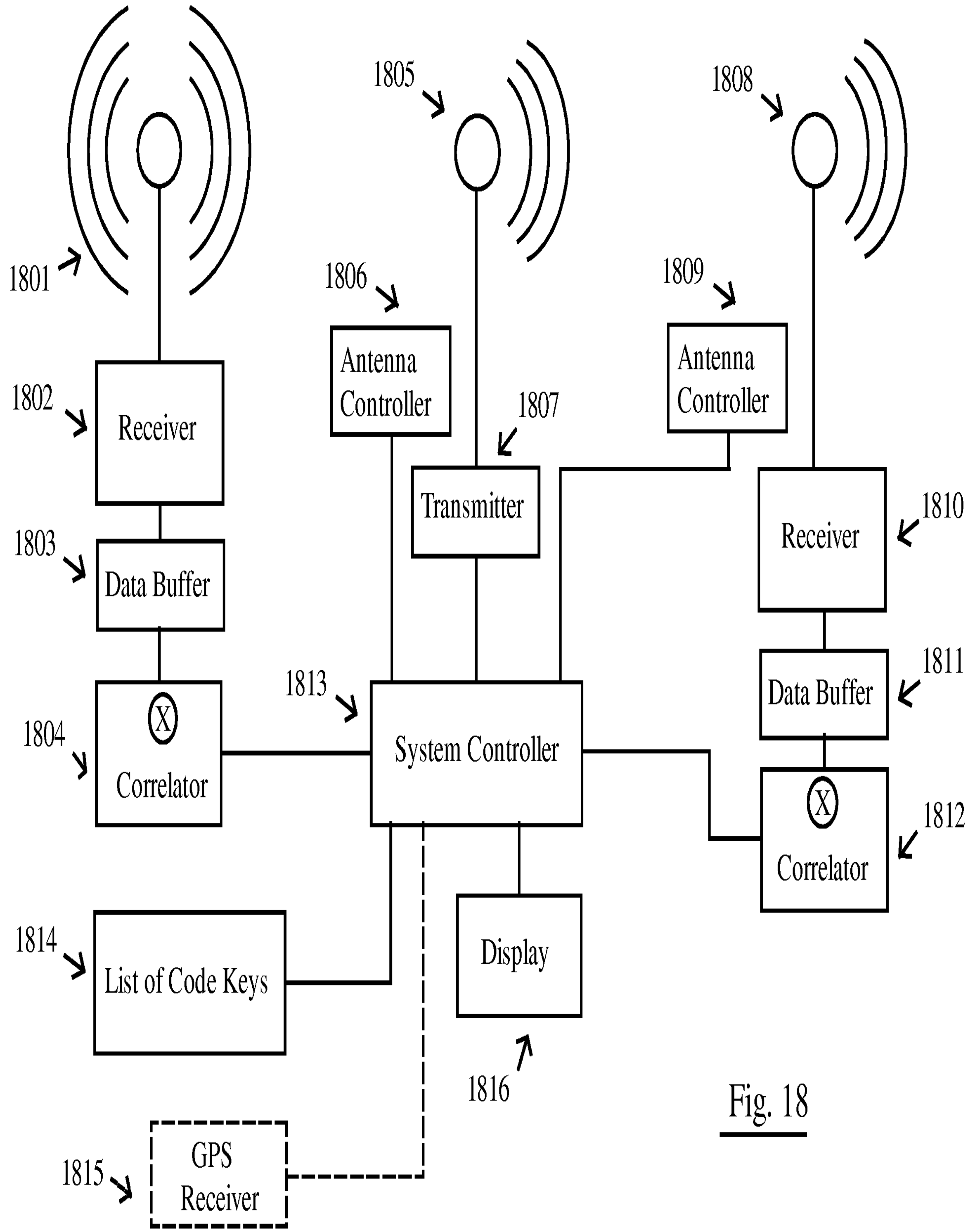
1801
1802
Receiver
1803
Data Buffer
1804
X
Correlator
1805
1806
Antenna Controller
1807
Transmitter
1808
1809
Antenna Controller
1810
Receiver
1811
Data Buffer
1812
X
Correlator
1813
System Controller
1814
List of Code Keys
1815
GPS Receiver
1816
Display

Fig. 18

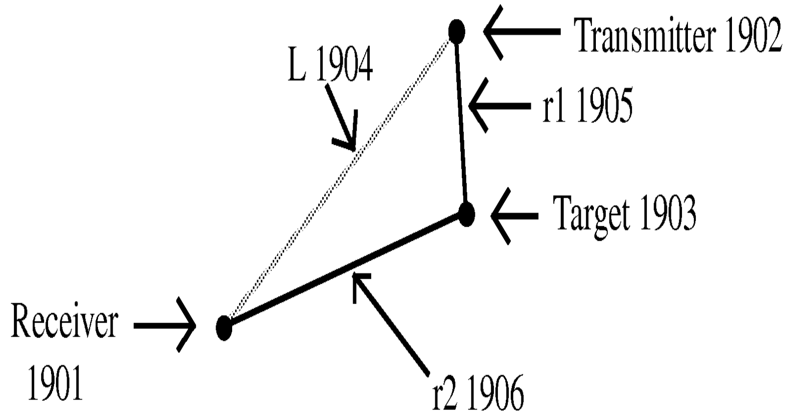
Transmitter 1902
L 1904
r1 1905
Target 1903
Receiver
1901
r2 1906

Fig. 19

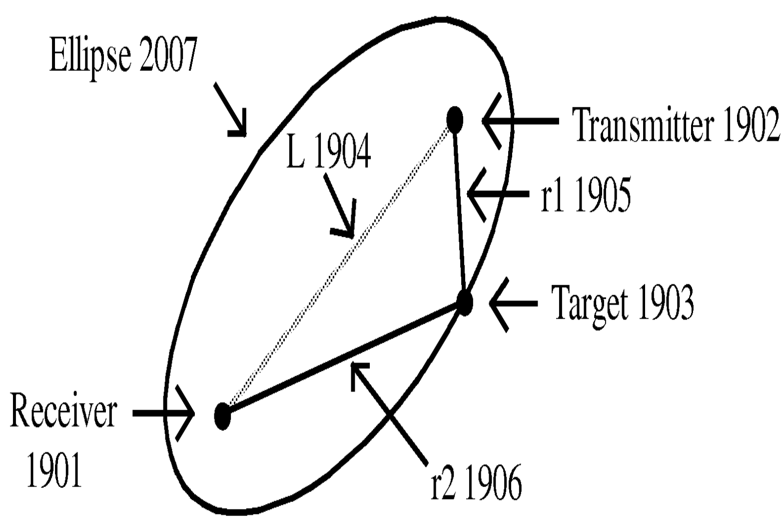
Ellipse 2007
Transmitter 1902
L 1904
r1 1905
Target 1903
Receiver
1901
r2 1906

Fig. 20

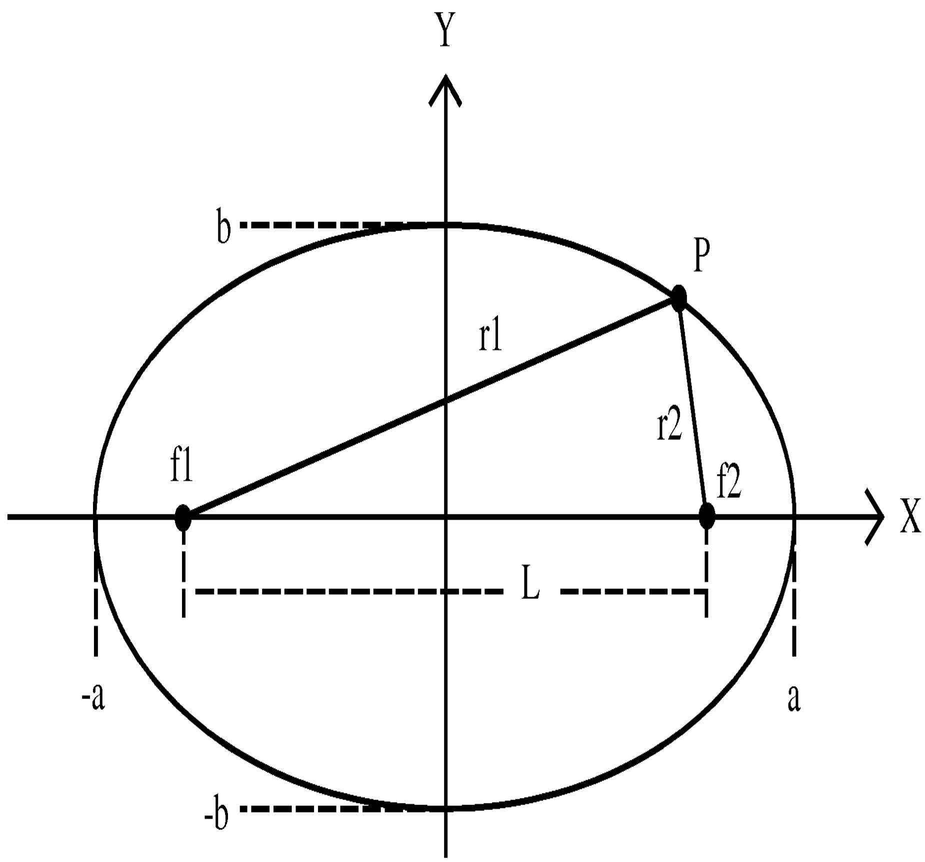

Fig. 21

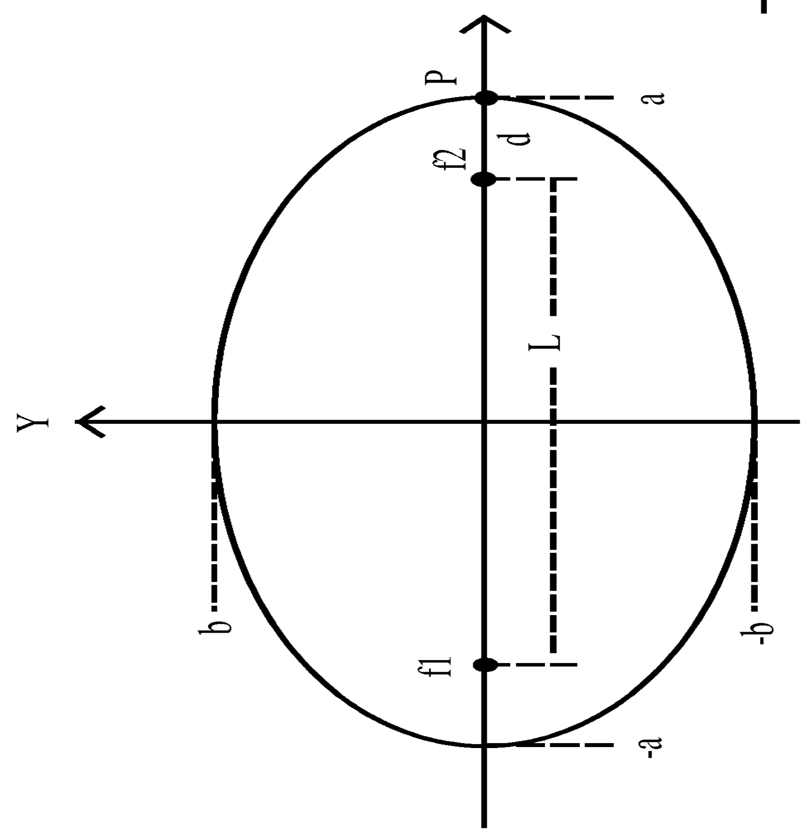

Fig. 22

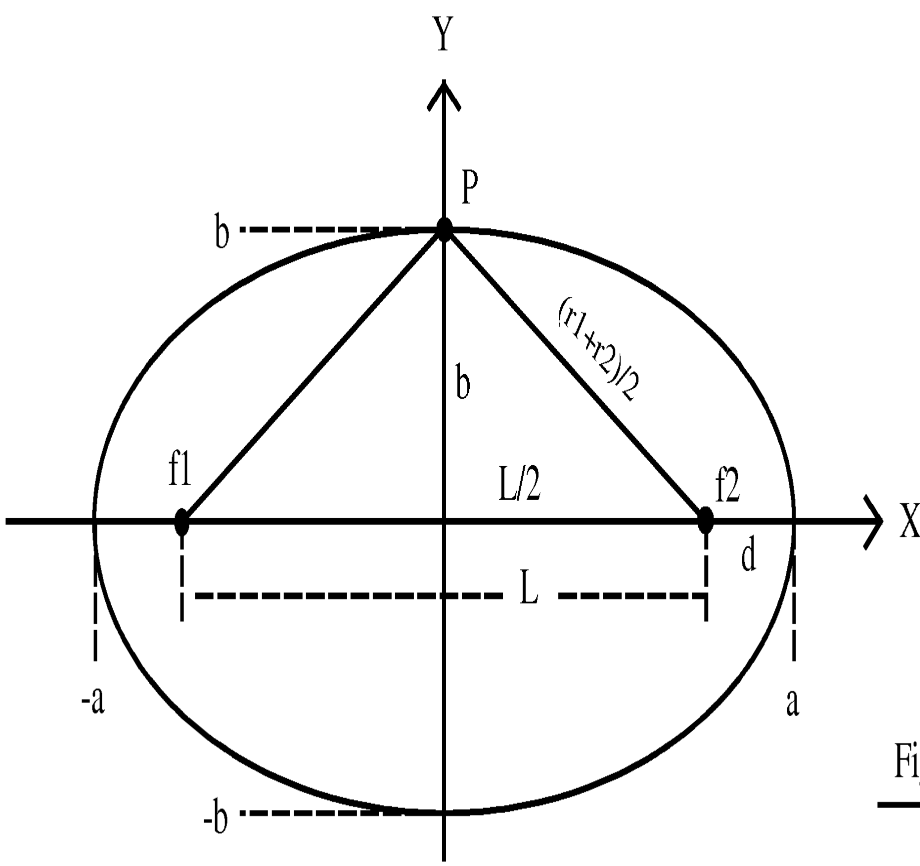

Fig. 23

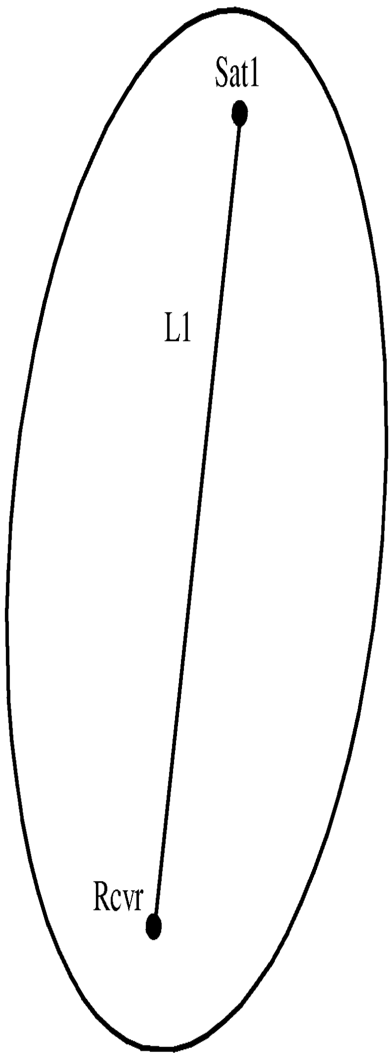

Fig. 24

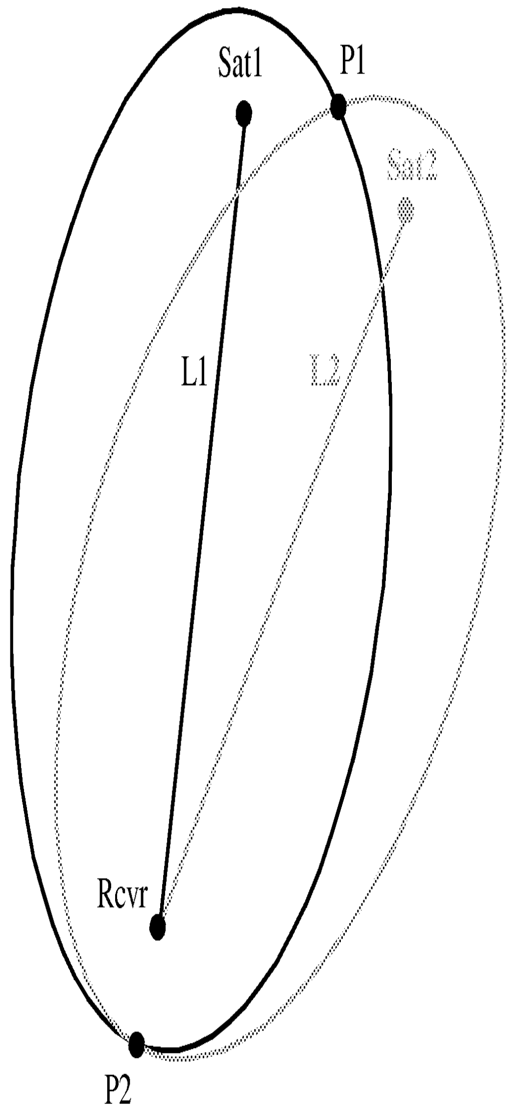

Fig. 25

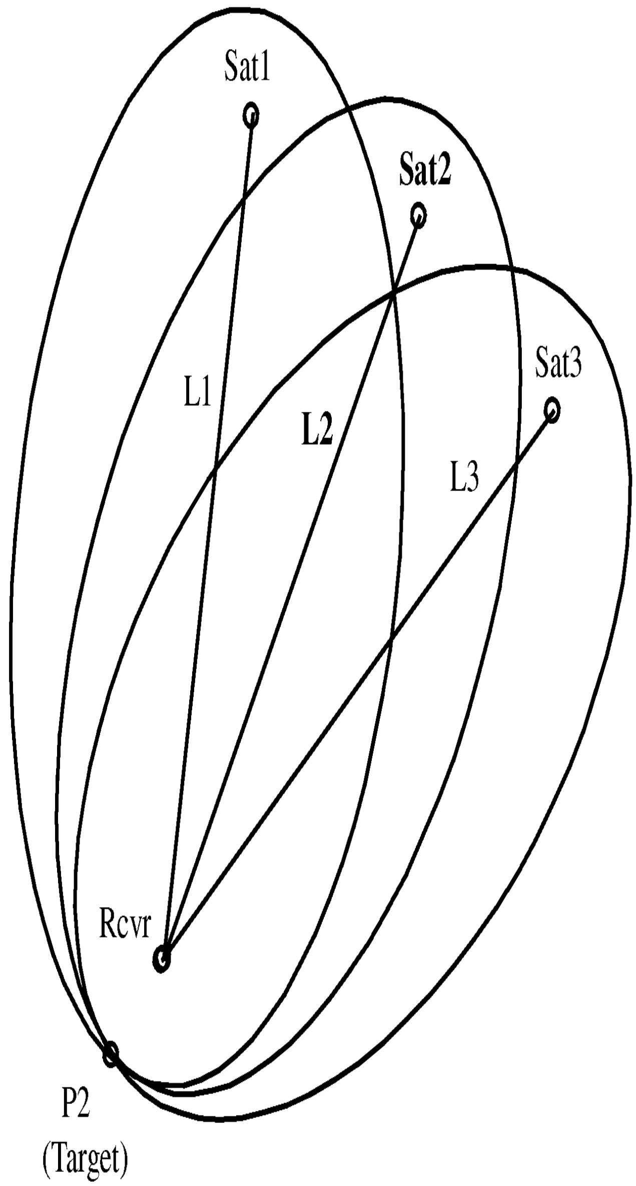

Fig. 26

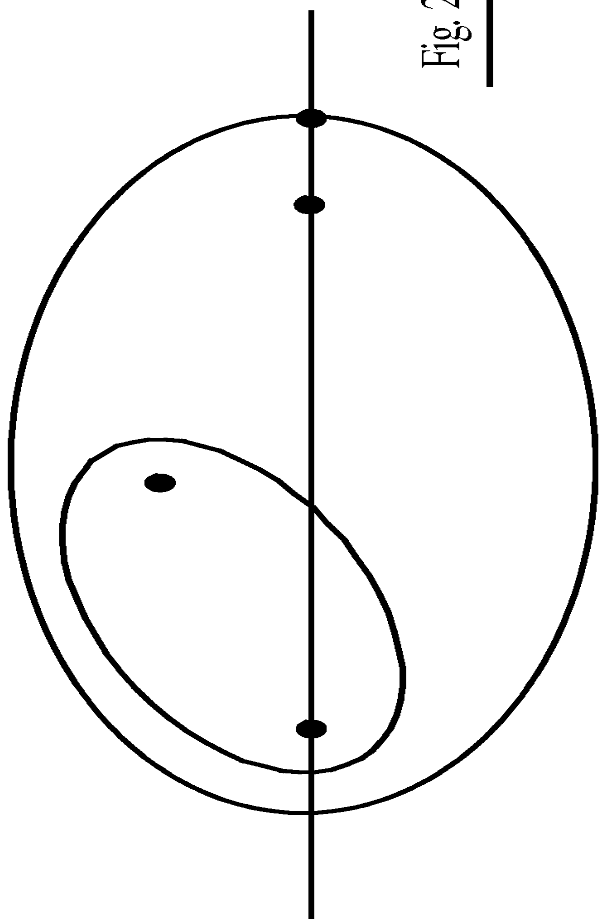

Fig. 27

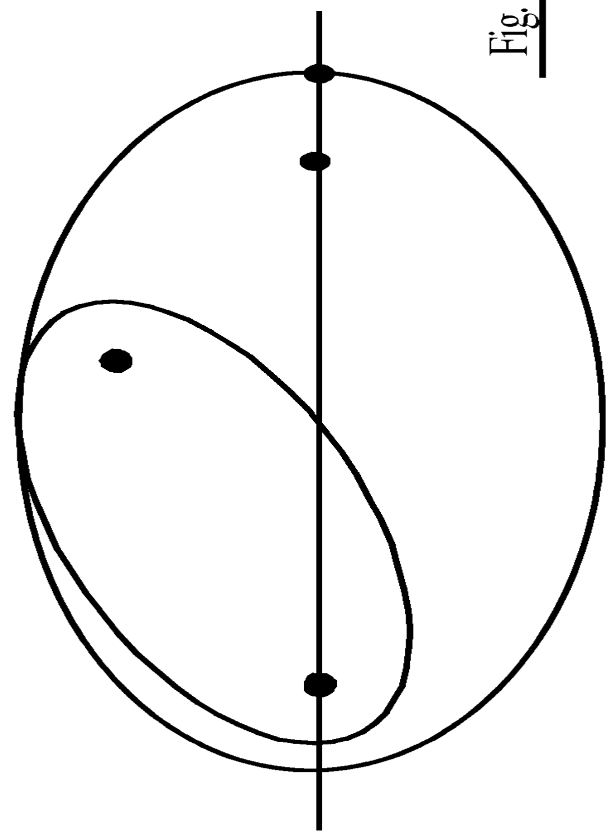

Fig. 28

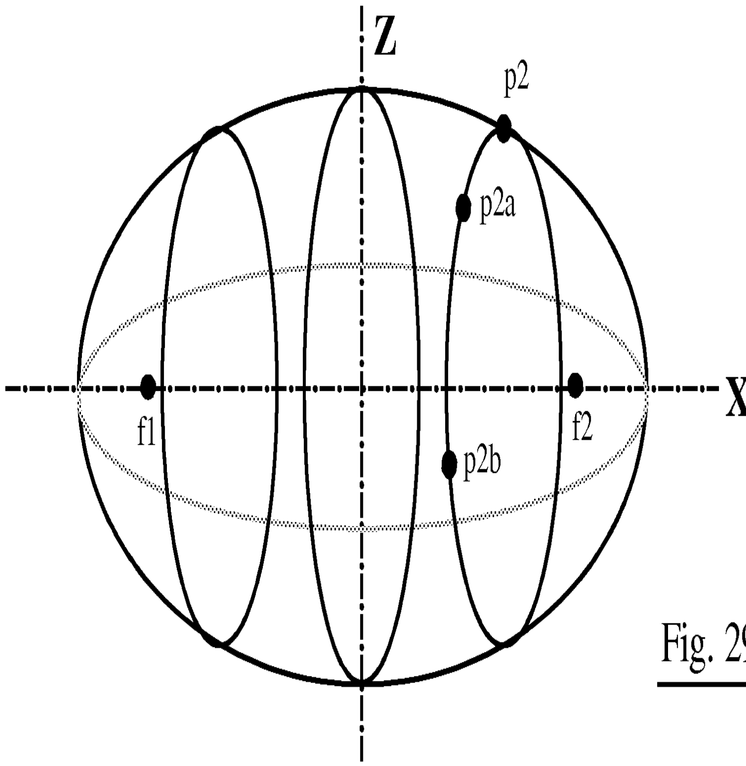

Fig. 29

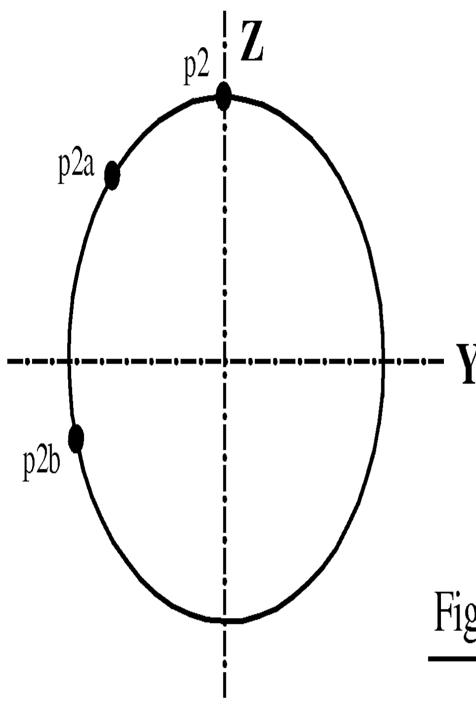

Fig. 30

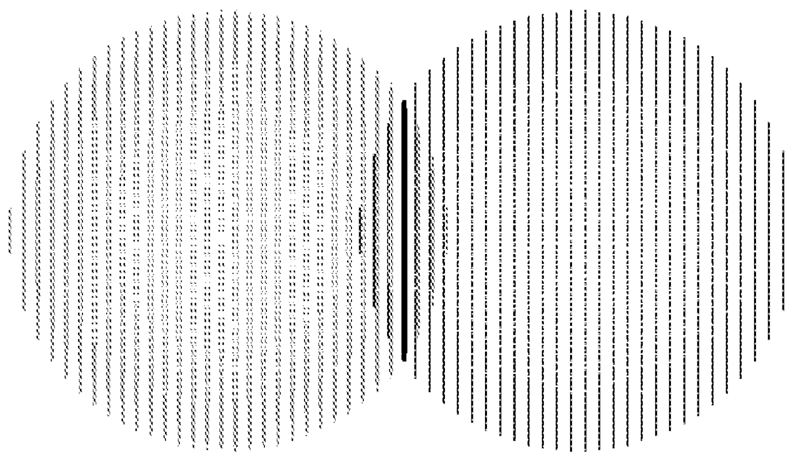

Fig. 31

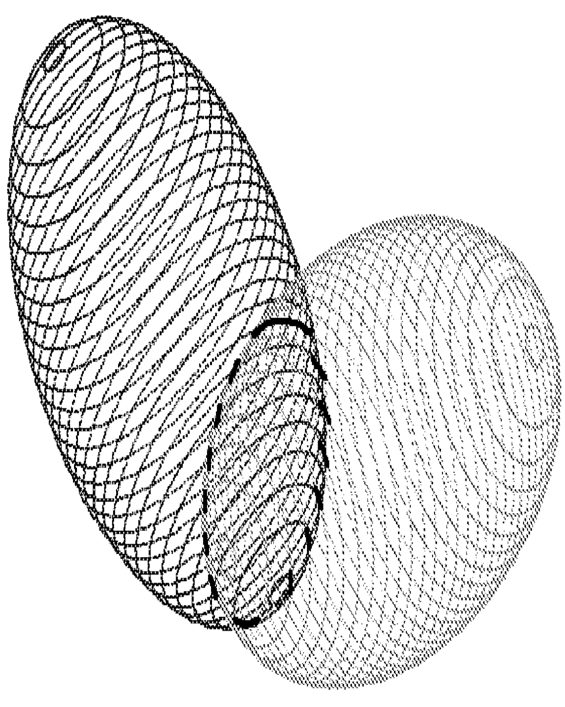

Fig. 32

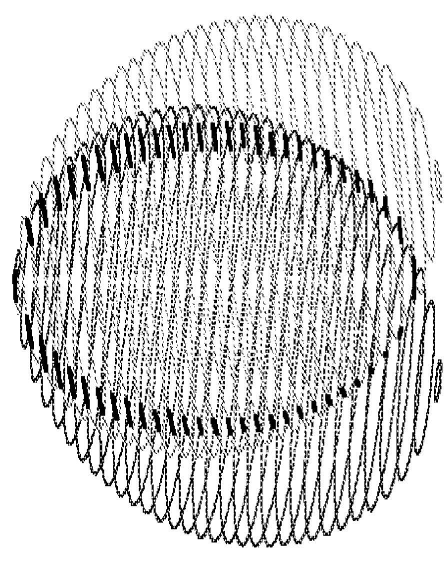

Fig. 33

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INFORMATION DISCLOSURE STATEMENT BY APPLICANT

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Sheet 1 of 4

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Filing Date	
First Named Inventor	Jed Margolin
Art Unit	
Examiner Name	
Attorney Docket Number	

U. S. PATENT DOCUMENTS

Examiner Initials*	Cite No.[1]	Document Number Number-Kind Code[2] (if known)	Publication Date MM-DD-YYYY	Name of Patentee or Applicant of Cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear
	3	US- 4,782,450	11-01-1998	Flax	Abstract
	5	US- 5,153,836	10-06-1992	Fraughton, et al.	Abstract
	7	US- 5,187,485	02-16-1993	Tsui, et al.	
	9	US- 5,724,041	03-03-1998	Inoue, et al.	Abstract
	11	US- 4,195,293	03-25-1980	Margolin	
	12	US- 3,986,168	12-12-1976	Anderson	
	13	US- 3,515,805	06-02-1970	Fracassi et al.	
	25	US- 6,377,436 B1	05-23-2002	Margolin	
		US- 7,737,878	06-15-2008	va Tooren, et al.	
		US- 5,036,330	07-30-1991	Imae, et al.	
		US- 5,955,993	09-21-1999	Houghton, et al.	
		US- 6,031,485	02-29-2000	Cellai, et al.	
		US-			
		US-			
		US-			
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Examiner Initials*	Cite No.[1]	Include name of the author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc.), date, page(s), volume-issue number(s), publisher, city and/or country where published.	T[2]
	1	14 CFR § 91.113(b) Right-of-way rules: Except water operations.	
	2	14 CFR § 91.115(a) Right-of-way rules: Water operations.	
	4	Introduction to TCAS II Version 7, United States Department of Transportation, Federal Aviation Administration November 2000, Page 11	
	6	Gulf of Mexico Helo Ops Ready for ADS-B, Aviation Week & Space Technology, FRANCIS FIORINO, 02/26/2007, page 56.	
	8	Test Results from a Novel Passive Bistatic GPS Radar Using a Phased Sensor Array, ALISON BROWN and BEN MATHEWS, NAVSYS Corporation, Proceedings of ION NTM 2007, San Diego, CA, January 2007. www.navsys.com/Papers/07-01-002.pdf	
	10	Shift Register With Feedback Generates White Noise, MARC DAMASHEK, Electronics magazine, May 27, 1976.	
	14	Shift Register Sequences, S. GOLOMB (Holden-Day Inc., San Francisco, 1967, and Aegean Park Press, 1982)	
	15	The ABCs of Spread Spectrum - A Tutorial, RANDY ROBERTS, Director of RF/Spread Spectrum Consulting. http://sss-mag.com/ss.html	
	16	Undetectable Radar? (Probably Not), ERIK HUNDMAN, Defensetech.org, August 3, 2006. http://www.defensetech.org/archives/002641.html	

Examiner Signature		Date Considered	

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Examiner Name	
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	17	From a Different Perspective: Principles, Practice, and Potential of Bistatic Radar by H.D. GRIFFITHS, Dept. of Electron. & Electr. Eng., Univ. Coll. London, UK; Radar Conference, 2003. Proceedings of the International; Publication Date: 3-5 Sept. 2003; ISBN: 0-7803-7870-9; INSPEC Accession Number: 7892750, Abstract	
	18	Sensing Requirements for Unmanned Air Vehicles, AFRL's Air Vehicles Directorate, Control Sciences Division, Systems Development Branch, Wright-Patterson AFB OH, June 2004, http://www.afrlhorizons.com/Briefs/Jun04/VA0306.html .	
	19	Presentation entitled, Developing Sense & Avoid Requirements for Meeting an Equivalent Level of Safety (6MB | ppt), given by RUSS WOLFE, Technology IPT Lead, Access 5 Project at UVS Tech 2006. 18 January 2006.	
	20	Presentation: Integration into the National Airspace System (NAS) given by JOHN TIMMERMAN of the FAA's Air Traffic Organization (July 12, 2005)	
	21	Zone Ready for Drone, April 7, 2006, on the web site for the FAA's Air Traffic Organization Employees, http://www.ato.faa.gov/DesktopDefault.aspx?tabindex=4&tabid=17&itemid=937&mid=103	

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First Named Inventor	Jed Margolin
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Attorney Docket Number	

NON PATENT LITERATURE DOCUMENTS

Examiner Initials*	Cite No.[1]	Include name of the author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc.), date, page(s), volume-issue number(s), publisher, city and/or country where published.	T[2]
	22	Quadrennial Roles and Missions Review Report, Department of Defense, January 2009, Page 29 (PDF page 37) www.defenselink.mil/news/Jan2009/QRMFinalReport_v26Jan.pdf	
	23	Analog Devices, Inc. AD9481: 8-Bit, 250 MSPS, 3.3 V A/D Converter http://www.analog.com/en/analog-to-digital-converters/ad-converters/ad9481/products /product.html	
	24	Texas Instruments C6713B http://focus.ti.com/docs/prod/folders/print/tms320c6713b.html#features	
	26	Simple Solutions for Hyperbolic and Related Position Fixes, BERTRAND T. FANG, The Analytic Sciences Corp.; IEE Transactions on Aerospace and Electronic Systems, Publication Date: Sep 1990; Volume: 26, Issue: 5; page(s): 748-753; ISSN: 0018-9251, Page 751 https://svn.v2.nl/andres/Documentation/TDOA/Simple_Solutions_for_TDOA-fang.pdf	
	27	Lissajous Figures, JED MARGOLIN, May 2001; http://www.jmargolin.com/mtest/LJfigs.htm	

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Electronic Code of Federal Regulations
e-CFR™

e-CFR Data is current as of October 1, 2009

Title 14: Aeronautics and Space

PART 91—GENERAL OPERATING AND FLIGHT RULES
Subpart B—Flight Rules
General

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§ 91.113 Right-of-way rules: Except water operations.

(a) *Inapplicability.* This section does not apply to the operation of an aircraft on water.

(b) *General.* When weather conditions permit, regardless of whether an operation is conducted under instrument flight rules or visual flight rules, vigilance shall be maintained by each person operating an aircraft so as to see and avoid other aircraft. When a rule of this section gives another aircraft the right-of-way, the pilot shall give way to that aircraft and may not pass over, under, or ahead of it unless well clear.

(c) *In distress.* An aircraft in distress has the right-of-way over all other air traffic.

(d) *Converging.* When aircraft of the same category are converging at approximately the same altitude (except head-on, or nearly so), the aircraft to the other's right has the right-of-way. If the aircraft are of different categories—

(1) A balloon has the right-of-way over any other category of aircraft;

(2) A glider has the right-of-way over an airship, powered parachute, weight-shift-control aircraft, airplane, or rotorcraft.

(3) An airship has the right-of-way over a powered parachute, weight-shift-control aircraft, airplane, or rotorcraft.

However, an aircraft towing or refueling other aircraft has the right-of-way over all other engine-driven aircraft.

(e) *Approaching head-on.* When aircraft are approaching each other head-on, or nearly so, each pilot of each aircraft shall alter course to the right.

(f) *Overtaking.* Each aircraft that is being overtaken has the right-of-way and each pilot of an overtaking aircraft shall alter course to the right to pass well clear.

(g) *Landing.* Aircraft, while on final approach to land or while landing, have the right-of-way over other aircraft in flight or operating on the surface, except that they shall not take advantage of this rule to force an aircraft off the runway surface which has already landed and is attempting to make way for an aircraft on final approach. When two or more aircraft are approaching an airport for the purpose of landing, the aircraft at the lower altitude has the right-of-way, but it shall not take advantage of this rule to cut in front of another which is on final approach to land or to overtake that aircraft.

[Doc. No. 18334, 54 FR 34294, Aug. 18, 1989, as amended by Amdt. 91-282, 69 FR 44880, July 27, 2004]

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e-CFR™

e-CFR Data is current as of October 1, 2009

Title 14: Aeronautics and Space

PART 91—GENERAL OPERATING AND FLIGHT RULES
Subpart B—Flight Rules
General

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§ 91.115 Right-of-way rules: Water operations.

(a) *General.* Each person operating an aircraft on the water shall, insofar as possible, keep clear of all vessels and avoid impeding their navigation, and shall give way to any vessel or other aircraft that is given the right-of-way by any rule of this section.

(b) *Crossing.* When aircraft, or an aircraft and a vessel, are on crossing courses, the aircraft or vessel to the other's right has the right-of-way.

(c) *Approaching head-on.* When aircraft, or an aircraft and a vessel, are approaching head-on, or nearly so, each shall alter its course to the right to keep well clear.

(d) *Overtaking.* Each aircraft or vessel that is being overtaken has the right-of-way, and the one overtaking shall alter course to keep well clear.

(e) *Special circumstances.* When aircraft, or an aircraft and a vessel, approach so as to involve risk of collision, each aircraft or vessel shall proceed with careful regard to existing circumstances, including the limitations of the respective craft.

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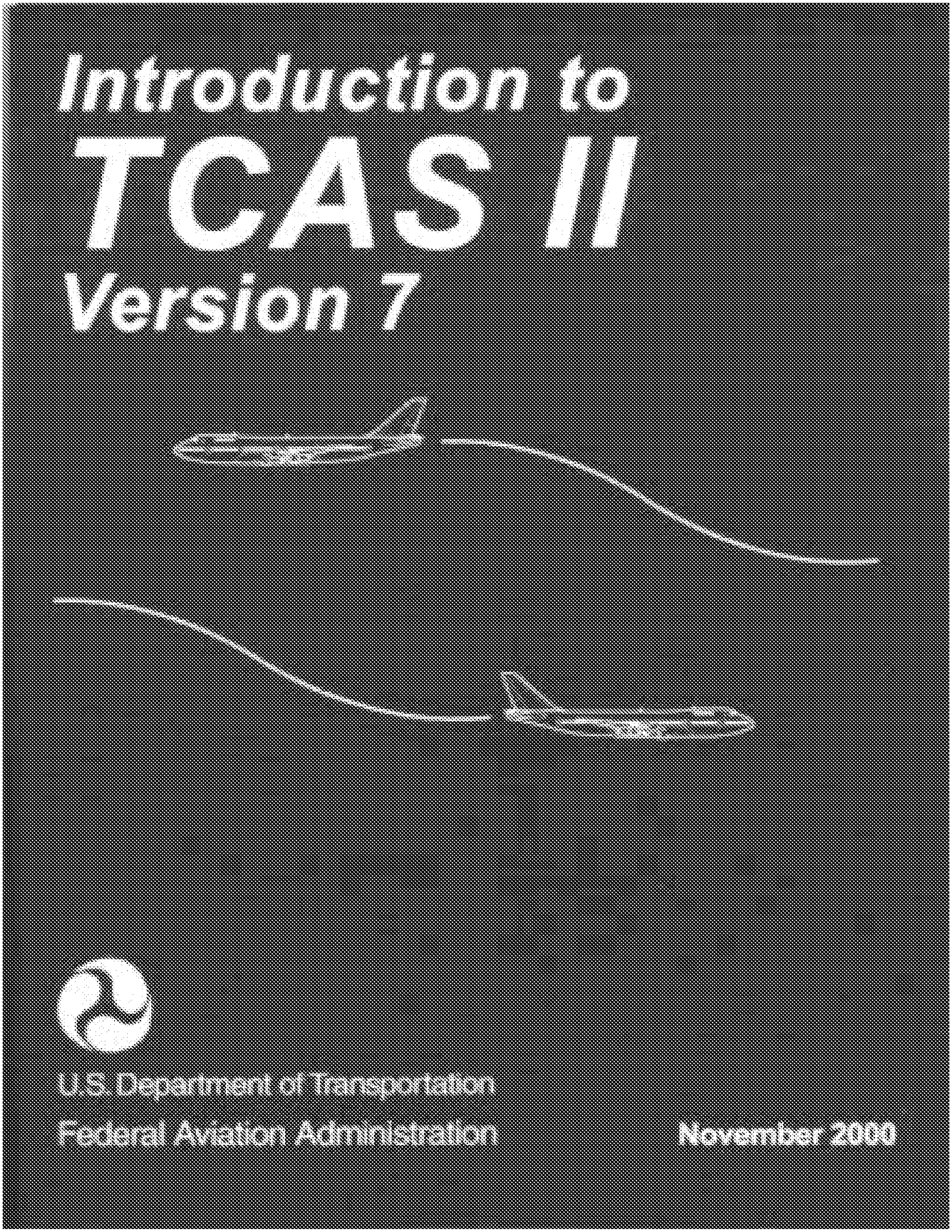

Introduction to
TCAS II
Version 7
U.S. Department of Transportation
Federal Aviation Administration
November 2000

Preface

This booklet provides the background for a better understanding of the Traffic Alert and Collision Avoidance System (TCAS II) by personnel involved in the implementation and operation of TCAS II. This booklet is an update of a similar booklet published in 1990 by the Federal Aviation Administration (FAA). This update describes TCAS II Version 7.

Table of Contents

The TCAS Solution

After many years of extensive analysis, development, and flight evaluation by the Federal Aviation Administration (FAA), other countries' Civil Aviation Authorities (CAAs), and the aviation industry, a solution has been found to reduce the risk of midair collisions between aircraft. This solution is known as the Traffic Alert and Collision Avoidance System or TCAS. In the international arena, the system is known as the Airborne Collision Avoidance System or ACAS.

TCAS is a family of airborne devices that function independently of the ground-based air traffic control (ATC) system and provide collision avoidance protection for a broad spectrum of aircraft types.

TCAS I provides traffic advisories (TA) and proximity warning of nearby traffic to assist the pilot in the visual acquisition of intruder aircraft. TCAS I is mandated for use in the United States for turbine-powered, passenger-carrying aircraft having more than 10 and less than 31 seats. TCAS I is also used by a number of general aviation fixed and rotary wing aircraft.

TCAS II provides traffic advisories and resolution advisories (RA), i.e., recommended escape maneuvers, in the vertical dimension to either increase or maintain the existing vertical separation between aircraft. Airline aircraft, including regional airline aircraft with more than 30 seats, and general aviation turbine-powered aircraft use TCAS II equipment.

The TCAS concept uses the same radar beacon transponders installed on aircraft to operate with ATC ground-based radars. The level of protection provided by TCAS equipment depends on the type of transponder the target aircraft is carrying. The level of protection is outlined in Table 1. It should be noted that TCAS provides no protection against aircraft that do not have an operating transponder.

Table 1. TCAS Levels of Protection

		Own Aircraft Equipment	
		TCAS I	**TCAS II**
Target Aircraft Equipment	Mode A XPDR ONLY	TA	TA
	Mode C or MODE S XPDR	TA	TA and Vertical RA
	TCAS I	TA	TA and Vertical RA
	TCAS II	TA	TA and Coordinated Vertical RA

Based on a Congressional mandate (Public Law 100-223), the FAA has issued a rule that requires all passenger-carrying aircraft with more than 30 seats be equipped with TCAS II.

Since the early 1990s, an operational evaluation, known as the TCAS Transition Program (TTP), has collected and analyzed a significant amount of data related to the performance and use of TCAS II in both the U.S. National Airspace System (NAS) and in other airspace worldwide. As a result of these analyses, changes to TCAS II have been developed, tested, and implemented. The latest changes, collectively known as TCAS II Version 7, were certified in early 2000 and are now being implemented by the industry.

TCAS II Version 7 is the only version of TCAS II that complies with the ICAO Standards and Recommended Practices (SARPs) for ACAS II. As such, Version 7 is currently being mandated for carriage in certain countries or regions, e.g., Europe, Australia, and India, and has been mandated for carriage in 2003 by the International Civil Aviation Organization (ICAO).

Background

The development of an effective airborne collision avoidance system has been a goal of the aviation industry for a number of years. As air traffic has continued to grow over the years, development of and improvements to ATC systems and procedures have made it possible for controllers and pilots to cope with this increase in operations, while maintaining the necessary levels of flight safety. However, the risk of airborne collision remains. That is why, as early as the 1950s, the concept and initial development of an airborne collision avoidance system, acting as a last resort, was being considered.

A series of midair collisions that occurred in the United States, has been the impetus for the development and refinement of an airborne collision avoidance system. These tragic milestones included the following collisions:

- In 1956, the collision between two airliners over the Grand Canyon spurred both the airlines and the aviation authorities to initiate system development studies for an effective system.
- In 1978, the collision between a light aircraft and an airliner over San Diego led the FAA to initiate the development of **TCAS.**
- Finally, in 1986, the collision between a DC-9 and a private aircraft over Cerritos, California, resulted in a Congressional mandate that required some categories of American and foreign aircraft to be equipped with TCAS for flight operations in U.S. airspace.

In parallel to the development of TCAS equipment in the United States, ICAO has been working since the early 1980s to develop standards for **ACAS**. **ICAO officially recognized ACAS on 11 November 1993**. Its descriptive definition appears in Annex 2 of the Convention on International Civil Aviation and its use is regulated in Procedures for Air Navigation Services — Aircraft Operations (PANS-OPS) and Procedures for Air Navigation Services — Rules of the Air and Air Traffic Services (PANS-RAC). In November 1995, the SARPs and Guidance Material for ACAS II were approved, and they appear in Annex 10 of the Convention on International Civil Aviation.

During the late 1950s and early 1960s, collision avoidance development efforts included an emphasis on passive and noncooperating systems. These concepts proved to be impractical. One major operational problem that could not be overcome with these designs was the need for nonconflicting, complementary avoidance maneuvers that require a high-integrity communications link between aircraft involved in the conflict.

One of the most important developments in the collision avoidance concept was the derivation of the range/range rate, or tau, concept by Dr. John S. Morrell of Bendix. This concept is based on time, rather than distance, to the closest point of approach in an encounter.

During the late 1960s and early 1970s, several manufacturers developed aircraft collision avoidance systems based on interrogator/transponder and time/frequency techniques. Although these systems functioned properly during staged aircraft encounter testing, the FAA and the airlines jointly concluded that in normal airline operations, they would generate a high rate of unnecessary alarms in dense terminal areas. This problem would have undermined the credibility of the system with the flight crews. In addition, each target aircraft would have to be equipped with the same equipment to provide protection to an equipped aircraft.

In the mid 1970s, the Beacon Collision Avoidance System (BCAS) was developed. BCAS used reply data from the Air Traffic

Control Radar Beacon System (ATCRBS) transponders to determine an intruder's range and altitude. At that time, ATCRBS transponders were installed in all airline and military aircraft and a large number of general aviation aircraft. Thus, any BCAS-equipped aircraft would be able to detect and be protected against the majority of other aircraft in the air without imposing additional equipment requirements on those other aircraft. In addition, the discrete address communications techniques used in the Mode S transponders then under development permitted two conflicting BCAS aircraft to perform coordinated escape maneuvers with a high degree of reliability.

TCAS II development

In 1981, the FAA made a decision to develop and implement TCAS utilizing the basic BCAS design for interrogation and tracking, but providing additional capabilities.

TCAS is designed to work autonomously of the aircraft navigation equipment and independently of the ground systems used to provide ATC services. TCAS interrogates ICAO-compliant transponders of all aircraft in the vicinity and based on the replies received, tracks the slant range, altitude (when it is included in the reply message), and bearing of surrounding traffic. From several successive replies, TCAS calculates a time to reach the CPA (Closest Point of Approach) with the intruder, by dividing the range by the closure rate. This time value is the main parameter for issuing alerts. If the transponder replies from nearby aircraft includes their altitude, TCAS also computes the time to reach co-altitude. TCAS can issue two types of alerts:

- TAs to assist the pilot in the visual search for the intruder aircraft and to prepare the pilot for a potential RA; and
- RAs to recommend maneuvers that will either increase or maintain the existing vertical separation from an intruder aircraft. When the intruder aircraft is also fitted with TCAS II, both TCAS' coordinate their RAs through the Mode S data link to ensure that complementary resolution senses are selected.

TCAS II is designed to operate in traffic densities of up to 0.3 aircraft per square nautical mile (nmi), i.e., 24 aircraft within a 5 nmi radius, which is the highest traffic density envisioned over the next 20 years.

Development of the TCAS II collision avoidance algorithms included the completion of millions of computer simulations to optimize the protection provided by the system, while minimizing the frequency of unacceptable or nuisance advisories. In addition to these computer simulations, early versions of the collision avoidance algorithms were evaluated via pilot in the loop simulations and during the operation of prototype equipment in FAA aircraft throughout the NAS.

Extensive safety studies were also performed to estimate the safety improvements that could be expected with the introduction of TCAS into service. These safety studies have been continuously updated throughout the refinement of the collision avoidance algorithms. The safety studies have shown that TCAS II will resolve nearly all of the critical near midair collisions involving airline aircraft. However, TCAS cannot handle all situations. In particular, it is dependent on the accuracy of the threat aircraft's reported altitude and on the expectation that the threat aircraft will not make an abrupt maneuver that defeats the TCAS RA. The safety study also shows that TCAS II will induce some critical near midair collisions, but overall, the number of near midair collisions with TCAS is less than 10% of the number that would have occurred without the presence of TCAS.

Extensive studies were also carried out to evaluate the interaction between TCAS and

ATC. The analysis of ATC radar data showed that in 90% of the cases, the vertical displacement required to resolve an RA was less than 300 feet. Based on these studies, it was concluded that the possibility of the response to a TCAS RA causing an aircraft to infringe on the protected airspace for another aircraft was remote. However, operational experience has shown that the actual displacement resulting from an RA response is often much greater than 300 feet, and TCAS has had an adverse affect on the controllers and the ATC system. Because of this operational experience, Version 7 contains numerous changes and enhancements to the collision avoidance algorithms, the aural annunciations, the RA displays, and pilot training programs to minimize the displacement while responding to an RA.

In-Service Operational Evaluations

To ensure that TCAS performed as expected in its intended operational environment, several operational evaluations of the system have been conducted. These evaluations provided a means for the pilots using TCAS and the controllers responsible for providing separation services to TCAS-equipped aircraft to have a direct influence on the final system design and performance requirements.

The initial operational evaluation of TCAS was conducted by Piedmont Airlines in 1982. Using a TCAS II prototype unit manufactured by Dalmo Victor, Piedmont flew approximately 900 hours in scheduled, revenue service while recording data on the performance of TCAS. These recorded data were analyzed to assess the frequency and suitability of the TAs and RAs. During this evaluation, the TCAS displays were not visible to the pilots, and observers from the aviation industry flew with the aircraft to monitor the system performance and to provide technical and operational comments on its design.

In 1987, Piedmont flew an upgraded version of the Dalmo Victor equipment for approximately 1200 hours. During this evaluation, the TCAS displays were visible to the pilots and the pilots were permitted to use the information provided to maneuver the aircraft in response to RAs. This installation included a dedicated TCAS data recorder so that quantitative data could be obtained on the performance of TCAS. In addition, pilot and observers completed questionnaires following each TA and RA so that assessments could be made regarding the value of the system to the flight crews.

This evaluation also provided the basis for the development of avionics certification criteria for production equipment, validated pilot training guidelines, provided the justification for improvements to the TCAS algorithms and displays, and validated the pilot procedures for using the equipment.

Following the successful completion of the second Piedmont evaluation, the FAA initiated the Limited Installation Program (LIP). Under the LIP, Bendix-King and Honeywell built and tested commercial quality, pre-production TCAS II equipment that was in compliance with the TCAS II Minimum Operational Performance Standards (MOPS). Engineering flight tests of this equipment were conducted on the manufacturers' aircraft, as well as FAA aircraft. Using data collected during these flight tests, together with data collected during factory and ground testing, both manufacturers' equipment was certified via a Supplemental Type Certificate (STC) for use in commercial, revenue service.

The Bendix-King units were operated by United Airlines on a B737-200 and a DC8-73 aircraft. Northwest Airlines operated the Honeywell equipment on two MD-80 aircraft. Over 2000 hours of operating experience were obtained with the United aircraft and approximately 2500 hours of operating experience were obtained with the Northwest installations.

The experience provided by these operational evaluations resulted in further enhancements to the TCAS II logic, improved test procedures, and finalized the procedures for certification of production equipment. The most important information obtained from the operational evaluations was the nearly unanimous conclusion that TCAS II was safe, operationally effective, and ready for more widespread implementation.

With the successful completion of these early operational evaluations, there was a high degree of confidence that a system with sufficient maturity was available to meet the Congressionally mandated implementation of TCAS II in U.S. airspace.

As part of this mandated implementation , the largest operational evaluation of TCAS, known as the TTP, was initiated. The TTP began in late 1991 and has continued through the initial implementation, the mandated upgrade to Version 6.04A Enhanced, and is still active as Version 7 enters operation. In conjunction with the TTP in the U.S., EUROCONTROL has conducted extensive evaluations of TCAS operations in Europe, and the Japan Civil Aviation Bureau (JCAB) has conducted similar assessments of TCAS II performance in Japanese and surrounding airspace. Other countries also conducted operational evaluations as the use of TCAS increased during the past 10 years.

The system improvements suggested as a result of these TCAS II evaluations led to the development and release of Version 6.04A Enhanced in 1993. The principal aim of this modification was the reduction of nuisance alerts, which were occurring at low altitudes and during level-off encounters, and the correction of a problem in the altitude crossing logic.

After the implementation of Version 6.04A Enhanced, operational evaluations continued with the same objective, and proposed performance improvements led to the development of Version 7. The MOPS for Version 7 was approved in December 1997 and Version 7 units became available for installation in late 1999. Version 7 is expected to further improve TCAS compatibility with the air traffic control system throughout the world.

Toward a Requirement for Worldwide Carriage

The United States was the first member of ICAO to mandate carriage of an airborne collision avoidance system for passenger carrying aircraft operating in its airspace.

Because of this mandate, the number of long-range aircraft fitted with TCAS II and operating in European and Asian airspace continued to increase, although the system carriage and operation were not mandatory in this airspace. As studies, operational experience, and evaluations continued to demonstrate the safety benefits of TCAS II, some non-U.S. airlines also equipped their short-haul fleets with TCAS.

In 1995, the EUROCONTROL Committee of Management approved an implementation policy and schedule for the mandatory carriage of TCAS II in Europe. The European Air Traffic Control Harmonization and Integration Program (EATCHIP) Project Board then ratified this policy. The approved policy requires the following:

- From 1 January 2000, all civil fixed-wing, turbine-powered aircraft having a maximum take-off mass exceeding 15,000 kg, or a maximum approved passenger seating configuration of more than 30, will be required to be equipped with TCAS II, Version 7; and
- From 1 January 2005, all civil fixed-wing, turbine-powered aircraft having a maximum take-off mass exceeding 5,700 kg, or a maximum approved passenger seating configuration of more that 19, will be required to be equipped with TCAS II, Version 7.

Because of delays in obtaining Version 7 equipment, a number of exemptions to the 1 January 2000 date were granted by EUROCONTROL. Each of the exemptions granted have a unique end date for the exemption, but all exemptions will expire on 31 March 2001.

Other countries, including Argentina, Australia, Chile, Egypt, India, and Japan, have also mandated carriage of TCAS II avionics on aircraft operating in their respective airspace.

The demonstrated safety benefits of the equipment, and the 1996 midair collision between a Saudia Boeing 747 and a Kazakhstan Ilyushin 76, resulted in an ICAO proposal for worldwide mandatory carriage of ACAS II on all aircraft, including cargo aircraft, beginning in 2003. To guarantee the effectiveness of this mandate, ICAO has also mandated the carriage and use of pressure altitude reporting transponders, which are a prerequisite for generating RAs.

After the mid-air collision between a German Air Force Tupolev 154 and a U.S. Air Force C-141 transport aircraft, off Namibia in September 1997, urgent consideration was given to the need to equip military transport aircraft with TCAS. Although only a limited number of countries have included military and other government-owned aircraft in their mandates for TCAS carriage, several countries, including the United States, have initiated programs to equip tanker, transport, and cargo aircraft within their military fleets with TCAS II Version 7.

Standards and Guidance Material

The data obtained from the FAA and industry sponsored studies, simulations, flight tests, and operational evaluations have enabled RTCA to publish the MOPS for TCAS II. The current version of the MOPS, DO-185A, describes the standards, requirements, and test procedures for TCAS Version 7.

RTCA has also published MOPS for TCAS I, DO-197A, which defines the requirements and test procedures for TCAS I equipment intended for use on airline aircraft operated in revenue service.

The FAA has issued Technical Standard Order (TSO) C118a that defines the requirements for the approval of TCAS I equipment. A draft Advisory Circular outlining the certification requirements and the requirements for obtaining operational approval of the system has been prepared and is being used by the FAA's Aircraft Certification Offices (ACO) as the basis for approving TCAS I installations and operation.

For TCAS II, TSO C119b and Advisory Circular 20-131a have been published for use by FAA airworthiness authorities in certifying the installation of TCAS II on various classes of aircraft. Advisory Circular 120-55a defines the procedures for obtaining operational approval for the use of TCAS II. While the FAA developed these documents, they have been used throughout the world by civil aviation authorities to approve the installation and use of TCAS.

ICAO SARPs and Guidance Material for ACAS I and ACAS II have been published in Annex 10. The procedures for use of ACAS have been published in PANS-RAC and PANS-OPS. These documents provide international standardization for collision avoidance systems.

For the avionics, the Airlines Electronic Engineering Committee (AEEC) has completed work on ARINC Characteristic 735 to define the form, fit, and function of TCAS II units. Similar work on the Mode S transponder has been competed, and the results of that work are contained in ARINC Characteristic 718.

TCAS II Technical Description

System components

Figure 1 is a block diagram of TCAS II. A TCAS II installation consists of the following major components.

TCAS Computer Unit

The TCAS Computer Unit, or TCAS Processor, performs airspace surveillance, intruder tracking, its own aircraft altitude tracking, threat detection, RA maneuver determination and selection, and generation of advisories. The TCAS Processor uses pressure altitude, radar altitude, and discrete aircraft status inputs from its own aircraft to control the collision avoidance logic parameters that determine the protection volume around the TCAS aircraft. If a tracked aircraft is a collision threat, the processor selects an avoidance maneuver that will provide adequate vertical miss distance from the intruder while minimizing the perturbations to the existing flight path. If the threat aircraft is also equipped with TCAS II, the avoidance maneuver will be coordinated with the threat aircraft.

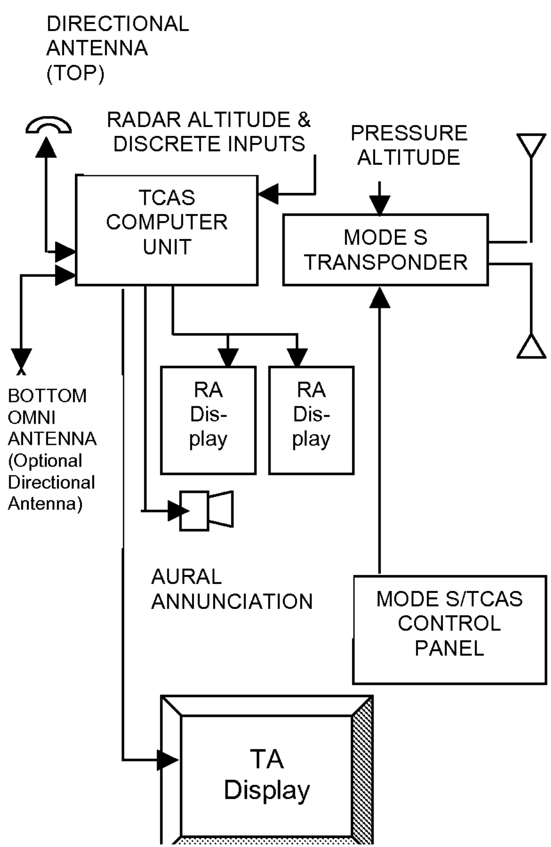


Figure 1. TCAS II Block Diagram

Mode S Transponder

A Mode S transponder is required to be installed and operational for TCAS II to be operational. If the Mode S transponder fails, the TCAS Performance Monitor will detect this failure and automatically place TCAS into Standby. The Mode S transponder performs the normal functions to support the ground-based ATC system and can work with either an ATCRBS or a Mode S ground sensor. The Mode S transponder is also used to provide air-to-air data exchange between TCAS-equipped aircraft so that coordinated, complementary RAs can be issued when required.

Mode S/TCAS Control Panel

A single control panel is provided to allow the flight crew to select and control all TCAS equipment, including the TCAS Processor, the Mode S transponder, and in some cases, the TCAS displays. A typical control panel provides four basic control positions:

- **Stand-by**: Power is applied to the TCAS Processor and the Mode S transponder, but TCAS does not issue any interrogations and the transponder will reply to only discrete interrogations.
- **Transponder**: The Mode S transponder is fully operational and will reply to all appropriate ground and TCAS interrogations. TCAS remains in Standby.
- **TA Only**: The Mode S transponder is fully operational. TCAS will operate normally and issue the appropriate

interrogations and perform all tracking functions. However, TCAS will only issue TAs, and the RAs will be inhibited.

- **Automatic** or **TA/RA**: The Mode S transponder is fully operational. TCAS will operate normally and issue the appropriate interrogations and perform all tracking functions. TCAS will issue TAs and RAs, when appropriate.

As indicated in Figure 1, all TCAS control signals are routed through the Mode S transponder.

Antennas

The antennas used by TCAS II include a directional antenna that is mounted on the top of the aircraft and either an omnidirectional or a directional antenna mounted on the bottom of the aircraft. Most installations use the optional directional antenna on the bottom of the aircraft.

These antennas transmit interrogations on 1030 MHz at varying power levels in each of four 90° azimuth segments. The bottom-mounted antenna transmits fewer interrogations and at a lower power than the top-mounted antenna. These antennas also receive transponder replies, at 1090 MHz, and send these replies to the TCAS Processor. The directional antennas permit the partitioning of replies to reduce synchronous garbling.

In addition to the two TCAS antennas, two antennas are also required for the Mode S transponder. One antenna is mounted on the top of the aircraft while the other is mounted on the bottom. These antennas enable the Mode S transponder to receive interrogations at 1030 MHz and reply to the received interrogations at 1090 MHz. The use of the top- or bottom-mounted antenna is automatically selected to optimize signal strength and reduce multipath interference.

TCAS operation is automatically suppressed whenever the Mode S transponder is transmitting to ensure that TCAS does not track its own aircraft.

Cockpit Presentation

The TCAS interface with the pilots is provided by two displays — the traffic display and the RA display. These two displays can be implemented in a number of ways, including displays that incorporate both displays into a single, physical unit. Regardless of the implementation, the information displayed is identical. The standards for both the traffic display and the RA display are defined in DO-185A.

Traffic Display

The traffic display, which can be implemented on either a part-time or full-time basis, depicts the position of nearby traffic, relative to its own aircraft. It is designed to provide information that will assist the pilot in visual acquisition of other aircraft. If implemented on a part-time basis, the display will automatically activate whenever a TA or an RA is issued. Current implementations include dedicated traffic displays; display of the traffic information on shared weather radar displays, MAP displays, Engine Indication and Crew Alerting System (EICAS) displays; and other multifunction displays.

A majority of the traffic displays also provide the pilot with the capability to select multiple ranges and to select the altitude band for the traffic to be displayed. These capabilities allow the pilot to display traffic at longer ranges and with greater altitude separation while in cruise flight, while retaining the capability to select lower display ranges in terminal areas to reduce the amount of display clutter.

Traffic Display Symbology

Both color and shape are used to assist the pilot in interpreting the displayed information.

The own aircraft is depicted as either a white or cyan arrowhead or airplane-like symbol. The location of the own aircraft symbol on the display is dependent on the display implementation. Other aircraft are depicted using geometric symbols, depending on their threat status, as follows:

- An unfilled diamond (◊), shown in either cyan or white, but not the same color as the own aircraft symbol, is used to depict non-threat traffic.
- A filled diamond (♦), shown in either cyan or white, but not the same color as the own aircraft symbol, is used to depict Proximate Traffic. Proximate Traffic is non-threat traffic that is within 6 nmi and ±1200 ft from own aircraft.
- A filled **amber or yellow circle (•) is used to display** intruders that have caused a TA to be issued.
- A **filled red square ( ) is used to display intruders that have caused an RA to be issued.**

Each symbol is displayed on the screen according to its relative position to own aircraft. To aid the pilot in determining the range to a displayed aircraft, the traffic display provides range markings at one-half the selected scale and at the full scale. Additional range markings may be provided at closer ranges, e.g., 2 nmi, on some display implementations. The selected display range is also shown on the display. The range markings and range annunciation are displayed in the same color as the own aircraft symbol unless the traffic display is integrated with an existing display that already provides range markings, e.g., a MAP display.

Vertical speed information and altitude information are also provided for all displayed traffic that are reporting altitude. Relative altitude is displayed in hundreds of feet above the symbol if the intruder is above own aircraft and below the symbol if the intruder is below own aircraft. When the intruder is above the own aircraft, the relative altitude information is preceded by a + sign. When the intruder is below the own aircraft, a – sign precedes the relative altitude information. In some aircraft, the flight level of the intruder can be displayed instead of its relative altitude. The flight level is shown above the traffic symbol if the intruder is above the own aircraft and below the traffic symbol is the intruder is below the own aircraft. If the intruder is not reporting its altitude, no altitude information in shown for the traffic symbol. The altitude information is displayed in the same color as the aircraft symbol.

An arrow is displayed immediately to the right of a traffic symbol when the target aircraft is reporting its altitude and is climbing or descending at more than 600 fpm. An up arrow is used for a climbing aircraft; a down arrow is used for a descending aircraft. The arrow is displayed in the same color as the aircraft symbol.

When an aircraft causing a TA or RA is beyond the currently selected range of the traffic display, half TA or RA symbols will be displayed at the edge of the display at the proper relative bearing. In some implementations, a written message such as TRAFFIC, TFC, or TCAS is displayed on the traffic display if the intruder is beyond the selected display range. The half symbol or the written message will remain displayed until the traffic moves within the selected display range; the pilot increases the range on a variable range display to allow the intruder to be displayed; or the pilot selects a display mode that allows traffic to be displayed.

In some instances, TCAS may not have a reliable bearing for an intruder causing a TA or RA. Because bearing information is used for display purposes only, the lack of bearing information does not affect the ability of TCAS to issue TAs and RAs. When a "No-Bearing" TA or RA is issued, the threat level, as well as the range, relative altitude, and vertical rate of the intruder, are written on the traffic display. This text is shown in red for an RA and in amber or yellow for a TA. For example, if an RA was issued against an intruder at a range of 4.5 nmi and with a relative altitude of +1200 feet and descending, the "No Bearing" indication on the traffic display would be:

RA 4.5 +12↓

Figure 2 shows the use of the various traffic symbology used on the traffic display.

Resolution Advisory Display

The RA display provides the pilot with information on the vertical speed or pitch angle to fly or avoid to resolve an encounter. The RA display is typically implemented on an instantaneous vertical speed indicator (IVSI); a vertical speed tape that is part of a Primary Flight Display (PFD); or using pitch cues displayed on the PFD. RA guidance has also been implemented on a Heads-Up Display (HUD). The implementations using the IVSI or a vertical speed tape use red and green lights or markings to indicate the vertical speeds to be avoided (red) and the desired vertical speed to be flown (green). An implementation using pitch cues uses a unique shape on the PFD to show the pitch angle to be flown or avoided to resolve an encounter. HUD implementations also use a unique shape to indicate the flight path to be flown or avoided to resolve an encounter.

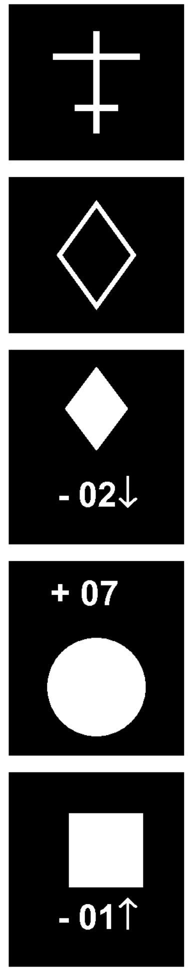
In general, the round-dial IVSI implementation is used on the older nonglass aircraft. However, some operators have implemented this display in their glass aircraft to provide a common display across their fleet types. Some IVSI implementations use mechanical instruments with a series of red and green LEDs around the perimeter of the display, while other implementations use an LCD display that draws the red and green arcs at the appropriate locations. The LCD display implementations also have the capability to provide both the traffic and RA display on a single instrument.

On glass aircraft equipped with a PFD, some airframe manufacturers have implemented the RA display on the vertical speed tape; some have elected to provide pitch cues; and other implementations provide both pitch cues and a vertical speed tape.

The standards for the implementation of RA displays are provided in DO-185A. In addition to the implementations outlined above, DO-185A defines requirements for implementation of the RA display via the flight director and a HUD.

Two RA displays are required — one in the primary field of view of each pilot.

Figure 3 shows an RA display implemented on an LCD display that also provides traffic information. Figure 4 shows the two possible implementations on the PFD.



Own Aircraft. Airplane Symbol in White or Cyan

Non Intruding Traffic Altitude Unknown Open Diamond in White or Cyan

Proximity Traffic, 200 Feet Below and Descending. Solid Diamond in White or Cyan.

Traffic Advisory (Intruder). 700 Feet above and level. Solid Amber Circle.

Resolution Advisory (Threat). 100 Feet Below and Climbing. Solid Red Square

Figure 2. Standardized Symbology for Use on the Traffic Display

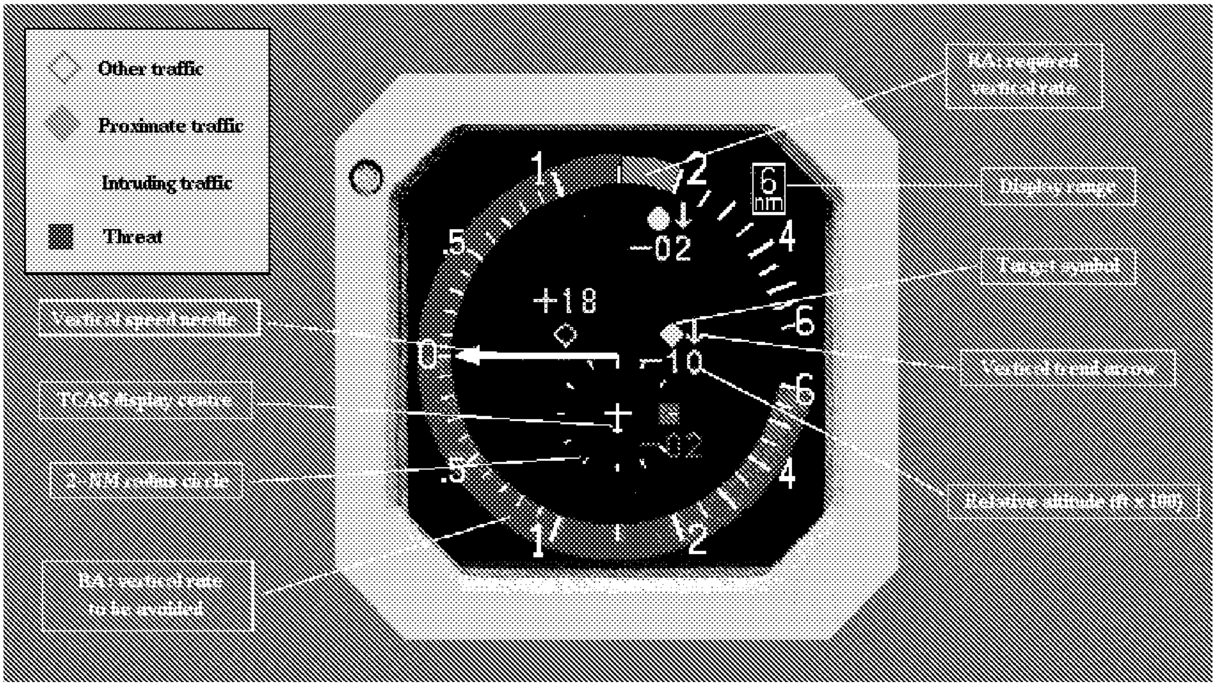
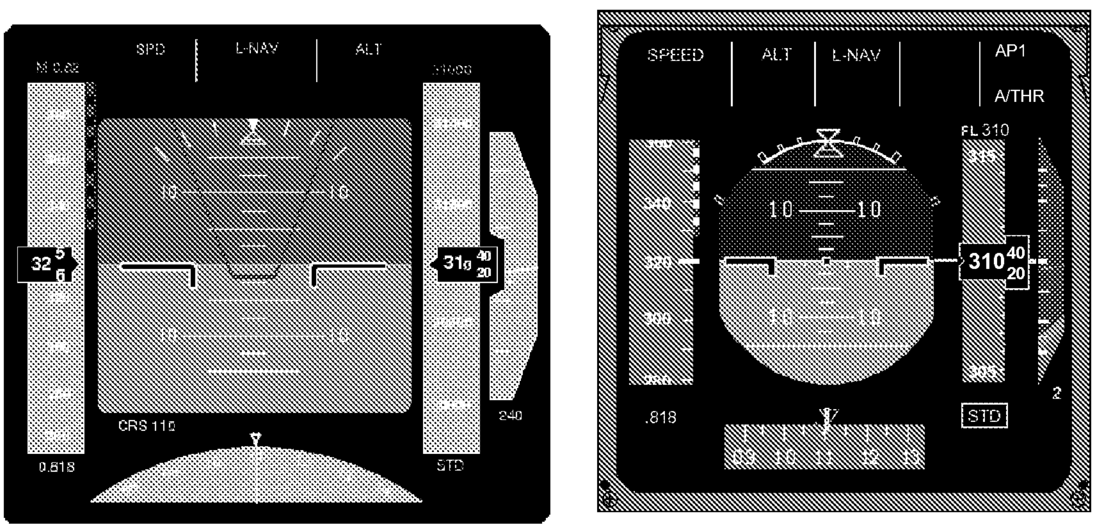


Figure 3. TCAS RA Display Implemented on an IVSI



Pitch Cue Implementation **Vertical Speed Tape Implementation**

Figure 4. TCAS RA Displays Implemented on a PFD

Target Surveillance

TCAS, independent of any ground inputs, performs surveillance of nearby aircraft to provide information on the position and altitude of these aircraft so the collision avoidance algorithms can perform their function. The TCAS surveillance function operates by issuing interrogations at 1030 MHz that transponders on nearby aircraft respond to at 1090 MHz. These replies are received and decoded by the surveillance portion of the TCAS software and the information is then provided to the collision avoidance algorithms.

TCAS has a requirement to provide reliable surveillance out to a range of 14 nmi and in traffic densities of up to 0.3 aircraft per square nautical mile. The surveillance function provides the range, altitude, and bearing of nearby aircraft to the collision avoidance function so threat determinations can be made and so the information displayed on the traffic display is accurate. The TCAS surveillance is compatible with both the ATCRBS and Mode S transponders.

TCAS can simultaneously track at least 30 transponder-equipped aircraft within its surveillance range.

Because TCAS surveillance operates on the same frequencies as that used by the ground-based ATC radars, there is a requirement imposed on TCAS that it not interfere with the functions of the ATC radars. Several design features have been developed and implemented to allow TCAS to provide reliable surveillance without degrading the performance of the ATC radars.

Mode S Surveillance

Because of the selective address feature of the Mode S system, TCAS surveillance of Mode S equipped aircraft is relatively straightforward. TCAS listens for the spontaneous transmissions, or squitters, that are generated once per second by the Mode S transponder. Among other information, the squitter contains the unique Mode S address of the sending aircraft.

Following the receipt and decoding of a squitter message, TCAS sends a Mode S interrogation to the Mode S address contained in the squitter. The Mode S transponder replies to this interrogation and the reply information is used by TCAS to determine the range, bearing, and altitude of the Mode S aircraft.

To minimize interference with other aircraft and ATC on the 1030/1090 MHz channels, the rate at which a Mode S aircraft is interrogated by TCAS is dependent on the range and closure rate between the two aircraft. As the target aircraft approaches the area where a TA may be required, the interrogation rate increases to once per second. At extended ranges, a target is interrogated at least once every five seconds.

TCAS tracks the range and altitude of each Mode S target. These target reports are provided to the collision avoidance logic for use in the detection and advisory logic and for presentation to the pilot on the traffic display. The relative bearing of the target is also provided to the collision avoidance logic so that the target's position can be properly shown on the traffic display. The bearing information is not used by the collision avoidance logic for threat detection and advisory selection.

Mode C Surveillance

TCAS uses a modified Mode C interrogation known as the Mode C Only All Call to interrogate nearby Mode A/C transponders. The nominal interrogation rate for these transponders is once per second. Because TCAS does not use Mode A interrogations, the Mode A transponder codes of nearby aircraft are not known to TCAS.

Aircraft that are not equipped with an operating altitude encoder reply to these interrogations with no data contained in the altitude field of the reply. TCAS uses the framing pulses of the reply to initiate and maintain a range and bearing track on these targets. As with the Mode S tracks, these replies are passed to the collision avoidance logic for traffic advisory detection and for presentation on the traffic display.

The replies from aircraft that are capable of providing their Mode C altitude are tracked in range, altitude, and bearing. These target reports are passed to the collision avoidance logic for TA and RA detection and for presentation on the traffic display.

TCAS surveillance of Mode C targets is complicated by problems of synchronous and nonsynchronous garbling, as well as reflections of signals from the ground (multipath). When a Mode C Only All Call interrogation is issued by TCAS, all Mode C transponders that detect the interrogation will reply. Because of the length of the reply message (21 microseconds), all Mode C equipped aircraft within a range difference of 1.7 nmi from the TCAS aircraft will generate replies that garble, or overlap each other, when received by TCAS. This is shown in Figure 5 and is called synchronous garble. Various techniques have been incorporated into TCAS to cope with this condition.

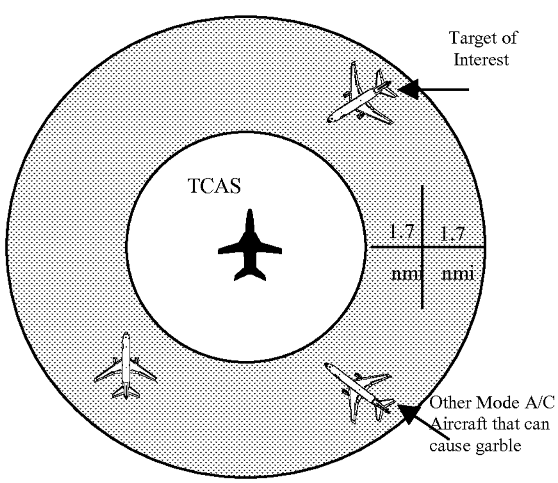


Figure 5. Synchronous Garble Area

Hardware degarblers can reliably decode up to three overlapping replies, and the combined use of variable interrogation power levels and suppression pulses reduces the number of transponders that reply to a single interrogation. This technique, known as whisper-shout (WS) takes advantage of differences between the receiver sensitivity of transponders and the transponder antenna gains of target aircraft.

A low power level is used for the first interrogation step in a WS sequence. During the next WS step, a suppression pulse is first transmitted at a slightly lower level than the first interrogation. The suppression pulse is followed two microseconds later by an interrogation at a slightly higher power level. This action suppresses most of the transponders that had replied to the previous interrogation, but elicits replies from an additional group of transponder that did not reply to the previous interrogation. As shown in Figure 6, the WS procedure is followed progressively in 24 steps, to separate the Mode C replies into several groups, and thus reduces the possibility of garbling. The WS sequence is transmitted once during each surveillance update period, which is nominally one second.

Another technique used to reduce synchronous garble is the use directional transmissions to further reduce the number of potential overlapping replies. This technique is shown in Figure 7. Slightly overlapping coverage must be provided in all directions to ensure 360 degree coverage. Synchronous garble is also reduced by the use of the Mode C Only All Call interrogation. This interrogation inhibits Mode S transponders from replying to a Mode C interrogation.

Nonsynchronous garble is caused by the receipt of undesired transponder replies that were generated in response to interrogations from ground sensors or other TCAS interrogations. These so-called *fruit* replies are transitory so they are typically identified and

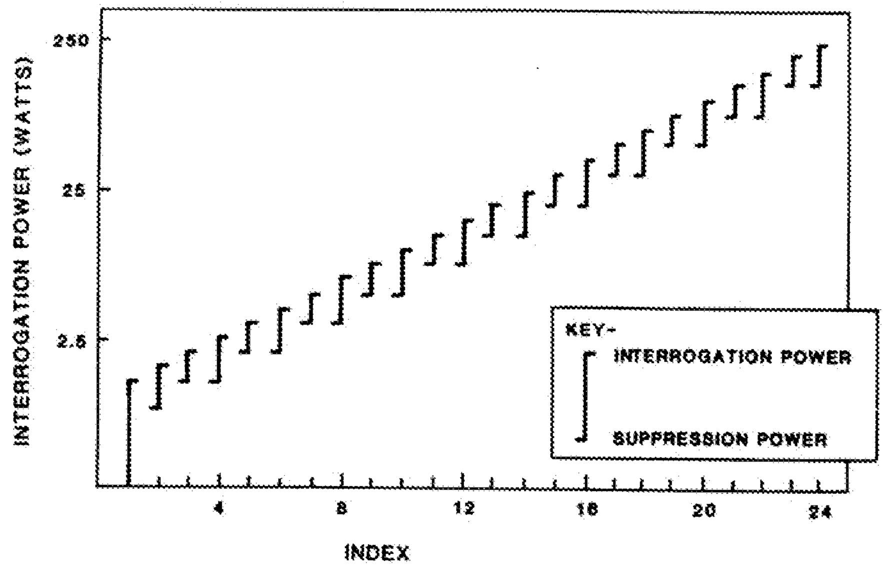


Figure 6. Whisper-Shout Interrogation Sequence

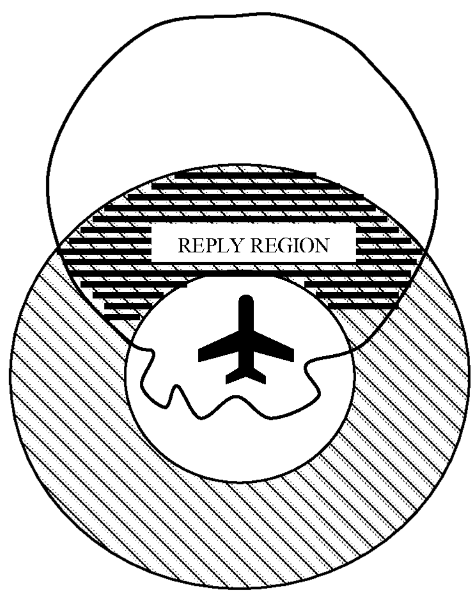


Figure 7. Directional Transmission

discarded by correlation algorithms in the surveillance logic. Operational experience with TCAS has shown that the probability of initiating and maintaining a track based on fruit replies is extremely remote.

Avoiding the initiation of surveillance tracks based on multipath replies is another important consideration in the design of the TCAS surveillance. Multipath results in the detection of more than one reply to the same interrogation, generally of lower power, from the same aircraft. It is caused by a reflected interrogation and usually occurs over flat terrain. To control multipath, the direct-path power level is used to raise the minimum triggering level (MTL) of the TCAS receiver enough to discriminate against the delayed and lower power reflections. This technique, referred to as Dynamic MTL (DMTL), is shown in Figure 8. As shown in Figure 8, the four-pulse direct reply is above the DMTL level, while the delayed, lower-power multipath reply is below the DMTL threshold, and is thus rejected by TCAS.

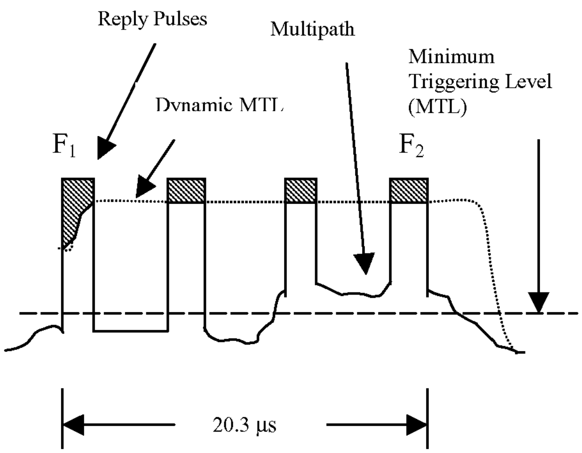


Figure 8. Dynamic Thresholding of ATCRBS Replies

Interference Limiting

Interference limiting is a necessary part of the surveillance function. To ensure that no transponder is suppressed by TCAS activity for more than 2% of the time, and that TCAS does not create an unacceptably high fruit rate for the ground-based ATC radars, multiple TCAS units within detection range of one another, i.e., approximately 30 nmi, are designed to limit their own transmissions under certain conditions. As the number of such TCAS units within this region increases, the interrogation rate and power allocation for each of them must decrease to prevent undesired interference with the ATC radars.

To achieve this, every TCAS unit counts the number of other TCAS units within detection range. This is done by periodically transmitting TCAS broadcast messages that include the Mode S address of the transmitting aircraft every eight seconds. Mode S transponders are designed to accept the broadcast messages without replying. These messages are monitored by the TCAS interference limiting algorithms to develop an estimate of the number of TCAS units within detection range. The number of total TCAS units is used by each TCAS to limit the interrogation rate and power as required.

While interference limiting has been an integral part of TCAS since its inception, initial operational experience with TCAS indicated that refinements were necessary in the surveillance design to meet the above-stated requirements. In Version 7, the interference limiting algorithms have been modified to address problems seen during operation. These modifications account for different distributions in TCAS aircraft in the terminal area because of the increased traffic density near airports.

The modifications also inhibit the interference algorithms at altitudes above Flight Level (FL) 180 and provide longer surveillance ranges in high-density traffic environments. A key feature of the modifications is the guarantee that reliable surveillance will always be available out to a range of six nautical miles. In high density traffic areas at altitudes below FL180, the interrogation rate will be reduced from one per second to once every five seconds for non-threat aircraft that are at least three nautical miles away and are at more than 60 seconds from closest point of approach (CPA).

Electromagnetic Compatibility

TCAS incorporates a number of design features to ensure that TCAS does not interfere with other radio services that operate in the 1030/1090 MHz frequency band. The design of the Mode S waveforms used by TCAS provide compatibility with the Mode A and Mode C interrogations of the ground-based secondary surveillance radar system and the frequency spectrum of Mode S transmissions is controlled to protect adjacent distance measuring equipment (DME) channels.

The interference limiting features of TCAS also help to ensure electromagnetic compatibility with the ATC radar system. An extensive series of analyses, equipment test, and computer simulations have shown that the surveillance design contained in the Version 7 software have demonstrated that operationally significant interference will not occur between TCAS, secondary surveillance radar, and DME systems.

Collision Avoidance Concepts

Airborne collision avoidance is a complex problem. It has taken many years to develop an operationally acceptable solution and the refinement of the system continues to maximize the compatibility between TCAS, ATC systems throughout the world, and existing cockpit procedures. The heart of collision avoidance is the collision avoidance system logic or the CAS logic. To explain the operation of the CAS logic, the basic CAS concepts of sensitivity level, tau, and protected volume need to be understood.

Sensitivity Level

Effective CAS logic operation requires a trade-off between necessary protection and unnecessary advisories. This trade-off is accomplished by controlling the sensitivity level (SL), which controls the time or tau thresholds for TA and RA issuance, and therefore the dimensions of the protected airspace around each TCAS-equipped aircraft. The higher the SL, the larger the amount of protected airspace. However, as the amount of protected airspace increases, the incidence of unnecessary alerts has the potential to increase.

TCAS uses two means of determining the operating SL.

1. Pilot Selection. The TCAS Control Panel provides a means for the pilot to select three operating modes:
    - When the Control Panel switch is placed in the Standby Position, TCAS is operating in SL1. In SL1, TCAS does not transmit any interrogations. SL1 is normally selected only when the aircraft is on the ground or if TCAS has failed. The pilot selection of Standby on the Control Panel is normally the only way that SL1 will be selected.
    - When the pilot selects TA-ONLY on the control panel, TCAS is placed into SL2. While in SL2, TCAS performs all surveillance functions and will issue TAs, as required. RAs are inhibited in SL2.
    - When the pilot selects TA-RA or the equivalent mode on the control panel, the TCAS logic automatically selects the appropriate SL based on the altitude of the own aircraft. Table 2 provides the altitude threshold at which TCAS automatically changes SL and the associated SL for that altitude band. In these SLs, TCAS performs all surveillance functions and will issue TAs and RAs, as required
2. Ground-Based Selection. Although the use of ground-based control of SL has not been agreed to between pilots, controllers, and the FAA and is not envisioned for use in U.S. airspace, the capability for ground-based selection of SL is included in the TCAS design. This design feature allows the operating SL to be selected from the ground by using a Mode S uplink message. The TCAS design allows the selection of any SL shown in Table 2 with the exception of SL1.

When the pilot has selected the TA-RA mode on the Control Panel, the operating SL is automatically selected via inputs from the aircraft's radar or pressure altimeter. SL2 will be selected when the TCAS aircraft is below 1,000 feet above ground level (AGL) (±100 feet) as determined by the radar altimeter input. As previously stated, when in SL2, RAs are inhibited and only TAs will be issued.

In SL3 through SL7, RAs are enabled and issued at the times shown in Table 2. SL3 is set based on inputs from the radar altimeter, while the remaining SLs are set based on

Table 2. Sensitivity Level Definition and Alarm Thresholds

Own Altitude (feet)	SL	Tau (Seconds)		DMOD (nmi)		Altitude Threshold (feet)	
		TA	RA	TA	RA	TA	RA (ALIM)
< 1000	2	20	N/A	0.30	N/A	850	N/A
1000 - 2350	3	25	15	0.33	0.20	850	300
2350 – 5000	4	30	20	0.48	0.35	850	300
5000 – 10000	5	40	25	0.75	0.55	850	350
10000 – 20000	6	45	30	1.00	0.80	850	400
20000 – 42000	7	48	35	1.30	1.10	850	600
> 42000	7	48	35	1.30	1.10	1200	700

pressure altitude using inputs from the own aircraft barometric altimeter.

Tau

TCAS uses time-to-go to CPA, rather than distance, to determine when a TA or an RA should be issued. TCAS uses the time to CPA to determine the range tau and the time to coaltitude to determine the vertical tau. Tau is an approximation of the time, in seconds, to CPA or to the aircraft being at the same altitude. The range tau is equal to the slant range (nmi) divided by the closing speed (knots) multiplied by 3600. The vertical tau is equal to the altitude separation (feet) divided by the combined vertical speed of the two aircraft (feet/minute) times 60.

TCAS II operation is based on the tau concept for all alerting functions. Table 2 provides the TA and RA tau thresholds used in each sensitivity level. The boundary lines shown in Figure 9 indicate the combinations of range and closure rate that would trigger a TA with a 40-second range tau and an RA with a 25-second range tau. This represents the range taus used in SL5. Similar graphs can be generated for other sensitivity levels. Figure 10 shows the combinations of altitude separation and combined vertical speeds that would trigger a TA with a 40-second vertical tau and an RA with a 25-second vertical tau.

In events where the rate of closure is very low, as shown in Figure 11, an intruder aircraft can come very close in range without crossing the range tau boundaries and thus, without causing a TA or an RA to be issued. To provide protection in these types of advisories, the range tau boundaries are modified as shown in Figure 12. This modification is referred to as DMOD and allows TCAS to use a fixed-range threshold to issue TAs and RAs in these slow closure encounters. The value of DMOD varies with the different sensitivity levels and the values used to issue TAs and RAs are shown in Table 2.

When the combined vertical speed of the TCAS and the intruder aircraft is low, TCAS will use a fixed-altitude threshold to determine whether a TA or an RA should be issued. As with DMOD, the fixed altitude thresholds vary with sensitivity level, and the TA and RA thresholds are shown in Table 2.

For either a TA or an RA to be issued, both the range and vertical criteria, in terms of tau or the fixed thresholds, must be satisfied only one of the criteria is satisfied, TCAS will not issue an advisory.

Protected Volume

A protected volume of airspace surrounds each TCAS-equipped aircraft. The tau and DMOD criteria described above shape the horizontal boundaries of this volume. The vertical tau and the fixed altitude thresholds determine the vertical dimensions of the protected volume.

The horizontal dimensions of the protected airspace are not based on distance, but on tau. Thus, the size of the protected volume depends on the speed and heading of the aircraft involved in the encounter.

TCAS II is designed to provide collision avoidance protection in the case of any two aircraft that are closing horizontally at any rate up to 1200 knots and vertically up to 10,000 feet per minute (fpm).

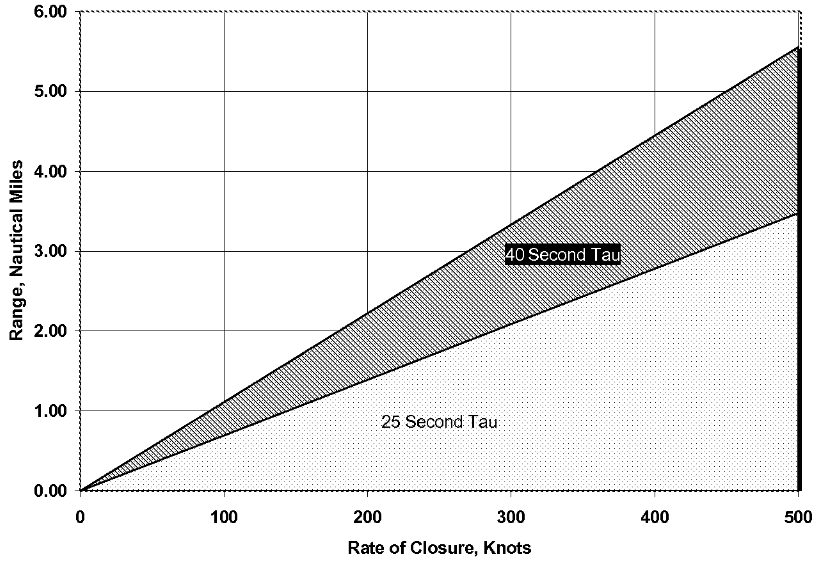


Figure 9. TA/RA Range Tau Values for SL5

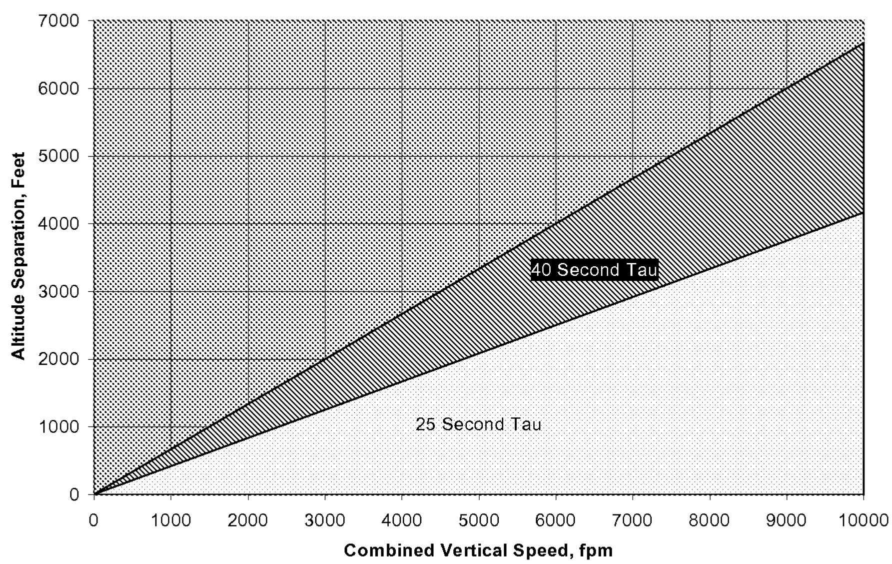


Figure 10. TA/RA Vertical Tau Values for SL5

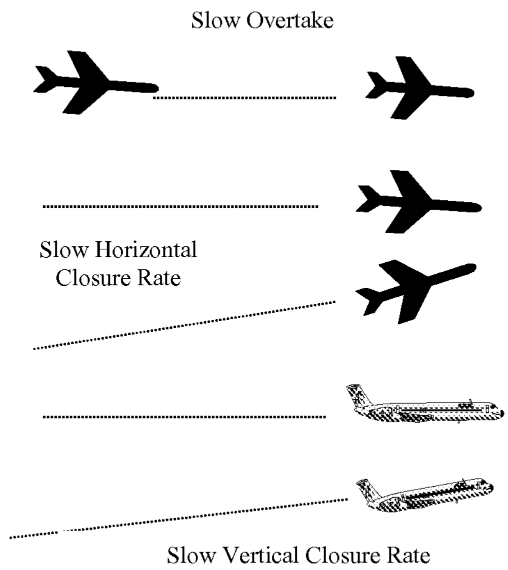


Figure 11. Need for Modified Tau

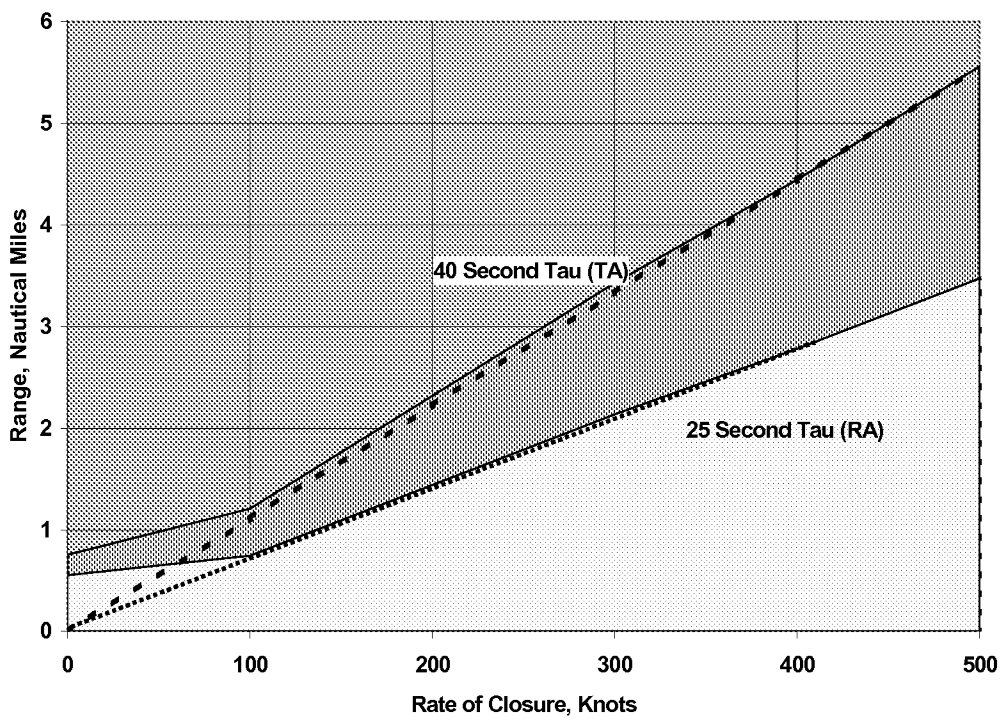


Figure 12. Modified TA/RA Range Tau Values for SL5

CAS Logic Functions

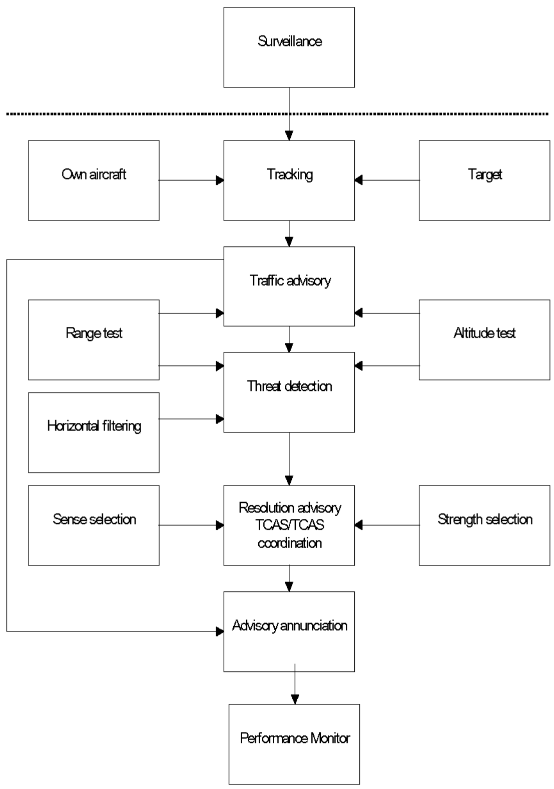


Figure 13. CAS Logic Functions

The logic functions employed by TCAS to perform its collision avoidance function are shown in Figure 13. The following descriptions of these functions are intended to provide a general level of understanding of these functions. The nature of providing an effective collision avoidance system results in the need to have numerous special conditions spread throughout the functions and these are dependent on encounter geometry, range and altitude thresholds, and aircraft performance. These special conditions are beyond the scope of this document. A complete description of the CAS logic and additional details of its design and performance are contained in RTCA DO-185A.

Tracking

Using range, altitude (when available), and bearing from nearby aircraft that are provided to CAS by the Surveillance function, the CAS logic initiates and maintains a three-dimensional track of each aircraft and uses this information to determine the time to CPA and the altitude of each aircraft at CPA. The CAS logic uses the altitude information to estimate the vertical speed of each nearby aircraft and maintains a vertical track for each aircraft. The altitude tracking can use altitude that is quantized in either 100- or 25-foot increments. The CAS tracking function is designed to track aircraft with vertical rates of up to 10,000 fpm.

The CAS logic also uses the data from its own aircraft pressure altitude to determine the own aircraft altitude, vertical speed, and relative altitude of each aircraft. The CAS logic uses the altitude source on the own aircraft that provides the finest resolution. The own aircraft data can be provided in either one, 25-, or 100-foot increments. The outputs from the CAS tracking algorithm, i.e., range, range rate, relative altitude, and vertical rate, are provided to the TA and Threat Detection logic so that the need for a TA or an RA can be determined.

The CAS tracker also uses the difference between its own aircraft pressure altitude and radar altitude to estimate the approximate elevation of the ground above mean sea level. This ground estimation logic functions whenever the own aircraft is below 1750 ft AGL. The ground level estimate is then subtracted from the pressure altitude received from each nearby Mode C-equipped aircraft to determine the approximate altitude of each aircraft above the ground. If this difference is less than 360 feet, TCAS considers the reporting aircraft to be on the ground. If TCAS determines the intruder to be on the ground, it inhibits the generation of advisories against this aircraft.

This methodology is shown graphically in Figure 14.

A Mode S-equipped aircraft is considered to be on the ground if the on-the-ground status bit indicates the aircraft is on the ground.

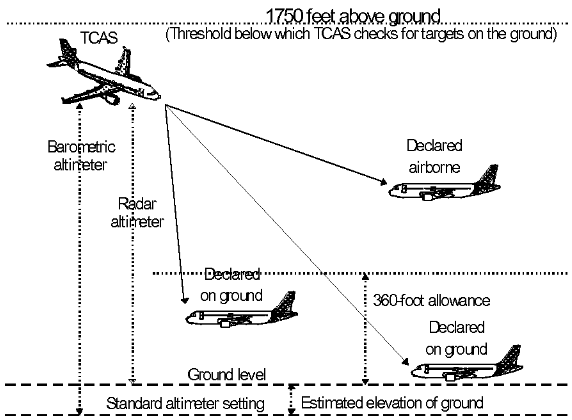


Figure 14. Mode C Target on Ground Determination

Traffic Advisory

Using the tracks for nearby aircraft, range and altitude tests are performed for each altitude-reporting target. Nonaltitude reporting aircraft are assumed to be coaltitude and only range tests are performed on these targets. The range test is based on tau, and the TA tau must be less than the threshold shown in Table 2. In addition, the current or projected vertical separation at CPA must be within the TA altitude threshold shown in Table 2 for a target to be declared an intruder. If the TA logic declares an aircraft to be an intruder, a TA will be issued against that aircraft.

A nonaltitude reporting aircraft will be declared an intruder if the range test alone shows that the calculated tau is within the RA tau threshold associated with the current SL being used as shown in Table 2.

Version 7 includes changes to ensure that a target's TA status is maintained in slow closure rate encounters by invoking more stringent requirements for removing a TA. These changes address problems reported in which multiple TAs were issued against the same target in parallel approach encounters and in RVSM airspace.

Threat Detection

Range and altitude tests are performed on each altitude-reporting intruder. If the RA tau and either the time to co-altitude or relative altitude criteria associated with the current SL are met, the intruder is declared a threat. Depending on the geometry of the encounter and the quality and age of the vertical track data, an RA may be delayed or not selected at all. RAs cannot be generated for nonaltitude reporting intruders.

Version 7 includes changes in the Threat Detection logic to improve the performance of this portion of the logic. These changes include the following:

- Declaring the own aircraft to be on the ground when the input from the radar altimeter is valid and below 50 feet AGL. This precludes complete reliance on the own aircraft's weight-on-wheels switch that has been shown to be unreliable in some aircraft.
- Preventing the SL from decreasing during a coordinated encounter to maintain the continuity of a displayed RA, and thus prevent multiple RAs from being issued against the same intruder.
- Inhibiting threat declaration against intruder aircraft with vertical rates in excess of 10,000 fpm.
- Reducing alert thresholds to account for the reduction in vertical separation to 1000 feet above FL290 in RVSM airspace.
- Modifying the criteria used to reduce the frequency of bump-up or high vertical rate encounters. This modification allows a level aircraft to delay the issuance of an RA for up to five seconds to allow additional time

for detecting a level-off maneuver by a climbing or descending aircraft.

- Introducing a horizontal miss distance (HMD) filter to reduce the number of RAs against intruder aircraft having a large horizontal separation at CPA. The HMD filter can also weaken an RA prior to ALIM being obtained to minimize altitude displacement when the filter is confident that the horizontal separation at CPA will be large.

Resolution Advisory Selection

When an intruder is declared a threat, a two step process is used to select the appropriate RA for the encounter geometry. The first step in the process is to select the RA sense, i.e., upward or downward. Based on the range and altitude tracks of the intruder, the CAS logic models the intruder's flight path from its present position to CPA. The CAS logic then models upward and downward sense RAs for own aircraft, as shown in Figure 15, to determine which sense provides the most vertical separation at CPA. In the encounter shown in Figure 15, the downward sense logic will be selected because it provides greater vertical separation.

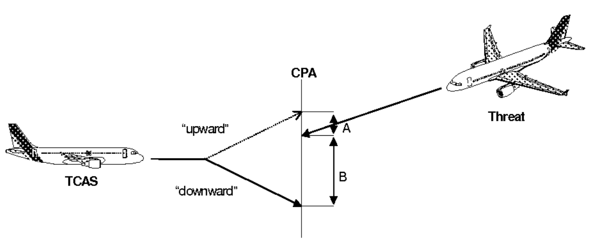


Figure 15. RA Sense Selection

In encounters where either of the senses results in the TCAS aircraft crossing through the intruder's altitude, TCAS is designed to select the nonaltitude crossing sense if the noncrossing sense provides the desired vertical separation, known as ALIM, at CPA. The value of ALIM varies with SL and the value for each SL is shown in Table 2. If the nonaltitude crossing sense provides at least ALIM feet of separation at CPA, this sense will be selected even if the altitude-crossing sense provides greater separation. If ALIM cannot be obtained in the nonaltitude crossing sense, an altitude crossing RA will be issued. Figure 16 shows an example of encounters in which the altitude crossing and nonaltitude crossing RA senses are modeled and the noncrossing RA sense is selected.

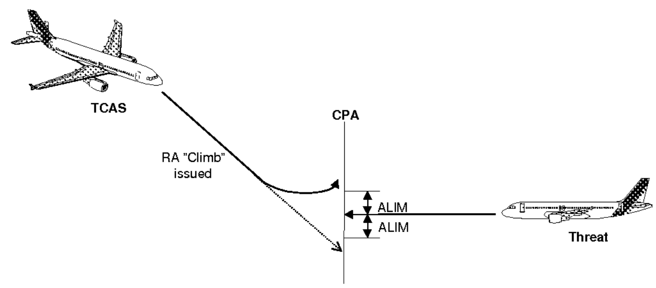


Figure 16. Selection of Noncrossing RA Sense

The second step in selecting an RA is to choose the strength of the advisory. TCAS is designed to select the RA strength that is the least disruptive to the existing flight path, while still providing ALIM feet of separation. Table 3 provides a list of possible advisories that can be issued as the initial RA when only a single intruder is involved in the encounter. After the initial RA is selected, the CAS logic continuously monitors the vertical separation that will be provided at CPA and if necessary, the initial RA will be modified.

A new feature was implemented in Version 7 to reduce the frequency of RAs that reverse the existing vertical rate of the own aircraft. When two TCAS-equipped aircraft are converging vertically with opposite rates and are currently well separated in altitude, TCAS will first issue a vertical speed limit (Negative) RA to reinforce the pilots' likely intention to level off at adjacent flight levels. If no response to this initial RA is detected, or if either aircraft accelerates toward the other aircraft, the initial RA will strengthen as required. This change was implemented to reduce the frequency of initial RAs that reversed the vertical rate of the own aircraft (e.g., posted a climb RA for a descending aircraft) because pilots did not follow a majority of these RAs, and those that were followed, were considered to be disruptive by controllers.

In some events, the intruder aircraft will maneuver vertically in a manner that thwarts the effectiveness of the issued RA. In these cases, the initial RA will be modified to either increase the strength or reverse the sense of the initial RA. The RA issued when an increased strength RA is required is dependent on the initial RA that was issued. Figure 17 depicts an encounter where it is necessary to increase the climb rate from the 1500 fpm required by the initial RA to 2500 fpm. This is an example of an Increase Climb RA. Figure 18 depicts an encounter where an initial Descend RA requires reversal to a Climb RA after the intruder maneuvers.

In a coordinated encounter in which an aircraft appears to ignore an initial nonaltitude crossing RA, Version 7 will inhibit Increase Rate RAs for this aircraft and only consider RA reversals if the other aircraft maneuvers.

Version 7 permits sense reversals in coordinated encounters. This sense reversal logic is very similar to that previously available in encounters with non-TCAS threats. In TCAS-TCAS encounters, RA reversals are not permitted for the first nine seconds after the initial RA to allow time for both aircraft to initiate their RA response. RA reversals are not permitted if the aircraft are within 300 feet of each other and the reversal would result in an altitude crossing RA. In coordinated encounters, the logic that considers issuing an Increase Rate RA late in an altitude crossing RA is disabled.

Because of aircraft climb performance limitations at high altitude or in some flap and landing gear configurations, an aircraft installation may be configured to inhibit Climb or Increase Climb RA under some conditions. These inhibit conditions can be provided via program pins in the TCAS connector or in real-time via an input from a Flight Management System (FMS). If these RAs are inhibited, the RA Selection Criteria will not consider them in the RA selection and will choose an alternative upward sense RA if the downward sense RA does not provide adequate vertical separation.

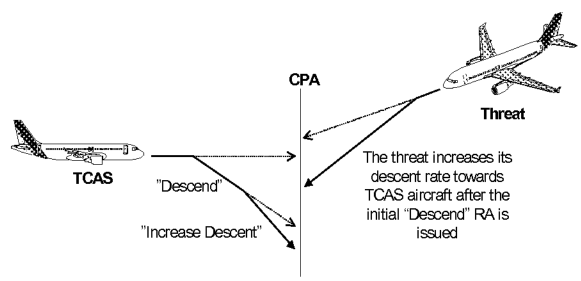


Figure 17. Increase Rate RA

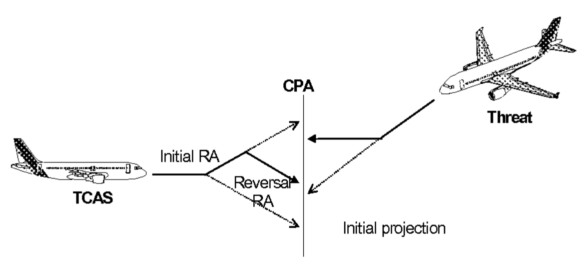


Figure 18. RA Reversal

TCAS is designed to handle multiaircraft encounters, i.e., those encounters in which more that one intruder is detected at the same time. (It should be noted that in more than 10 years of TCAS operation, less than a half dozen true multiaircraft encounters have been recorded worldwide.) TCAS will attempt to resolve these types of encounters by selecting a single RA that will provide adequate separation from each of the intruders. This RA can be any of the initial RAs shown in Table 3, or a combination of upward and downward sense RAs, e.g., Do Not Climb and Do Not Descend. It is

Table 3. Possible Initial RAs

RA TYPE	UPWARD SENSE		DOWNWARD SENSE	
	RA	Required Vertical Rate	RA	Required Vertical Rate
Positive	Climb	1500 to 2000 fpm	Descend	-1500 to -2000 fpm
Positive	Crossing Climb	1500 to 2000 fpm	Crossing Descend	-1500 to -2000 fpm
Positive	Maintain Climb	1500 to 4400 fpm	Maintain Descend	-1500 to -4400 fpm
Negative	Do Not Descend	> 0 fpm	Do Not Climb	< 0 fpm
Negative	Do Not Descend > 500 fpm	> -500 fpm	Do Not Climb > 500 fpm	< + 500 fpm
Negative	Do Not Descend > 1000 fpm	> -1000 fpm	Do Not Climb > 1000 fpm	< + 1000 fpm
Negative	Do Not Descend > 2000 fpm	> -2000 fpm	Do Not Climb > 2000 fpm	< + 2000 fpm

possible that the RA selected in such encounters may not provide ALIM separation from all intruders. Version 7 provides new capabilities to the multiaircraft logic to allow this logic to utilize Increase Rate RAs and RA Reversals to better resolve encounters.

During an RA, if the CAS logic determines that the response to a Positive RA (see Table 3) has provided ALIM feet of vertical separation before CPA, the initial RA will be weakened to either a Do Not Descend RA (after an initial Climb RA) or a Do Not Climb RA (after an initial Descend RA). This is done to minimize the displacement from the TCAS aircraft's original altitude. Negative RAs will not be weakened and the initial RA will be retained until CPA unless it is necessary to strengthen the RA or reverse the RA sense.

TCAS is designed to inhibit Increase Descent RAs below 1450 feet AGL; Descend RAs below 1100 feet AGL; and all RAs below 1000±100 feet AGL. If a Descend RA is being displayed as the own aircraft descends through 1100 feet AGL,the RA will be modified to a Do Not Climb RA.

After CPA is passed and the range between the TCAS aircraft and threat aircraft begins to increase, all RAs are cancelled.

TCAS/TCAS Coordination

In a TCAS/TCAS encounter, each aircraft transmits interrogations to the other via the Mode S link to ensure the selection of complementary RAs by the two aircraft. The coordination interrogations use the same 1030/1090 MHz channels used for surveillance interrogations and replies and are transmitted once per second by each aircraft for the duration of the RA. Coordination interrogations contain information about an aircraft's intended RA sense to resolve the encounter with the other TCAS-equipped intruder. The information in the coordination interrogation is expressed in the form of a complement. For example, when an aircraft selects an upward sense RA, it will transmit a coordination interrogation to the other aircraft that restricts that aircraft's RA selection to those in the downward sense. The strength of the downward sense RA would be determined by the threat aircraft based on the encounter geometry and the RA Selection logic.

The basic rule for sense selection in a TCAS/TCAS encounter is that each TCAS must check to see if it has received an intent message from the other aircraft before selecting an RA sense. If an intent message has been received, TCAS selects the opposite sense from that selected by the other aircraft and communicated via the coordination interrogation. If TCAS has not received an intent message, the sense is selected based on the encounter geometry in the same manner as would be done if the intruder were not TCAS equipped.

In a majority of the TCAS/TCAS encounters, the two aircraft will declare the other aircraft to be a threat at slightly different times. In these events, coordination proceeds in a straightforward manner with the first aircraft declaring the other to be a threat, selecting its RA sense based on the encounter geometry, and transmitting its intent to the other aircraft. At a later time, the second aircraft will declare the other aircraft to be a threat, and having already received an intent from the first aircraft, will select a complementary RA sense. The complementary sense that is selected will then be transmitted to the other aircraft in a coordination interrogation.

Occasionally, the two aircraft declare each other as threats simultaneously, and therefore, both aircraft will select their RA sense based on the encounter geometry. In these encounters, there is a chance that both aircraft will select the same sense. When this happens, the aircraft with the higher Mode S address will detect the selection of the same sense and will reverse its sense.

Version 7 includes the capability for TCAS to issue RA reversals in coordinated encounters if the encounter geometry changes after the initial RA is issued. The RA reversals in coordinated encounters are annunciated to the pilot in the same way as RA reversals against non-TCAS intruders. In a coordinated encounter, if the aircraft with the low Mode S address has Version 7 installed, the low Mode S address can reverse the sense of its initial RA and communicate this to the high Mode S address aircraft. The high Mode S address aircraft will then reverse its displayed RA. The aircraft with the high Mode S address can be equipped with either Version 6.04 or Version 7.

In a coordinated encounter, only one RA reversal based on changes in the encounter geometry can be issued. The initial RA sense will not be reversed until it has been displayed for at least nine seconds, unless the low Mode S address aircraft has a vertical rate higher than 2500 feet per minute and acts contrary to the RA. This delay is included in the design to allow sufficient time for the two aircraft to initiate a response to the initial RA.

Advisory Annunciation

The CAS logic also performs the function of setting flags that control the displays and aural annunciations. The traffic display, the RA display, and the aural devices use these flags to alert the pilot to the presence of TAs and RAs. Aural annunciations are inhibited below 500±100 feet AGL.

The TCAS aural annunciations are integrated with other environmental aural alerts available on the aircraft. The priority scheme established for these aural alerts gives windshear detection systems and ground proximity warning systems (GPWS) a higher annunciation priority than a TCAS alert. TCAS aural annunciations will be inhibited during the time that a windshear or GPWS alert is active.

Air/Ground Communications

Using the Mode S data link, TCAS can downlink RA reports to Mode S ground sites. These reports can be provided in the Mode S transponder's 1090 MHz response to an interrogation from the Mode S ground sensor requesting information and it can also be provided automatically using the TCAS 1030 MHz transmitter.

During the time an RA is displayed, TCAS will automatically generate a downlink message containing information on the RA being displayed to the crew. This information, known as the RA Broadcast, is provided when an RA is initially issued and when the RA is updated. It is rebroadcast every eight seconds using the TCAS 1030 MHz transmitter. At the end of an RA, an indication will be provided to the ground that the RA is no longer being displayed.

Traffic Advisory Display

The functions of the traffic advisory display are to aid the flight crew in visually acquiring intruder aircraft; discriminating between intruder aircraft and other nearby aircraft; determining the horizontal position of nearby aircraft; and providing confidence in the performance of TCAS.

Traffic advisory displays have been implemented in a number of different ways and with varying levels of flexibility. The requirements for the various means of implementing the traffic displays are documented in RTCA DO-185A. An overview of the traffic display features and capabilities was provided earlier in this booklet.

Version 7 requirements inhibit the display of intruders with relative altitudes of more than ±9900 feet if the pilot has selected the display of relative altitude. This display range is the maximum possible because only two digits are available to display the relative altitude.

Resolution Advisory Displays

The RA display is used by TCAS to advise the pilot how to maneuver, or not maneuver in some cases, to resolve the encounter as determined by the CAS logic. Examples for various RA display implementations are shown in Figure 3 and Figure 4. The requirements for RA displays are contained in RTCA DO-185A.

To accommodate physical limitations on some IVSI displays, Version 7 will not allow the display of any Maintain Rate RAs that call for vertical rates in excess of 4400 fpm. Because of this, the logic will model the minimum of the own aircraft's vertical rate and 4400 fpm if a Maintain Rate RA is required; and will select the sense that provides the best separation, even if the selected sense is opposite the existing vertical speed.

Aural Annunciations

Whenever the collision avoidance logic issues a TA or an RA, a voice alert is issued to ensure that the pilots are aware of the information being displayed on the traffic and RA displays. These aural annunciations can be provided via a dedicated speaker installed in the cockpit or via the aircraft's audio panels so that they are heard in the pilots' headsets. Table 4 provides a listing of the aural annunciations that are used by TCAS in Version 7, as well as those used in existing implementations. The changes incorporated in Version 7 are highlighted.

Performance Monitoring

TCAS is equipped with performance monitoring software that continuously and automatically monitors the health and performance of TCAS. The performance monitoring operates whenever power is applied to TCAS. In addition, the performance monitor includes a pilot-initiated test feature that includes expanded tests of the TCAS displays and aural annunciations. The performance monitor also supports expanded maintenance diagnostics that are available to maintenance and engineering personnel while the aircraft is on the ground.

The performance monitor validates many of the inputs received from other aircraft systems and validates the performance of the TCAS processor. These include the own aircraft pressure altitude input and the connection of TCAS to the aircraft suppression bus.

When the performance monitor detects anomalous performance within TCAS or an invalid input from a required on-board system, the failure is annunciated to the pilot. If appropriate, all or a portion of the TCAS functions may be disabled or inhibited. If the performance monitor disables any TCAS capability, it will continue to monitor the remaining functions and if the detected failure is removed, the full operational capability will be restored.

Table 4. TCAS Aural Annunciations

TCAS Advisory	Version 7 Aural Annunciation	Existing Aural Annunciation
Traffic Advisory	Traffic, Traffic	Traffic, Traffic
Climb RA	Climb, Climb	Climb, Climb, Climb
Descend RA	Descend, Descend	Descend, Descend, Descend
Altitude Crossing Climb RA	Climb, Crossing Climb; Climb, Crossing Climb	Climb, Crossing Climb; Climb, Crossing Climb
Altitude Crossing Descend RA	Descend, Crossing Descend; Descend, Crossing Descend	Descend, Crossing Descend; Descend, Crossing Descend
Reduce Climb RA	Adjust Vertical Speed, Adjust	Reduce Climb, Reduce Climb
Reduce Descent RA	Adjust Vertical Speed, Adjust	Reduce Descent, Reduce Descent
RA Reversal to a Climb RA	Climb, Climb, NOW; Climb, Climb NOW	Climb, Climb, NOW; Climb, Climb NOW
RA Reversal to a Descend RA	Descend, Descend NOW; Descend, Descend NOW	Descend, Descend NOW; Descend, Descend NOW
Increase Climb RA	Increase Climb, Increase Climb	Increase Climb, Increase Climb
Increase Descent RA	Increase Descent, Increase Descent	Increase Descent, Increase Descent
Maintain Rate RA	Maintain Vertical Speed, Maintain	Monitor Vertical Speed
Altitude Crossing, Maintain Rate RA (Climb and Descend)	Maintain Vertical Speed, Crossing Maintain	Monitor Vertical Speed
Weakening of Initial RA	Adjust Vertical Speed, Adjust	Monitor Vertical Speed
Preventive RA (No change in vertical speed required)	Monitor Vertical Speed	Monitor Vertical Speed, Monitor Vertical Speed
RA Removed	Clear of Conflict	Clear of Conflict

Use of TCAS

The operational use TCAS II throughout the world during the last 10 years has demonstrated the efficiency of TCAS II as an airborne collision avoidance system. During this time period, the procedures for the use of TCAS II have been developed and refined to ensure that the operation of TCAS provides aircraft with effective collision avoidance protection without having unnecessary affects on the controllers responsible for separating aircraft. These operating practices and procedures are now included within FAA, ICAO, and other countries' regulations and provide the basis for the practical training of pilots and controllers.

Regulations and Operational Guidance

Within the U.S., the guidance on the operational use of TCAS is contained in Advisory Circular (AC) 20-155. This AC provides guidelines for developing flight crew training programs, procedures for responding to an RA, a list of good operating practices, sample forms for providing inputs on the performance of TCAS, and suggested phraseology to be used when advising controllers of an RA event.

Information similar to that contained in AC 20-155 has been included in ICAO Annexes and other documentation. Individual countries have used the information contained in the ICAO documentation to develop and promulgate their own requirements and procedures.

The guidance regarding TCAS operation for controllers is contained in the ATC Controllers Handbook (Order 7110.65) and in various policy letters issued by FAA Headquarters.

Controllers Responsibilities

The controller's responsibilities during a TCAS RA are defined in FAA Order 7110.65 and are repeated below.

When an aircraft under your control jurisdiction informs you that it is responding to a TCAS RA, do not issue control instructions that are contrary to the RA the crew has advised you that they are executing. Provide safety alerts regarding terrain or obstructions and traffic advisories for the aircraft responding to the RA and all other aircraft under your control jurisdiction, as appropriate.

Unless advised by other aircraft that they are also responding to a TCAS RA, do not assume that other aircraft in the proximity of the responding aircraft are involved in the RA maneuver or are aware of the responding aircraft's intended maneuvers. Continue to provide control instructions, safety alerts, and traffic advisories as appropriate to such aircraft.

When the responding aircraft has begun a maneuver in response to an RA, the controller is not responsible for providing standard separation between the aircraft that is responding to an RA and any other aircraft, airspace, terrain, or obstructions. Responsibility for standard separation resumes when one of the following conditions is met:

1. The responding aircraft has returned to its assigned altitude.
2. The flightcrew informs you that the TCAS maneuver is completed and you observe that standard separation has been reestablished.
3. The responding aircraft has executed an alternate clearance and you observe that standard separation has been reestablished.

FAA Order 7110.65 also references AC 120-55 to provide information on the suggested phraseology to be used by pilots to notify the controller about a TCAS event. The suggested phraseology is discussed in the following section, *Pilot Responsibilities.*

Pilot Responsibilities

In general terms, the following procedures and practices have been developed regarding the pilots responsibilities and actions while using TCAS. These procedures and practices have been extracted from AC 20-155.

Respond to TAs by attempting to establish visual contact with the intruder aircraft and other aircraft that may be in the vicinity. Coordinate to the degree possible with other crewmembers to assist in searching for traffic. Do not deviate from an assigned clearance based only on TA information. For any traffic that is acquired visually, continue to maintain or attain safe separation in accordance with current Federal Aviation Regulations (FAR) and good operating practices.

When an RA occurs, the pilot flying should respond immediately by direct attention to RA displays and maneuver as indicated unless doing so would jeopardize the safe operation of the flight or unless in the approach environment the flight crew can assure separation with the help of definitive visual acquisition of the aircraft causing the RA. By not responding to an RA, the flightcrew effectively takes responsibility for achieving safe separation.

Satisfy RAs by disconnecting the autopilot, using prompt, positive control inputs in the direction and with the magnitude TCAS advises. To achieve the required vertical rate (normally 1,500 fpm climb or descent), first adjust the aircraft's pitch using the suggested guidelines shown in Table 5.

Table 5. Suggested Pitch Adjustment Required to Comply with TCAS RA

Speed	Pitch Adjustment
.80 Mach	2 degrees
250 Knots Indicated Airspeed (KIAS) Below 10,000 feet	4 degrees
Below 200 KIAS	5 to 7 degrees

Then refer to the vertical speed indicator and make necessary pitch adjustments to place the vertical speed indicator in the green arc of the RA display. On aircraft with pitch guidance TCAS RA displays, follow the RA pitch command for initial, increase, and weakening RAs.

Excursions from assigned altitude, when responding to an RA, typically should be no more than 300 to 500 feet to satisfy the conflict. Vertical speed responses should be made to avoid red arcs or outlined pitch avoidance areas, and, if applicable, to accurately fly to the green arc or outlined pitch guidance area.

Respond immediately to any increase or reversal RA maneuver advisories. Initial vertical speed response to an increase or reversal RA is expected by TCAS, using 1/3 g acceleration, within 2-1/2 seconds after issuance of the advisory. Again, avoid red arcs or outlined pitch avoidance areas and fly to the green arc or outlined pitch guidance area.

If an initial corrective RA is downgraded or weakened (for example, a Climb RA downgrades to a Do Not Descend RA), pilots should respond to the weakening RA and adjust the aircraft's vertical speed accordingly but still keep the needle or pitch guidance symbol out of the red arc or outlined pitch avoidance area. Pilots are reminded that attention to the RA display and prompt reaction to the weakened RA will minimize altitude excursions and potential disruptions to ATC. This will allow for proper TCAS-to-TCAS resolution of encounters and reduce the probability of additional RAs against the intruder or other traffic.

In some instances, it may not be possible to respond to a TCAS RA and continue to satisfy a clearance at the same time. Even if a TCAS RA maneuver is inconsistent with the current clearance, respond appropriately to the RA. Because TCAS tracks all transponder-equipped aircraft in the vicinity, responding to an RA for an intruder assures a safe avoidance maneuver from that intruder and from other Mode C-equipped aircraft.

If a TCAS RA response requires deviation from an ATC clearance, expeditiously return to the current ATC clearance when the traffic conflict is resolved or the TCAS message "Clear of Conflict" is heard, or follow any subsequent change to clearance as advised by ATC. In responding to a TCAS RA that directs a deviation from assigned altitude, communicate with ATC as soon as practicable after responding to the RA. When the RA is cleared, the flight crew should advise ATC that they are returning to their previously assigned clearance or should acknowledge any amended clearance issued.

Unless approved by the Administrator, pilots are expected to operate TCAS while in-flight in all airspace, including oceanic, international, and foreign airspace.

TCAS does not alter or diminish the pilot's basic authority and responsibility to ensure safe flight. Because TCAS does not respond to aircraft that are not transponder-equipped or aircraft with a transponder failure, TCAS alone does not ensure safe separation in every case. Further, TCAS RAs may, in some cases, conflict with flight path requirements because of terrain, such as an obstacle limited climb segment or an approach to rising terrain. Because many approved instrument procedures and Instrument Flight Rules (IFR) clearances are predicated on avoiding high terrain or obstacles, it is particularly important that pilots maintain situational awareness and continue to use good operating practices and judgment when following TCAS RAs. Maintain frequent outside visual scan, use see and avoid vigilance, and continue to communicate as needed and as appropriate with ATC.

The pilot is to inform the controller about the RA deviation as soon as possible. The phraseology, to be used by pilots, is shown in Table 6. The phraseology was developed by ICAO and has been published in PANS-RAC. The FAA has incorporated these recommendations into AC 20-155.

Table 6. Recommended Phraseology for Reporting RAs

Situation	Phraseology
Responding to an RA	"TCAS Climb" or "TCAS Descend"
Initial RA report issued after RA is completed	"TCAS Climb (or descent), returning to [assigned clearance]"
Initial RA report issued after returning to assigned clearance	"TCAS Climb (or descent) completed, [assigned clearance] resumed"
Unable to follow a newly issued clearance because of an RA	"Unable to comply, TCAS resolution advisory"
Controller acknowledgement of any TCAS report	No specific phraseology is defined

The phraseology shown in Table 6 is suggested and should contain: (1) name of the ATC facility, (2) aircraft identification (ID), and (3) nature of the TCAS deviation. When a flight crew receives a TCAS RA to either climb or descend from their assigned altitude, or the RA otherwise affects their ATC clearance or their pending maneuver or maneuver in progress, the crew should inform ATC when beginning the excursion from clearance or as soon as workload allows in the following manner: "XYZ Center, (Aircraft ID), TCAS Climb/Descent."

Following such a communication, the designated air traffic facility is not required to provide approved standard separation to the TCAS maneuvering aircraft until the TCAS encounter is cleared and standard ATC separation is achieved. If workload permits, traffic information may be provided by the controller in accordance with FAA Order 7110.65.

When the RA is clear, the flight crew should advise ATC that they are returning to their previously assigned clearance or subsequent amended clearance. When the deviating aircraft has renegotiated its clearance with ATC, the designated air traffic facility is expected to resume providing appropriate separation services in accordance with FAA Order 7110.65.

NOTE: Communication is not required if the pilot is able to satisfy the RA guidance and maintain the appropriate ATC clearance.

Operational Experience

The evaluation of TCAS II performance during its implementation has demonstrated that this equipment provides an overall improvement in flight safety. In reportedly dangerous situations, TAs have made visual acquisition of intruders possible in sufficient time to avoid any risk of collision. In some events, RAs have been issued that are believed to have prevented critical near midair collisions and midair collisions from taking place.

However, the operational experience has indicated that some issues related to TCAS continue to occur. These issues include the following.

Pilots sometimes deviate significantly further from their original clearance than was required or desired while complying with an RA. Data and simulator trials have shown that pilots often are not aware of the RA being weakened and many pilots do not want to begin maneuvering back toward their original clearance until the RA is over. To reduce the frequency of the large altitude displacements while responding to an RA, Version 7 introduces new aural annunciations to accompany the weakening RAs and provides a target vertical speed on the RA display for the weakened RA. In addition, the CAS logic has been modified to provide only one type of weakened RA and that RA is either a Do Not Climb or Do Not Descend RA. This results in the weakened RA always calling for the aircraft to be leveled after ALIM feet of separation have been obtained.

Pilots are often slow in reporting the initial deviation to the controller and this resulted in situations where the controller was issuing clearances that were in the opposite sense than that directed by the RA. The standard ICAO phraseology is sometimes not used and at times, the controller does not understand the initial RA notification from the pilot. In some events, this resulted in distracting dialogue between the pilot and controller regarding the RA.

Some pilots request information, or refuse a clearance, based upon information shown on the traffic display. These practices are not encouraged because they can cause added congestion on the radio channel and may result in higher controller and pilot workloads. This improper use of the traffic display has been addressed via pilot training programs.

Aircraft have also been observed making horizontal maneuvers based solely on the information shown on the traffic display, without visual acquisition by the aircrew. Such maneuvers may cause a significant degradation in the level of flight safety and are contrary to a limitation contained in the TCAS Airplane Flight Manual Supplement.

Event reports also indicate that some pilots have not reacted to RAs, when they have traffic information from the controller, but have not visually acquired the intruder. This is a potentially hazardous situation if the ground radar is not tracking the intruder causing the RA. In addition, if the intruder is also TCAS-equipped, the RAs will be coordinated, and a nonresponse by one aircraft will result in the other aircraft having to maneuver further to resolve the RA.

An RA is generally unexpected by a controller and in a majority of the cases is a disruption to his or her workload. This disruption is due to an aircraft's unexpected deviation from the ATC clearance, the subsequent discussion regarding the RA on the active frequency, and the possibility of an induced conflict with a third aircraft. Although the latter concern is understandable, many controllers do not understand the multiaircraft logic that is provided by TCAS so that the initial RA can be modified if the response does result in a conflict with a third aircraft.

Operational experience has shown that the unexpected interactions between TCAS and the ATC systems can occur under the following conditions.

Aircraft leveling off at 1,000 ft above or below conflicting traffic that is level may result in RAs being issued to the level aircraft. These RAs are triggered because the climbing or descending aircraft maintains high vertical speeds when approaching the cleared altitude or flight level. The CAS logic contains algorithms that will recognize this encounter geometry and will delay the issuance of the RA to the level aircraft by up to five seconds to allow TCAS to detect the initiation of the level-off maneuver by the intruder. A previous version of the logic included these algorithms at lower altitudes, and these have been effective in reducing the frequency of this type of RA. Version 7 expands the use of this logic to higher altitudes to address the occurrence of these types of RAs in the en route airspace structure.

Altitude crossing clearances issued by a controller based on maintaining visual separation may result in RAs being issued, particularly if one of the aircraft is level

Advisories issued against some categories of aircraft, e.g., aircraft operating under visual flight rules **(VFR), high performance military aircraft during high g maneuvers, and helicopters operating in the immediate vicinity of the airport**. Although minor modifications have been made to TCAS to address these types of RAs, these problems are related as much to the airspace management, in general, as to the function of TCAS II.

Training Programs

Many of the operational issues identified during the initial operations of TCAS can be traced to misunderstandings regarding the operation of TCAS, its capabilities, and its limitations. For these reasons, it is essential that all pilots operating the system be trained in how to use the system and that all controllers receive training on how TCAS operates, how pilots are expected to use the systems, and the potential interactions between TCAS and the ATC system.

The FAA and the industry have worked together to develop and refine training guidelines for both pilots and controllers. AC 120-55 contains guidance for the development and implementation of pilot training programs. While this AC is not directly applicable to operators that are governed by Part 91 and Part 135 of the Federal Aviation Regulations, the training guidelines contained in the AC should be followed by these operators.

The FAA has also developed and distributed a controller training program to all of its ATC facilities.

ICAO has developed guidelines for both pilot and controller training programs, and this information has been distributed to all ICAO member countries.

Pilot Training Programs

Experience has shown that it is essential that crews operating TCAS-equipped aircraft complete an approved pilot-training course. The proper use of TCAS II by pilots is required to ensure the proper integration of TCAS into the air traffic control environment and the realization of the expected improvements in flight safety. Pilot training should include two complementary parts as defined below.

Theory. Pilots should have an understanding of how TCAS works. This includes an understanding of the alert thresholds, expected response to TAs and RAs, proper use of TCAS-displayed information, phraseology, and system limitations. This training is generally accomplished in a classroom environment.

Simulator practice. The response to an RA requires prompt and appropriate reactions from the aircrews involved. Therefore, it is necessary to include RA events in the routine flight simulator training exercises, so that pilots can experience the circumstances surrounding an RA in a realistic environment. When the inclusion of TCAS into simulator training programs is not possible, the FAA has approved the use of other interactive training devices to supplement the classroom training.

Controller Training Programs

While controllers do not use TCAS II, they need to be aware of its presence, capabilities, and limitations while performing their responsibilities. The controller training should be similar to the classroom training provided to pilots, but supplemented with material that demonstrates advisories that have had both positive and negative impacts on the control and traffic situation.

SUMMARY

TCAS is a last resort tool designed to prevent midair collisions between aircraft. Operational experience has demonstrated the utility and efficiency of TCAS. At the same time, operation of TCAS has identified areas in which the design and algorithms needed refinement or improvement to further enhance the efficiency of TCAS and its interaction with the controllers and the ATC system. As a result, the aviation industry has worked to develop, test, certify, and implement TCAS Version 7. Version 7 is now being introduced into service worldwide. The technical features of the system provide a significant improvement in flight safety, and this has now attained universal recognition in the world of aviation. Many countries have mandated the carriage of TCAS II, and ICAO has proposed a worldwide mandate of TCAS II Version 7 by 2003.

However, one must be aware that TCAS is not a perfect system. TCAS cannot preclude all collision risks and the system may, marginally, induce an additional risk. Consequently, it is essential that ATC procedures are designed to provide flight safety without any reliance upon the use of TCAS and that both pilots and controllers are well versed in the operational capabilities and limitations of TCAS.

For more information on TCAS and the capabilities and requirements for Version 7, contact the Aircraft Certification Office, AIR-130, 800 Independence Avenue, S.W., Washington, D.C. 20591.

ABBREVIATIONS

ACAS	Airborne Collision Avoidance System
ACO	**Aircraft Certification Office**
ADC	Air Data Computer
AEEC	Airline Electronic Engineering Committee
AGL	Above Ground Level
AIC	Aeronautical Information Circular
ALIM	Altitude Limit
ATCRBS	Air Traffic Control Radar Beacon System
BCAS	**Beacon Collision Avoidance System**
CAA	**Civil Aviation Authority**
CAS	Collision Avoidance System
CPA	Closest Point of Approach
DMOD	Distance MODification
DME	Distance Measuring Equipment
DMTL	Dynamic Minimum Triggering Level
EATCHIP	European Air Traffic Control Harmonization and Integration Program
EFIS	Electronic Flight Instrument System
EICAS	Engine Indication and Crew Alerting System
FAA	Federal Aviation Administration
FL	Flight Level
FMS	Flight Management System
FRUIT	False Replies from Unsynchronized Interrogator Transmissions
ft	feet
fpm	feet per minute
GPWS	Ground Proximity Warning System
HMD	Horizontal Miss Distance
HUD	Heads Up Display
ICAO	International Civil Aviation Organization
IFR	Instrument Flight Rules
IVSI	Instantaneous Vertical Speed Indicator
JCAB	Japan Civil Aviation Bureau
KIAS	Knots Indicated Airspeed
LCD	**Liquid Crystal Display**

LED	**Light Emitting Diode**
MDF	Miss Distance Filtering
MHz	Megahertz
MOPS	Minimum Operational Performance Standards
MTL	Minimum Triggering Level
NAS	National Airspace System
ND	Navigation Display
NMAC	Near-Midair-Collision
nmi	Nautical Miles
PANS	**Procedures for Air Navigation Services**
PFD	Primary Flight Display
RA	Resolution Advisory
RVSM	Reduced Vertical Separation Minimums
SARPs	Standards And Recommended Practices
SICASP	SSR Improvement and Collision Avoidance System Panel
SL	Sensitivity Level
SSR	Secondary Surveillance Radar
STC	Supplemental Type Certificate
TA	Traffic Advisory
TCAS	Traffic alert and Collision Avoidance System
TFC	Traffic
TSO	Technical Standard Order
VFR	Visual Flight Rules
VSI	Vertical Speed Indicator
WS	**Whisper Shout**
XPDR	Transponder

Glossary

ALTITUDE, RELATIVE: The difference in altitude between own aircraft and a target aircraft. The value is positive when the target is higher and negative when the target is lower.

BEARING: The angle of the target aircraft in the horizontal plane, measure clockwise from the longitudinal axis of the own aircraft.

CAS: Generic term for collision avoidance system.

COORDINATION: Data communications between TCAS-equipped aircraft to ensure that they will provide complementary, i.e., nonconflicting RAs.

CPA: Closest point of approach as computed from a threat's range and range rate.

CROSSOVER: Encounters in which own aircraft and the threat aircraft are projected to cross in altitude prior to reaching CPA.

ESCAPE MANEUVER: See resolution maneuver.

FRUIT: See Garble, Nonsynchronous

GARBLE, NONSYNCHRONOUS: Reply pulses received from a transponder that is being interrogated from some other source. Also called fruit.

GARBLE, SYNCHRONOUS: An overlap of the reply pulses received from two or more transponders answering the same interrogation.

INTRUDER: A target that has satisfied the traffic detection criteria.

OWN AIRCRAFT: The TCAS-equipped reference aircraft.

PROXIMITY TARGET: Any target that is less than 6 nmi in range and within ±1,200 feet vertically, but that does not meet the intruder or threat criteria.

RA: Resolution advisory. An indication given by TCAS II to a flight crew that a vertical maneuver should, or in some cases should not, be performed to attain or maintain safe separation from a threat.

RESOLUTION MANEUVER: Maneuver in the vertical plane resulting from compliance with an RA.

SENSE REVERSAL: Encounter in which it is necessary to reverse the sense of the original RA to avoid a threat. This is most likely to occur when an unequipped threat changes its vertical rate in a direction that thwarts the original RA.

SL: Sensitivity Level. A value used in defining the size of the protected volume around the own aircraft.

SQUITTER: Spontaneous transmission generated once per second by Mode S transponders.

TA: Traffic Advisory. An indication given by TCAS to the pilot when an aircraft has entered, or is projected to enter, the protected volume around the own aircraft.

TA-ONLY MODE: A TCAS mode of operation in which TAs are displayed when required, but all RAs are inhibited.

TARGET: An aircraft that is being tracked by a TCAS-equipped aircraft.

TCAS: Traffic Alert and Collision Avoidance System.

THREAT: An intruder that has satisfied the threat detection criteria and thus requires an RA to be issued.

TRANSPONDER, MODE C: ATC transponder that replies with both identification and altitude data. If the transponder does not have an interface with an encoding altimeter source, only the altitude bracket pulses are transmitted and no altitude data are provided.

TRANSPONDER, MODE S: ATC transponder that replies to an interrogation containing its own, unique 24-bit selective address, and typically with altitude data.

VSI: Vertical speed indicator.

WHISPER-SHOUT (WS): A method of controlling synchronous garble from ATCRBS transponders, through the combined use of variable power levels and suppression pulses.

Bibliography

Additional information on the performance, design, and requirements for TCAS can be found in the following documents.

- RTCA/DO-185A, Minimum Operational Performance Standards for Traffic Alert and Collision Avoidance System (TCAS II) Airborne Equipment
- FAA Technical Standard Order C-119B, Traffic Alert and Collision Avoidance System (TCAS) Airborne Equipment
- FAA Advisory Circular 20-131, Airworthiness Approval of Traffic Alert and Collision Avoidance System (TCAS II) and Mode S Transponders
- FAA Advisory Circular 120-55, Air Carrier Operational Approval and Use of TCAS II
- ICAO Annex 10, Standards and Recommended Practices and Guidance Material for Airborne Collision Avoidance Systems
- AEEC/ARINC Characteristic 735, Traffic Alert and Collision Avoidance System (TCAS)
- AEEC/ARINC Characteristic 718, Mark 2 Air Traffic Control Transponder (ATCRBS/ Mode S)
- RTCA/DO-197A, Minimum Operational Performance Standards for an Active Traffic Alert and Collision Avoidance System (Active TCAS I)
- FAA Technical Standard Order C-118, Traffic Alert and Collision Avoidance System (TCAS I) Airborne Equipment

Heli-Expo 2007

Gulf of Mexico Helo Ops Ready for ADS-B

Aviation Week & Space Technology
02/26/2007, page 56
Frances Fiorino
Washington

HAI members and FAA work to adapt next-gen 'backbone' in Gulf of Mexico

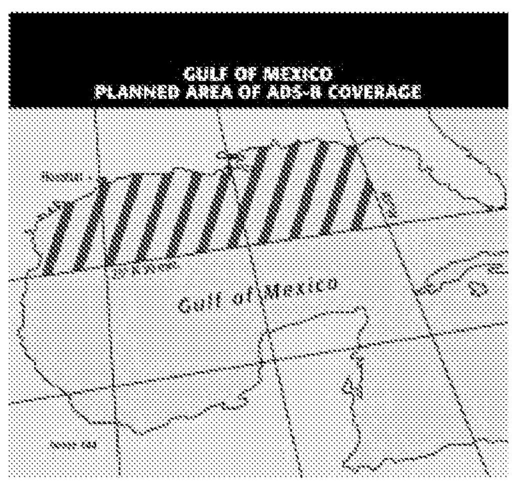
Printed headline: **Helo Ops Ready for ADS-B**

Helicopter operators are moving closer to reaping the benefits of ADS-B--a system that will "take the National Air Space and extend it out over the Gulf of Mexico."

At least that's how Vincent Capezzuto likes to describe the capability of Automatic Dependent Surveillance-Broadcast, which the FAA calls "the backbone" of the Next-Generation Air Transportation System. Capezzuto is FAA program manager for the FAA's national ADS-B office. For Gulf of Mexico operators, ADS-B means real-time ATC surveillance, communications and weather data--which, in effect, translate to conducting safe, low-altitude IFR operations in the gulf.

That's in sharp contrast to current operating conditions in the region, an area roughly 994 mi. (1,600 km.) east to west and 559 mi. from north to south, with a surface area spanning 579,153 sq. mi. Thousands of rigs offshore mine oil and gas riches round-the-clock in water with an average depth of 1,615 meters.

Approximately 650 helicopters and 2,000 pilots operate 7,500 shore-to-platform trips daily to fulfill their primary mission of ferrying personnel and equipment to thousands of platforms located about 150-200 mi. out from the Texas, Louisiana, Mississippi coastline. And all of this is accomplished while flying below 5,000 ft.



Once the flights leave the shore, "They operate in an environment devoid of the normal infrastructure found over land," says Helicopter Assn. International President Matt Zuccaro.

Radars cannot be installed on oil platforms, Capezzuto says. "It's a very harsh environment. Electromechanical devices don't like the salt water."

And Houston Center, which provides coverage of what is now classified as Oceanic airspace, can't see or talk to the helicopter operators--and as a result cannot provide direct surveillance, adds Zuccaro. Nor can pilots obtain real-time weather services.

But that will change. Under a May 2006 Memorandum of Agreement (MOA) with the FAA, the Gulf region, Louisville, Ky., Juneau, Alaska, and Philadelphia were selected to participate in "Segment One" ADS-B implementation. This involves initial installation of ground infrastructure that will support the system--and for which the FAA requested $80 million in the Fiscal 2007 budget.

Implementation committees are now assessing ground infrastructure and equipment and fielding of services. Zuccaro says the first platform site, conducted this month, was successful. Certain oil platforms will house ADS-B receivers. Under ADS-B , satellites provide GPS information to the aircraft avionics, which emit the data to ground-based receivers. Then these would couple the information to shore--in this case, Houston Center controller automation platforms. Eventually, weather-sensing devices will be installed on the platforms.

By the end of 2010, FAA expects to have the ADS-B system tested and operationally acceptable for the NAS, with Houston Center providing services in the Gulf region. By 2013, all of the U.S. is scheduled to be covered with ground infrastructure.

The avionics installation will take longer, says Capezzuto, because we will be dealing with a larger aircraft population--20,000 or more general aircraft and about 35,000 transport aircraft, all of which will have to be retro- or forward-fitted with ADS-B equipment (AW&ST Feb. 17, 2006, p. 52).

Subsequent program phases include HAI members voluntarily equipping aircraft with traffic display capability so pilots can self-separate from other aircraft. This ability, according to Capezzuto, leads to shared pilot-controller situational awareness, and therefore enhanced safety.

"The Gulf is probably the perfect implementation area for ADS-B. It's a clean slate. There's nothing down there," says Zuccaro. "Segment One is 'the true test' of ADS-B implementation in an area without support or infrastructure."

The Gulf of Mexico's area of coverage will extend to 25 deg. N. Lat. in the Gulf (see map). In about 5-10 years, it will extend to 26 deg. N. Lat., based on planned expansion of oil platform infrastructure, according to the FAA.

Zuccaro says that in the next decade activities in the gulf are expected to grow 25%, move into deeper water and extend toward the Florida coastline.

"This is a win-win situation for all stakeholders," says Capezzuto. "The operators not only get [ADS-B] service, [they also] provide FAA with data required to validate the service and get it certified."

ADS-B's precision is also seen as a way to improve capacity in the future NAS via streamlining separation standards. "Today's established standards--3 mi. to terminal and 5 mi. en route--are based on the traditional radars' infrastructure," says Capezzuto. "The reality is, everyone puts a little buffer around it . . . and the FAA is interested in removing those buffers. Its hope is to project forward as air traffic increases and start looking at reducing those separation standards," he says.

To accomplish that wouldn't require more air traffic controllers, Capezzuto says. Rather, ADS-B would increase situational awareness of pilots by putting information in the cockpit, and controllers can then shift more toward air traffic management function.

The nation's more crowded airspace of the future could and would be kept safe under current infrastructure, but ATC would not be able to accommodate traffic at the times airlines want to fly, says Capezzuto. And the Next-Gen system must be able to handle future growth.

Under the MOA, the FAA will fund, install and operate the ADS-B network in the gulf. The helicopter industry and platform operators will prove platform space for installation of system equipment. HAI's efforts in a 20-year period to provide transportation of personnel to the platform, along with power and telecommunications as well as the voluntary installation of the avionics equipment for their IFR fleet, is valued at more than $100 million.

The minimum equipment required on the aircraft would be a transmitter, which would allow ATC to "see" and control the aircraft. The next upgrade, the display unit, would open up available uplink data so pilots can visually monitor traffic on the panel and self-separate. When that will occur will depend on the completion of the evaluation of transmitters and equipment operation.

Louisville, Philadelphia and Juneau were selected for Segment One because they all pose a unique set of problems. Each Tracon or Center has different computer interfaces with the NAS, which would require the FAA to build and test new infrastructure to interface with various automation platforms.

The challenge at Philadelphia, a UPS hub, is in validating ADS-B within terminal airspace that has a high RF interference environment. The New York-Philadelphia region is rife with various types of radars and other devices that emit RF energy, says Capezzuto.

Louisville, UPS's main hub, is a "petri dish" in which the FAA will validate separation standards involving a large number of UPS aircraft operating within certain timeframes, similar to most major hubs.

Juneau offers the challenge of a mixture of equipment including multiple types of transponder devices, not to mention robust mountainous areas where radars are especially challenged.

Some general aviation sectors are exercising caution in fully embracing ADS-B. The National Business Aviation Assn. is in support of the system, but wants the FAA to set a firm plan for certification of equipment. The Aircraft Owners and Pilots Assn. also supports implementation of ADS-B, but is concerned about the affordability of equipment.

Shift register with feedback generates white noise

by Marc Damashek
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A shift register with linear feedback generates a pseudorandom sequence of pulses that can be used without digital-to-analog conversion or audio processing as extremely high-quality audio white noise. The output from the register, fed directly to an audio amplifier, produces a power spectrum that is flat to within ±1 decibel over the entire audio range.

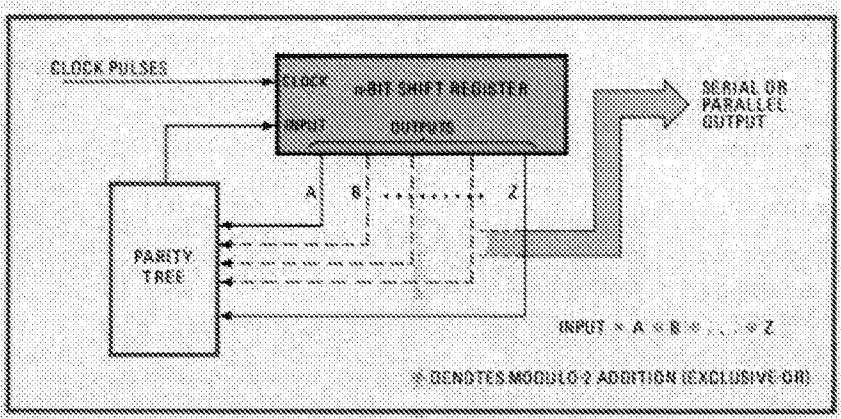
The operating principles of a linear-feedback shift register (LFSR) are illustrated in Fig. 1. The input to the first stage of an n-bit register is determined at each clock pulse by the exclusive-OR (parity) function of some output taps of the register. Choosing these taps is the crucial step in constructing a LFSR that performs as required.

For an n-bit shift register, taps can be chosen so that the register cycles through $2^n - 1$ different states before repeating any previous state. All possible n-bit words are generated except the word containing only 0s [*Electronics*, Nov. 27, 1975, p. 104]. In addition, with the use of only two taps, some shift-register lengths can produce these maximal-length sequences. A partial list of such registers is given in the table, which is excerpted from "Shift Register Sequences," by S. Golomb (Holden-Day Inc., San Francisco, 1967). As the table shows, even shift registers that are only moderately long can produce astronomically long sequences.

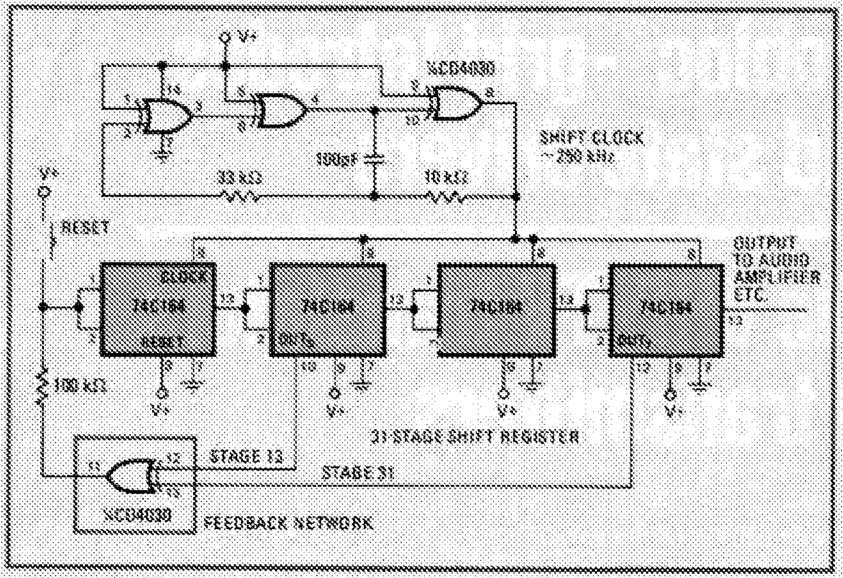
An appropriate clock and a sufficiently long register generate a flat power spectrum of audio white noise, using the digital bit stream itself as the noise source. Fig-

MAXIMUM LENGTH LINEAR FEEDBACK SHIFT REGISTERS THAT REQUIRE ONLY TWO FEEDBACK TAPS

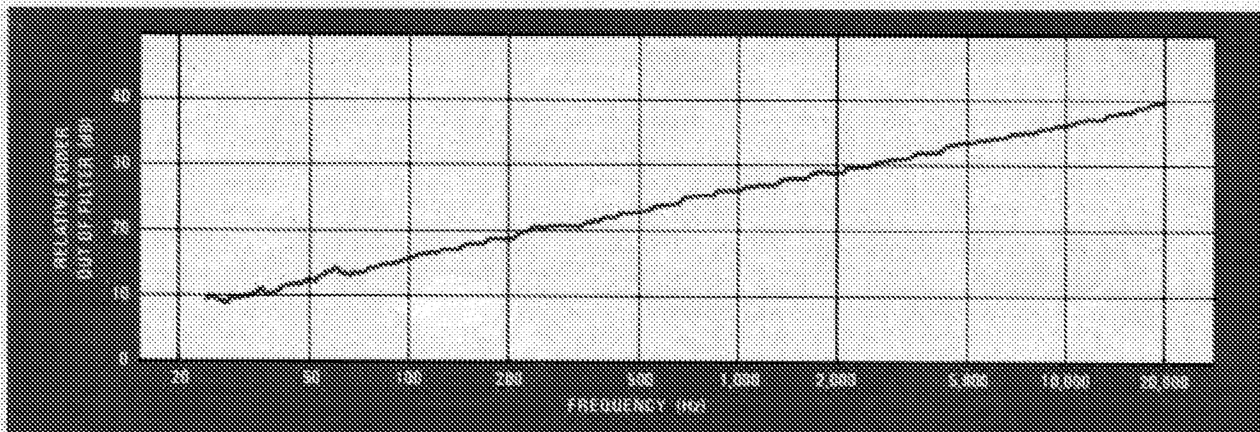
No. of stages	Stages at which taps are placed	Sequence length	Duration of sequence using 250 kHz clock
7	1, 7 or 3, 7	127	0.51 ms
9	4, 9	511	2.0 ms
10	3, 10	1,023	4.1 ms
11	2, 11	2,047	8.2 ms
15	1, 15 or 4, 15 or 7, 15	32,767	131 ms
17	3, 17 or 5, 17 or 6, 17	131,071	0.52 s
18	7, 18	262,143	1.0 s
20	3, 20	1,048,575	4.2 s
21	2, 21	2,097,151	8.4 s
22	1, 22	4,194,303	17 s
23	5, 23 or 9, 23	8,388,607	34 s
25	3, 25 or 7, 25	33,554,431	2.2 m
28	3, 28 or 9, 28 or 13, 28	268,435,455	18 m
29	2, 29	536,870,911	36 m
31	3, 31 or 6, 31 or 7, 31 or 13, 31	2,147,483,647	2.4 h
33	13, 33	8,589,934,591	9.5 h
35	2, 35	34,359,738,367	1.6 d
36	11, 36	68,719,476,735	3.2 d
39	4, 39 or 8, 39 or 14, 39	5.5×10^{11}	25 d
41	3, 41 or 20, 41	2.2×10^{12}	102 d



1. Pseudorandom pulses . . . In this linear-feedback shift register, some of the output ports are connected back to the input through an exclusive-OR circuit. Depending upon which output taps are fed back, a nonrepeating sequence of any length up to $2^n - 1$ binary words can be generated.



2. . . . generate noise . . . This 31-stage linear-feedback shift register is arranged to produce a maximum-length pseudorandom bit sequence by connection of stages 13 and 31 back to input. Output bit stream, which can be taken from any port, constitutes a white-noise source.



3. . . . like this. The output power spectrum of the circuit in Fig. 2, measured directly at the output of stage 31, slopes upward because filter bandwidth is proportional to frequency. The slope of 3 dB/octave indicates white noise. Reference level (0 dB) was chosen arbitrarily.

ure 2 shows a 31-stage LFSR, with taps at stages 13 and 31 and a shift clock running at 250 kilohertz.

Any shift register that provides access to the required feedback bits will serve. For instance, two CD4006s might have been used instead of the 74C164s. With only three ICs, these shift registers can give access to bits 13 and 31. For a white-noise generator in audio applications, the component values are noncritical. The reset button ensures that at least a single 1 is initially in the shift register, but the manual button can be replaced by a more elaborate initialization circuit if desirable.

The audio-power spectrum from the circuit in Fig. 2, measured directly at the output of stage 31, is shown in Fig. 3. A series of ⅓-octave filters measures the spectrum. The curve is inclined upward at a rate of 3 decibels per octave, matching the increasing bandwidth of the filters. The deviation from a straight line inclined 3 dB/octave is less than 1 dB over the frequency interval from 25 Hz to 20 kHz. The largest deviation occurs at the power-line frequency of 60 Hz. The table shows that the string produced by this register is longer than 2 billion bits and, at a 250-kHz clock rate, will take more than two hours to repeat.

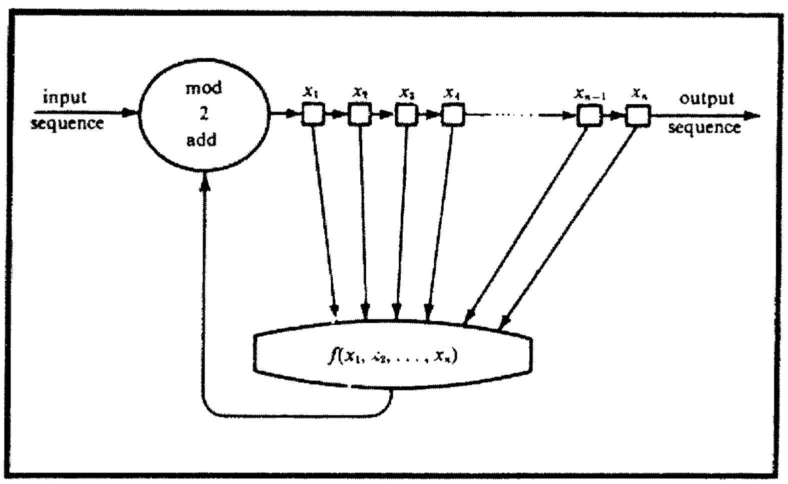
The LFSR pulse sequences are also used for error-correcting codes, spread-spectrum techniques [*Electronics*, May 29, 1975, p.127], and other random-selection processes. In a maximum-length LFSR n bits long, the bit string produced is statistically identical to $2^n - 1$ flips of an ideal coin (one with precisely equal probabilities of landing heads or tails). Thus, for example, a 17-stage LFSR can generate the equivalent of 131,071 coin-flips. Any stage of the register may provide the output, since every bit is eventually shifted the entire length of the register.

Such a device could be useful for producing uncorrelated stimuli in a psychophysical experiment, because it could easily determine which of two possible stimuli to present to a test subject. It can do so with an undiscernible, yet repeatable, pattern so that a second test subject could be given the same sequence of stimuli. If the bit string from the 31-stage register in Fig. 2 were used for test stimuli with an average interval between stimuli of 5 seconds, it would not repeat for 340 years. □

Designer's casebook is a regular feature in Electronics. We invite readers to submit original and unpublished circuit ideas and solutions to design problems. Explain briefly but thoroughly the circuit's operating principle and purpose. We'll pay $50 for each item published.

SHIFT REGISTER SEQUENCES

SECURE AND LIMITED-ACCESS CODE GENERATORS
EFFICIENCY CODE GENERATORS
PRESCRIBED PROPERTY GENERATORS
MATHEMATICAL MODELS



By SOLOMON W. GOLOMB

Aegean Park Press

SHIFT REGISTER SEQUENCES

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ISBN: 0-89412-048-4

Aegean Park Press
P.O. Box 2120
Walnut Creek, California 94595
(800) 736-3587
(925) 947-2533
Fax (925) 947-2144
www.aegeanparkpress.com

Manufactured in the United States of America

PREFACE

The theory of shift register sequences has found major applications in a wide variety of technological situations, including secure, reliable and efficient communications, digital ranging and tracking systems, deterministic simulation of random processes, and computer sequencing and timing schemes. Yet this theory has been presented previously only in disjointed and scattered form, in a variety of out-of-print or otherwise inaccessible company reports, and in scattered journal articles. The purpose of this book is to collect and present in a single volume a thorough treatment of both the linear and nonlinear theory, with a guide to the area of application, and a full bibliography of the related literature.

From an engineering viewpoint, the theory of shift register sequences is very well worked out and fully ready for use. However, from a mathematical standpoint, there are certainly many unresolved problems worthy of further study.

I was first introduced to the problem of shift register sequences in 1954, while on a summer job with the Glenn L. Martin Company in Baltimore; and that was the beginning of a long friendship. My initial reaction was that the mathematics involved was extremely beautiful and that unfortunately the application was probably just shortlived and insignificant. Little did I realize then how important shift register techniques were destined to become in our technology.

I returned to Harvard in the fall, and I took advantage of being in Cambridge to pay frequent visits to Neal Zierler and others at the Lincoln Laboratory of M. I. T. who were similarly interested in shift registers. Finally, in June, 1955, I submitted my paper "Sequences with Randomness Properties," as the final progress report on my consulting contract with the Martin Co.

In the summer of 1956, I took a position at the Jet Propulsion Laboratory, where there was already considerable interest in shift register sequences. At JPL I worked both individually and in collaboration with Lloyd Welch on these problems for several years, and a number of important reports were produced. The transfer of the JPL contract, in 1958, from Army Ordnance to NASA, meant a major redirection in the type of *applications* we sought for shift register sequences, but, as it turned out, the theoretical foundation was already almost complete. One of the many major applications of this work has been to a remarkably precise interplanetary-distance ranging system, which has been adopted by the Deep Space Network, operated by JPL for the Office of Tracking and Data Acquisition of NASA.

It is hard to establish accurate priorities as to who did what first. For example, E. N. Gilbert of the Bell Telephone Laboratories derived much of the linear theory a year or so earlier than either Zierler, Welch, or myself, but his memorandum had very limited distribution. Many others have rederived the linear theory independently since that time, and doubtless others will continue to do so. Of course, the first investigation of linear recurrence relations modulo p goes back as far as Lagrange, in the eighteenth century, and an excellent modern treatment was given (as a purely mathematical exposition) by Marshall Hall in 1937.

In assembling this volume, the procedure which I followed was to take the most important reports and articles of which I was an author or co-author, and edit them into a systematic exposition, with a reasonable continuity of both style and subject matter.

To preserve the historical flavor and continuity of the material, I have indicated the original publications from which the various papers were extracted, and in those relatively rare cases where the original version contained errors of fact or flaws in reasoning, I have not hesitated to correct them.

The two chapters which form Part One are chronologically the most recent. However, they are written from a tutorial standpoint, and thus serve to put the more technical material which follows into better perspective. Also, being more recently written, they give a more up-to-date indication of the place of shift register theory and applications in our current technology. Chapter II indicates the broader framework (namely, mathematical machine theory) within which shift registers are such an important special case.

Part Two deals with the linear theory. Although the term *linear* has been much overworked and abused, there is a reasonably consistent usage common to the terms *linear algebra*, *linear differential equations*, *linear operators*, *linear difference equations*, and *linear systems theory*. Moreover, there are a number of standard techniques for analyzing linear systems-matrix methods, operator methods, Laplace-Stieltjes transform methods, flow graph methods, impulse-response methods, etc.

All of these methods succeed in replacing a linear system by its "characteristic equation," and the behavior of the system is related to the factorization and the roots of the characteristic equation.

Linear shift registers are *linear* in this standardized sense. However, the underlying arithmetic is not that of the real or complex numbers, but of the field of two elements, 0 and 1, operating modulo 2. The analysis of linear shift register behavior, then, reduces to the study of their characteristic equations, which are polynomials with coefficients in the field of two elements.

In Chapter III, "Sequences with Randomness Properties," we start with certain desirable constraints on binary sequences, and are led to linear shift registers for the generation of such sequences. The analysis of linear shift registers uses the method recently popularized among electrical engineers under the name of the "*Z*-transform," and known to mathematicians since the late eighteenth century as the method of "generating functions." It would have been equally valid to use any of the other methods for analyzing linear systems, and there are articles by various authors which do so. In any case, the same theorems result, and the same correspondence between shift registers and polynomials occurs.

In Chapter IV, "Structural Properties of PN Sequences," we pay special attention to the correlation properties and spectra of shift register sequences. The correlation results provide a deeper insight into the behavior of the linear shift register sequences, and the spectral results are particularly important when the shift register sequence is used to modulate a radio signal.

Finally, in Chapter V, "Factorization of Trinomials over GF(2)," there is a detailed discussion of the theory of polynomial factorization over the field of two elements, with special emphasis on trinomials (i.e. three term polynomials), which correspond to the simplest shift registers to construct. Chapter V concludes with a factorization table for trinomials through degree 46.

Part Three deals with the nonlinear theory. The "nonlinear" case is, of course, the general case, in which almost anything can happen. Unlike the highly restricted "linear" case, where we developed the necessary analytical procedures to determine exact lengths of sequences, it is sufficiently ambitious in general to ask *qualitative* questions.

In Chapter VI, "Nonlinear Shift Register Sequences," we concern ourselves with such problems as when the state diagram has only "pure" cycles, without branches, and how often all the states lie on a single cycle. In the case of branchless cycles, a simple criterion is given for whether the total number of cycles is even or odd, and a number of important corollaries are deduced from this result.

In Chapter VII, "Cycles from Nonlinear Shift Registers," we develop a *statistical* model for the number of cycles, the expected lengths of the cycles, the probability that a given vector lies on the longest cycle, etc. Also, a construction is explained for obtaining cycles of any length from 1 to 2^n inclusive from a shift register of n stages.

A nonlinear shift register necessarily involves a Boolean function of n variables to compute the feedback term. We conclude the discussion of the nonlinear case with Chapter VIII, "On the Classification of Boolean Functions," which explains the reduction in the number of truly distinct cases which need to be considered, based on symmetry properties of the Boolean functions.

Not surprisingly, the nonlinear theory leaves many important questions as yet unanswered. However, the treatment presented here resolves most of the basic qualitative issues, and sets up procedural guidelines and methodology for further investigations.

PREFACE
TO THE REVISED EDITION

In the fifteen years since *Shift Register Sequences* was originally published in hard cover by Holden-Day, Inc., a great many developments have taken place. Far more is now known about both the theory and the applications of these sequences, and it would be a monumental undertaking to revise the book so as to reflect all of this. The present objective is more modest. There has been great demand for copies of the book since it went out of print, and even for the long-unobtainable Martin Co. and Jet Propulsion Laboratory reports which were reincarnated as some of its chapters. To fill this demand, the paperback edition faithfully reprints the original text, with two significant additions. One is a Comprehensive Bibliography with more than 400 entries, which gives the ambitious reader a head start on getting fully up to date in those areas in which he is most interested. The other is a new Chapter 9, titled *Selective Update*, which describes some of the most important recent developments involving topics which are already treated in the text. It is my hope to publish another volume, based on nine or ten of the most important papers which have appeared about shift register sequences since 1967, within the next two years.

I wish to express my gratitude to Wayne G. Barker, President of the Aegean Park Press, for his interest in publishing this edition, and for prodding me into doing the required work; and to Holden-Day, Inc., and its President, Fredrick H. Murphy, for the assignment of copyright from the original edition.

Solomon W. Golomb
Los Angeles, California
May 1, 1982

Spread Spectrum Scene

The ABCs of Spread Spectrum — *A Tutorial*

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Contents of Our SS Tutorial Pages

Introduction to Spread Spectrum

by Randy Roberts, Director of RF/Spread Spectrum Consulting (Retired)

Over the last eight or nine years a new commercial marketplace has been emerging. Called spread spectrum, this field covers the art of secure digital communications that is now being exploited for commercial and industrial purposes. In the next several years hardly anyone will escape being involved, in some way, with spread spectrum communications. Applications for commercial spread spectrum range from "wireless" LAN's (computer to computer local area networks), to integrated bar code scanner/palmtop computer/radio modem devices for warehousing, to digital dispatch, to digital cellular telephone communications, to "information society" city/area/state or country wide networks for passing faxes, computer data, email, or multimedia data.

The *IEEE Spectrum* of August, 1990 contained an article entitled *Spread Spectrum Goes Commercial,* by Donald L. Schilling of City College of New York, Raymond L. Pickholtz of George Washington University, and Laurence B. Milstein of UC San Diego. This article summarized the coming of commercial spread spectrum:

> "Spread-spectrum radio communications, long a favorite technology of the military because it resists jamming and is hard for an enemy to intercept, is now on the verge of potentially explosive commercial development. The reason: spread-spectrum signals, which are distributed over a wide range of frequencies and then collected onto their original frequency at the receiver, are so inconspicuous as to be 'transparent.' Just as they are unlikely to be intercepted by a military opponent, so are they unlikely to interfere with other signals intended for business and consumer users -- even ones transmitted on the same frequencies. Such an advantage opens up crowded frequency spectra to vastly expanded use.
>
> "A case in point is a two-year demonstration project the Federal Communications Commission (FCC) authorized in May (1990) for Houston, Texas, and Orlando, Fla. In both places, a new spread spectrum personal communications network (PCN) will share the 1.85-1.9-gigahertz band with local electric and gas utilities. The FCC licensee, Millicom Inc., a New York City-based cellular telephone company, expects to enlist 45000 subscribers.
>
> "The demonstration is intended to show that spread-spectrum users can share a frequency band with conventional microwave radio users--without one group interfering with the other -- thereby increasing the efficiency with which that band is used. . . . "

How Spread Spectrum Works

Spread Spectrum uses wide band, noise-like signals. Because Spread Spectrum signals are noise-like, they are hard to detect. Spread Spectrum signals are also hard to Intercept or demodulate. Further, Spread Spectrum signals are harder to jam (interfere with) than narrowband signals. These Low Probability of Intercept (LPI) and anti-jam (AJ) features are why the military has used Spread Spectrum for so many years. Spread signals are intentionally made to be much wider band than the information they are carrying to make them more noise-like.

Spread Spectrum signals use fast codes that run many times the information bandwidth or data rate. These special "Spreading" codes are called "Pseudo Random" or "Pseudo Noise" codes. They are called "Pseudo" because they are not real gaussian noise.

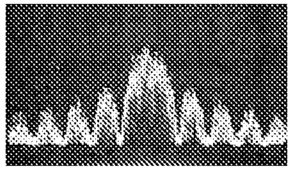
Spread Spectrum transmitters use similar transmit power levels to narrow band transmitters. Because Spread Spectrum signals are so wide, they transmit at a much lower spectral power density, measured in Watts per Hertz, than narrowband transmitters. This lower transmitted power density characteristic gives spread signals a big plus. Spread and narrow band signals can occupy the same band, with little or no interference. This capability is the main reason for all the interest in Spread Spectrum today.

More Details on Spread Spectrum

Over the last 50 years, a class of modulation techniques usually called "Spread Spectrum," has been developed. This group of modulation techniques is characterized by its wide frequency spectra. The modulated output signals occupy a much greater bandwidth than the signal's baseband information bandwidth. To qualify as a spread spectrum signal, two criteria should be met:

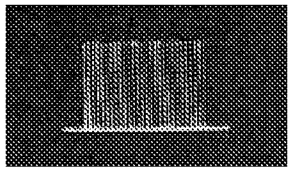
1. The transmitted signal bandwidth is much greater than the information bandwidth.

2. Some function other than the information being transmitted is employed to determine the resultant transmitted bandwidth.



A Spectrum Analyzer Photo of a Direct Sequence (DS) Spread Spectrum signal.

Most commercial part 15.247 spread spectrum systems transmit an RF signal bandwidth as wide as 20 to 254 times the bandwidth of the information being sent. Some spread spectrum systems have employed RF bandwidths 1000 times their information bandwidth. Common spread spectrum systems are of the "direct sequence" or "frequency hopping" type, or else some combination of these two types (called a "hybrid").



A Spectrum Analyzer Photo of a Frequency Hop (FH) Spread Spectrum signal.

There are also "Time Hopped" and "Chirp" systems in existence. Time hopped spread spectrum systems have found no commercial application to date. However, the arrival of cheap random access memory (RAM) and fast micro-controller chips make time hopping a viable alternative spread spectrum technique for the future. "Chirp" signals are often employed in radar systems and only rarely used in commercial spread spectrum systems.

Direct sequence systems -- Direct sequence spread spectrum systems are so called because they employ a high speed code sequence, along with the basic information being sent, to modulate their RF carrier. The high speed code sequence is used directly to modulate the carrier, thereby directly setting the transmitted RF bandwidth. Binary code sequences as short as 11 bits or as long as [2^(89) - 1] have been employed for this purpose, at code rates from under a bit per second to several hundred megabits per second.

The result of modulating an RF carrier with such a code sequence is to produce a signal centered at the carrier frequency, direct sequence modulated spread spectrum with a (sin x/x)2 frequency spectrum. The main lobe of this spectrum has a bandwidth twice the clock rate of the modulating code, from null to null. The sidelobes have a null to null bandwidth equal to the code's clock rate. Figure 1 illustrates the most common type of direct sequence modulated spread spectrum signal. Direct sequence spectra vary somewhat in spectral shape depending upon the actual carrier and data modulation used. The signal illustrated is that for a binary phase shift keyed (BPSK) signal, which is the most common modulation signal type used in direct sequence systems.

Frequency hopping systems -- The wideband frequency spectrum desired is generated in a different manner in a frequency hopping system. It does just what its name implies. That is, it "hops" from frequency to frequency over a wide band. The specific order in which frequencies are occupied is a function of a code sequence, and the rate of hopping from one frequency to another is a function of the information rate. The transmitted spectrum of a frequency hopping signal is quite different from that of a direct sequence system. Instead of a [(sin x)/x]^2-shaped envelope, the frequency hopper's output is flat over the band of frequencies used. Figure 2 shows an output spectrum of a frequency hopping system. The bandwidth of a frequency hopping signal is simply w times the number of frequency slots available, where w is the bandwidth of each hop channel.

"Inside" Spread Spectrum

This section is intended to gently introduce the reader to the more intricate aspects of the rapidly growing world of spread spectrum, wireless local and wide area networks, as well as introduce the evolution (some may call it explosion) in new communications technologies such as PCN/PCS. We will also try to thoroughly define new terms and concepts the first time we use them.

As an introduction, a little history lesson and a few definitions seem to be in order. Spread Spectrum (SS) dates back to World War II. A German lady scientist was granted a patent on a simple frequency hopping CW system. The allies also experimented with spread spectrum in World War II. These early research and development efforts tried to provide countermeasures for radar, navigation beacons and communications. The U. S. Military has used SS signals over satellites for at least 25 years. An old, but faithful, highly capable design like the Magnavox USC-28 modem is an example of this kind of equipment. Housed in two or three six foot racks, it had selectable data rates from a few hundred bits per second to about 64 kBits per second. It transmitted a spread bandwidth of 60 MHZ. Many newer commercial satellite systems are now converting to SS to increase channel capacity and reduce costs.

Over the last twenty years, many spread spectrum signals have appeared on the air. The easiest way to characterize these modulations is by their frequency spectra. These SS signals occupy a much greater bandwidth than needed by the information bandwidth of the transmitted data. To rate being called an SS signal, two technicalities must be met:

- The signal bandwidth must be much wider than the information bandwidth.
- Some code or pattern, other than the data to be transmitted, determines the actual on-the-air transmit bandwidth.

In today's commercial spread spectrum systems, bandwidths of 10 to 100 times the information rates are used. Military systems have used spectrum widths from 1000 to 1 million times the information bandwidth. There are two very common spread spectrum modulations: frequency hopping and direct sequence. At least two other types of spreading modulations have been used: time hopping and chirp.

What Exactly is Spread Spectrum?

One way to look at spread spectrum is that it trades a wider signal bandwidth for better signal to noise ratio. Frequency hop and direct sequence are well-known techniques today. The following paragraphs will describe each of these common techniques in a little more detail and show that pseudo noise code techniques provide the common thread through all spread spectrum types.

Frequency hopping is the easiest spread spectrum modulation to use. Any radio with a digitally controlled frequency synthesizer can, theoretically, be converted to a frequency hopping radio. This conversion requires the addition of a pseudo noise (PN) code generator to select the frequencies for transmission or reception. Most hopping systems use uniform frequency hopping over a band of frequencies. This is not absolutely necessary, if both the transmitter and receiver of the system know in advance what frequencies are to be skipped. Thus a frequency hopper in two meters, could be made that skipped over commonly used repeater frequency pairs. A frequency hopped system can use analog or digital carrier modulation and can be designed using conventional narrow band radio techniques. De-hopping in the receiver is done by a synchronized pseudo noise code generator that drives the receiver's local oscillator frequency synthesizer.

The most practical, all digital version of SS is direct sequence. A direct sequence system uses a locally generated pseudo noise code to encode digital data to be transmitted. The local code runs at much higher rate than the data rate. Data for transmission is simply logically modulo-2 added (an EXOR operation) with the faster pseudo noise code. The composite pseudo noise and data can be passed through a data scrambler to randomize the output spectrum (and thereby remove discrete spectral lines). A direct sequence modulator is then used to double sideband suppressed carrier modulate the carrier frequency to be transmitted. The resultant DSB suppressed carrier AM modulation can also be thought of as binary phase shift keying (BPSK). Carrier modulation other than BPSK is possible with direct sequence. However, binary phase shift keying is the simplest and most often used SS modulation technique.

An SS receiver uses a locally generated replica pseudo noise code and a receiver correlator to separate only the desired coded information from all possible signals. A SS correlator can be thought of as a very special matched filter -- it responds only to signals that are encoded with a pseudo noise code that matches its own code. Thus, an SS correlator can be "tuned" to different codes simply by changing its local code. This correlator does not respond to man made, natural or artificial noise or interference. It responds only to SS signals with identical matched signal characteristics and encoded with the identical pseudo noise code.

What Spread Spectrum Does

The use of these special pseudo noise codes in spread spectrum (SS) communications makes signals appear wide band and noise-like. It is this very characteristic that makes SS signals possess the quality of Low Probability of Intercept. SS signals are hard to detect on narrow band equipment because the signal's energy is spread over a bandwidth of maybe 100 times the information bandwidth.

The spread of energy over a wide band, or lower spectral power density, makes SS signals less likely to interfere with narrowband communications. Narrow band communications, conversely, cause little to no interference to SS systems because the correlation receiver effectively integrates over a very wide bandwidth to recover an SS signal. The correlator then "spreads" out a narrow band interferer over the receiver's total detection bandwidth. Since the total integrated signal density or SNR at the correlator's input determines whether there will be interference or not. All SS systems have a threshold or tolerance level of interference beyond which useful communication ceases. This tolerance or threshold is related to the SS processing gain. Processing gain is essentially the ratio of the RF bandwidth to the information bandwidth.

A typical commercial direct sequence radio, might have a processing gain of from 11 to 16 dB, depending on data rate. It can tolerate total jammer power levels of from 0 to 5 dB stronger than the desired signal. Yes, the system can work at negative SNR in the RF bandwidth. Because of the processing gain of the receiver's correlator, the system functions at positive SNR on the baseband data.

Besides being hard to intercept and jam, spread spectrum signals are hard to exploit or spoof. Signal exploitation is the ability of an enemy (or a non-network member) to listen in to a network and use information from the network without being a valid network member or participant. Spoofing is the act of falsely or maliciously introducing misleading or false traffic or messages to a network. SS signals also are naturally more secure than narrowband radio communications. Thus SS signals can be made to have any degree of message privacy that is desired. Messages can also, be cryptographically encoded to any level of secrecy desired. The very nature of SS allows military or intelligence levels of privacy and security to be had with minimal complexity. While these characteristics may not be very important to everyday business and LAN (local area network) needs, these features are important to understand.

Some Spread Spectrum Terms Defined

Spread spectrum technology seems to present an alphabet soup to most newcomers. We define some of the more commonly used terms in this field in the following text box. For a complete glossary, see our complete Glossary.

A Brief Spread Spectrum Glossary

For more definitions of spread spectrum terms, please visit our Technical Glossary.

- **AJ:** Anti-Jam, designed to resist interference or jamming.
- **BPSK:** Binary Phase Shift Keying -- Digital DSB suppressed carrier modulation.
- **CDMA:** Code Division Multiple Access -- a way to increase channel capacity.
- **CHIP:** The time it takes to transmit a bit or single symbol of a PN code.
- **CODE:** A digital bit stream with noise-like characteristics.
- **CORRELATOR:** The SS receiver compponent that demodulates a Spread Spectrum signal.
- **DE-SPREADING:** The process used by a correlator to recover narrowband information from a spread spectrum signal.
- **WIRELESS LAN:** Wireless Local Area Network - a 1,000-foot or less range computer-to-computer data communications network.
- **PCN:** Personal Communication Network. PCNs are usually short range (hundreds of feet to 1 mile or so) and involve cellular radio type architecture. Services include digital voice, FAX, mobile data and national/international data communications.
- **PCS:** Personal Communication System. PCSs are usually associated with cordless telephone type devices. Service is typically digital voice only.
- **PN:** Pseudo Noise - a digital signal with noise-like properties.
- **RF:** Radio Frequency - generally a frequency from around 50 kHz to around 3 GHz. RF is usually referred to whenever a signal is radiated through the air.
- **SS:** Spread Spectrum, a wideband modulation which imparts noise-like characteristics to an RF signal.
- **WIRELESS UAN:** Wireless Universe Area Network - a collection of wireless MANs or WANs that link together an entire nation or the world. UANs use very small aperture (VSAT) earth station gateway technology.

Conclusion

Our world is rapidly changing -- computers have gone from mainframes to palmtops. Radio communications has gone from lunchbox sized (or trunk mounted/remote handset car phone) to cigarette-pack-sized micro-cellular telephone technology. The technical challenges of this progress are significant. The new opportunities created by this new technology are also significant. We've talked here about some of the very basic principles in spread spectrum and talked about evolving career opportunities -- isn't it time somebody did something about moving forward in the new millennium?

About the Author:

Randy Roberts has over 30 years experience in communications, electronics and spread spectrum system design. He graduated with a BSEE in 1970 from UC Irvine. For many years prior to his retirement he operated RF/Spread Spectrum Consulting, an independent product development, publishing, strategic planning and training company. He is the founder and former publisher of Spread Spectrum Scene Online.

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Revised August 14, 2008

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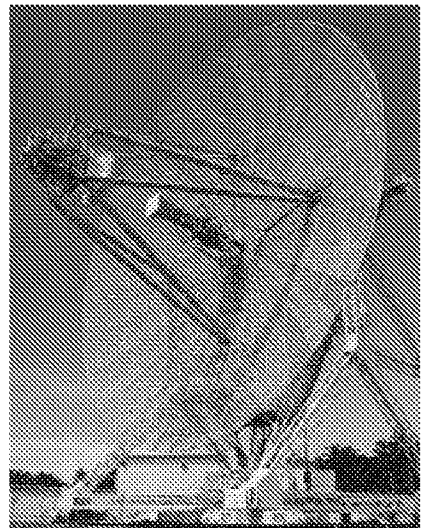
UNDETECTABLE RADAR? (PROBABLY NOT)

Active radar signals, due to those pesky laws of physics, are generally easy to detect. Because a radar system emits a powerful beam of electromagnetic radiation, traditionally in a very narrow frequency band, an adversary equipped with only a passive radiation detector can easily zero in on the platform carrying the radar.



For decades the military has been searching for a less visible (and vulnerable) "low probability of intercept" (LPI) radar. This June, Ohio State University's ElectroScience Laboratory claimed that its engineers—led by Dr. Eric K. Walton—had succeeded and "invented a radar system that is virtually undetectable."

A flurry of fawning press coverage followed. Even Dr. Walton, though, acknowledges that he did not invent noise radar, as the technology is called—it was first proposed in the 1950s. He did, however, receive the first patent for the technology earlier this year. Heavy signal-processing requirements kept noise radars in the lab for decades, but they have finally proved feasible (and, according to Walton, cheap—he claims around $100 per unit).

And they probably are undetectable—by typical radar detectors.

Typical radar signals are high-power, narrowly focused pulses;* each signal is extremely short. Most radars can't send and receive at the same time, so immediately after a pulse is sent out the radar switches to listening mode and strains to hear the pulses's echo. Incidentally, this makes them farsighted—-they can't see objects up close.

To detect these radar signals, an adversary can simply sweep his field of view searching for high-powered pulses that are narrowly focused at a single frequency. Since radar signals cannot be perfectly focused and are not constrained like lasers—the beams become larger as they travel, to form a cone—this is easier than it might sound.

Engineers have developed new techniques to make detection more difficult. For example, frequency-hopping radars move each chirp to a different frequency (the F-22 radar system reportedly does this), while spread-spectrum (radars and radios) use a (small) band of frequencies simultaneously. The signals are still extremely powerful compared to background noise, though, and are relatively easy to find with the simple detectors mentioned above.

Noise radar is different in two main ways. Like spread-spectrum radar, it spreads its signal over a band of frequencies, but the band is about 1,000 times wider than most spread-spectrum technologies. Furthermore, the signal is also shaped to look like noise—the radio equivalent of ants racing on a TV screen.

The wide band of frequencies has several advantages. Different frequencies interact with different materials in different ways—basically, using an ultra-wideband (UWB) signal allows you to see through walls, trees, rock, and many other obstacles if the signal is well constructed.

More relevant to this discussion, UWB noise radar signals also spread their power out over the different frequencies; the result is that traditional detectors, searching for very powerful signals near a particular frequency won't see noise radar. They will just "hear" more static.

And since the noise radar signal is shaped like, well, noise, it would also be hard—if not impossible—to find it by looking for a pattern in the chaos. The noise radar can only detect its own returned signal by first recording it, then comparing a time-delayed version of the recording to what it hears reflected back. (This characteristic also means noise radars detect in "rings" -- the simplest version would detect movement only at a fixed radius from the radar, but it is possible to scan many "rings" very quickly for a more complete picture. The computing requirements for this type of scanning make placing noise radars on fast-moving platforms impractical for now, but they would make exceptionally good proximity detectors, for example.)

Because of their UWB signals, noise radars work best by looking for specific targets -- they must incorporate some knowledge of what a specific target's reflection will look like. They would have great difficulty detecting an unforeseen obstacle—without prior knowledge of what its reflection

The best way for an adversary to detect a noise radar would be to search, directionally, for sources of UWB noise. The key question here is how "loud" the radar's noise would be, compared to background sources like the sun, the galactic center, local power lines, battlefield electronics, etc. Noise radars could be constructed in any number of different ways, and the signal could also be endlessly changed for different applications; lacking specific data, it is hard to speculate on how difficult they will be to detect with this technique.

From what we know now, the "undetectable" claim is something of a stretch, but these radars will almost certainly find uses. They do not interfere with each other or nearby electronics (which are designed to filter out noise), and they can see through walls. If ever used in a military capacity, they would likely force a change in radar detection and seeking technologies. It might cost the Pentagon a pretty penny to detect these new toys, but undetectable radars are probably still a long way off.

-- Eric Hundman

*UPDATE: Thanks to Rutty for the clarification. I originally wrote "chirps" here rather than pulses, which was incorrect. "Chirping" in this context refers to a popular type of signal modulation often used in radars--it ultimately allows for greater resolution.

August 3, 2006 05:43 PM | Gadgets and Gear | SHARE

Comments

rutty comments that "Noise, by definition, has infinite bandwidth". This is only true for "white" noise which does not exist. Non-white noise is called "Pink" noise and is band-limited.
The basic problem with Pink noise is that it has high correlation sidelobes when compared to, say, "chirp" pulses. If there are any large companies in the Radar or Sonar business, I have solved the problem of turning Pink noise into Almost White noise having correlation sidelobes of -100 dB. Please contact me at radson@verizon.com for licensing information.

Posted by: Dr. Renato D'Antonio at January 31, 2008 12:39 PM

"Typical radar signals are high-power, narrowly focused "chirps;" not because they sound like birds, but because each signal is extremely short"

Actually, they are called chirp signals because they are linearly frequncy modulated just like a chirp you would here from a bird. LFM signals are popular because they have a high pulse compression ratio, meaning that you can compress a long duration signal into a 'short duration' signal, typically using a matched filter or what is known as 'deramping'. The width to which a pulse compress is a direct function of its RF bandwidth (0.886 * speedOfLight / 2 / bandwidth to be exact). Transmitted bandwidth, however, in LFM systems is a function of two things: the chirp rate and the pulse length. So the short pulse asumtpion is not correct either. It may sound counter intuitive, but the a longer pulse will have a finer resolution than on half as long if the chirp rates are equal. (Google 'chirp matched filters' for more easy-to-find info.) The length of the chirp chose for a given system, like all things in engineering, depends on many things (SNR requirements and transmit power, for example) and will be tradeoff to meet design requirements.

"To detect these radar signals, an adversary can simply sweep his field of view searching for high-powered pulses that are narrowly focused at a single frequency."

Single frequency radars (most likely continuous wave) are not the most common. Most have bandwidth for the reason outlined above. I'm not sure what you mena by 'leak sideways'. The beampatern is function of the shape of the antenna amongst other things.

Noise, by definition, has infinite bandwidth.

"The wide band of frequencies has several advantages. Different frequencies interact with different materials in different ways—basically, using an ultra-wideband (UWB) signal allows you to see through walls, trees, rock, and many other obstacles if the signal is well constructed."

I havent got my learn on with foilage penetration in a while, but I believe it is the frequency band more than anything that allows for this, viz., VHF/UHF. The UWB name comes about beacuse of the fractional bandwidth required to get decent resoltuion (factionalBandwidth = RFBandwidth / carrierFrequency). This requires more sophisticated signal processing techniques than narrow band signals.

As for Nicholas' comment, there has been a lot of research in this field. I remember reading about a project where a cheap plane would be used to actually paint the sky and then it would send its detections out to the fighters so they would have to give away their location. And, isn't that how the serbs will able to track the stealh bomber? I remember something along the lines of it flying between the transmit/recieve path for some communications system or something.

Anyways, I'd bet dollar to doughnuts that there is a wealth of research out there on noise radar, it just hasnt been declassified yet.

Posted by: rutty at August 3, 2006 07:31 PM

What will be far worse, however, are multipath radars. Rather than a single sender/receiver, a multipath radar uses a group of distributed senders, all sending, and a group of distributed receivers.

This is critical: it detects many stealth techniques (any stealth technique which requires scattering rather than absorbtion or being tranparent), AND it separates out the transmitters from the receivers.

All the transmitters are dumb, cheap, plentiful, and noisy. The USAF can launch all the HARMs they want. But the receivers are smart and silent: now the anti-radar attacks are far less effective.

I've heard reports of british researchers doing multipath radar using cell-phone towers as the (ambient) transmitters.

Posted by: Nicholas Weaver at August 3, 2006 07:06 PM

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From a Different Perspective : Principles, Practice and Potential of Bistatic Radar

H. D. Griffiths

Bistatic radar systems have been studied and built since the earliest days of radar. They have the advantages that the receivers are passive, and hence undetectable. The receiving systems are also potentially simple and cheap. Bistatic radar may have a counter-stealth capability, since target shaping to reduce monostatic RCS will in general not reduce the bistatic RCS. In spite of those advantages, rather few bistatic radar systems have got past the 'technology demonstrator' phase. It has also been remarked that activity in bistatic radar tends to vary on a period of approximately fifteen years, and that currently we are at a peak of that cycle; there is particular current interest in passive coherent location (PCL) techniques, using broadcast and communications signals as 'illuminators of opportunity'.

This paper presents a review of some of the history, and the properties and current developments in the subject, and conjectures whether or not the present interest is just another peak in the cycle.

Index Terms— bistatic radar, passive coherent location.

I. INTRODUCTION

Bistatic radar systems have been studied and built since the earliest days of radar. As an early example, the Germans used the British Chain Home radars as illuminators for their *Klein Heidelberg* bistatic system. Bistatic radars have some obvious advantages. The receiving systems are passive, and hence undetectable. The receiving systems are also potentially simple and cheap. Bistatic radar may also have a counter-stealth capability, since target shaping to reduce target monostatic RCS will in general not reduce the bistatic RCS. Furthermore, bistatic radar systems can utilize VHF and UHF broadcast and communications signals as 'illuminators of opportunity', at which frequencies target stealth treatment is likely to be less effective.

Bistatic systems have some disadvantages. The geometry is more complicated than that of monostatic systems. It is necessary to provide some form of synchronization between transmitter and receiver, in respect of transmitter azimuth angle, instant of pulse transmission, and (for coherent processing) transmit signal phase. Receivers which use transmitters which scan in azimuth will probably have to utilize 'pulse chasing' processing.

Over the years a number of bistatic radar systems have been built and evaluated. However, rather few have progressed beyond the 'technology demonstrator' phase. Willis [32] has remarked that interest in bistatic radar tends to vary on a period of approximately fifteen years, and that currently we are at a peak of that cycle.

The purpose of this paper is therefore to present a subjective review of the properties and current developments in the subject, with particular emphasis on 'passive coherent location' and to consider whether or not the present interest is just another peak in the cycle.

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II. PROPERTIES OF BISTATIC RADAR

A. Bistatic radar geometry

The properties of bistatic radar are described in detail by Willis [30, 31] and by Dunsmore [6]. Jackson [17] has analyzed the geometry of bistatic radar systems, and his notation has been widely adopted.

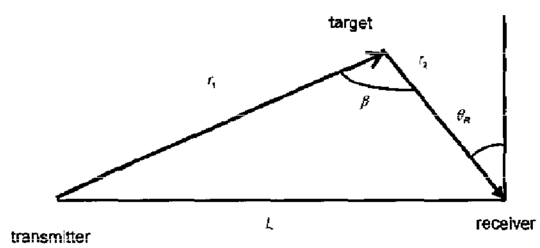


Figure 1. Bistatic radar geometry.

From this:

$$r_2 = \frac{\left(r_1 + r_2\right)^2 - L^2}{2\left(r_1 + r_2 + L\sin\theta_R\right)} \tag{1}$$

Contours of constant bistatic range are ellipses, with transmitter and receiver as the two foci.

The bistatic radar equation is derived in the same way as the monostatic radar equation:

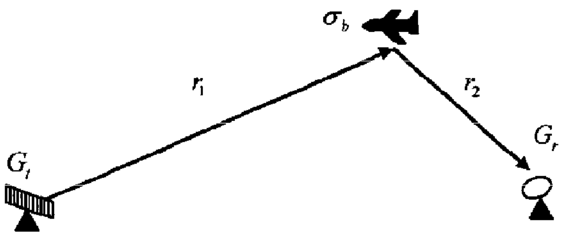
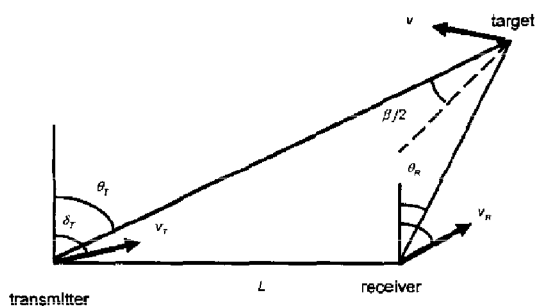


Figure 2. Bistatic radar equation.

$$\frac{P_r}{P_n} = \frac{P_t G_t G_r \lambda^2 \sigma_b}{(4\pi)^3 r_1^2 r_2^2 k T_0 BF} \qquad (2)$$

The factor $1/(r_1 r_2)$, and hence the signal-to-noise, has a minimum value for $r_1 = r_2$. Thus the signal-to-noise ratio is highest for targets close to the transmitter or close to the receiver.

Doppler shift depends on the motion of target, transmitter and receiver (Figure 3), and in the general case the equations are quite complicated [17, 31].



$$\beta = \theta_T - \theta_R$$

Figure 3. Bistatic Doppler (after Jackson [17]).

In the case when only the target is moving the Doppler shift is given by:

$$f_D = \left(\frac{2V}{\lambda}\right)\cos\delta\cos(\beta/2) \qquad (3)$$

B. Bistatic radar cross section

The bistatic RCS of targets has been studied extensively [7], though relatively little has been published in the open literature. Early work [4, 18] resulted in the bistatic equivalence theorem, which states that the bistatic RCS σ_b is equal to the monostatic RCS at the bisector of the bistatic angle β, reduced in frequency by the factor cos (β/2), given (i) sufficiently smooth targets, (ii) no shadowing, and (iii) persistence of retroreflectors. These assumptions are unlikely to be universally valid, particularly for stealthy targets, so the results should be used with care.

C. Forward scatter

A limiting case of the bistatic geometry occurs when the target lies on the transmitter-receiver baseline. Whilst this means that range information cannot be obtained, the geometry does give rise to a substantial enhancement in scattering, even for stealthy targets, due to the forward scatter phenomenon. This may be understood by reference to Babinet's principle, which shows that a perfectly absorbing target will generate the same forward scatter as a target shaped hole in a perfectly conducting screen. The forward scatter RCS is approximately $\sigma_b = 4\pi A^2/\lambda^2$, where A is the target projected area, and the angular width θ_B of the scattering will be of the order of λ/d radians, where d is the target linear dimension. Figure 4 shows how these vary with frequency, for a target of the size of a typical aircraft, and shows that frequencies around VHF / UHF are likely to be optimum for exploiting forward scatter.

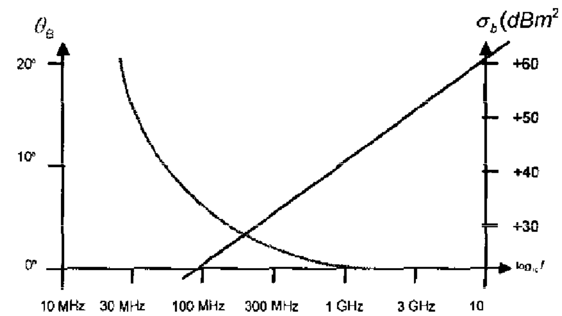


Fig. 4. Variation of forward scatter RCS and angular width of response (d = 10m, A = 10m²).

D. Bistatic clutter

Bistatic clutter is subject to greater variability than the monostatic case, because there are more variables associated with the geometry [30]. The clutter RCS σ_c is the product of the bistatic backscatter coefficient σ_b^0 and the clutter resolution cell area A_c. Both σ_b^0 and A_c are geometry dependent, with the maximum value of σ_b^0 occurring at specular angles. There is relatively little experimental data available, and little work has been done in developing models for bistatic clutter.

There is some reason to suppose that bistatic sea clutter may be less 'spiky' than equivalent monostatic sea clutter, and hence that bistatic geometries may be more favourable for detection of small targets – but this remains to be investigated.

There is thus much scope for new work on bistatic clutter; to gather data, to analyze the results, and to develop bistatic clutter models.

III. PASSIVE COHERENT LOCATION

The use of broadcast or communications signals as 'illuminators of opportunity' has become known as 'passive coherent location' (PCL) or 'hitchhiking', and there has been particular interest in this aspect of bistatic radar in recent years.

The properties of transmissions for these purposes can be assessed in terms of (i) power density at the target, (ii) spatial and temporal coverage, and (iii) waveform. The power density Φ (in W/m^2) at the target is evaluated from:

$$\Phi = \frac{P_t G_t}{4\pi r^2} \tag{4}$$

The spatial and temporal coverage will depend on the location of the transmitter, its radiation pattern, and (for example) whether it is stationary or moving and whether it operates for 24 hours per day or not. In some cases the vertical plane radiation pattern of TV or radio transmissions is deliberately shaped so as to avoid wasting power above the horizontal.

The coverage achieved by VHF FM radio and TV transmissions is substantial. This is because such systems have to be designed to cope with non line-of-sight propagation and very inefficient antenna and receiver systems. Cellphone base stations are also potentially useful as PCL illuminators [33, 35]; whilst these are of rather lower power, there are many of them, especially in urban areas. Satellite-borne illuminators, such as DBS TV [12], satellite communications and navigation [2, 19] and spaceborne radar [13, 23, 34] are also of interest.

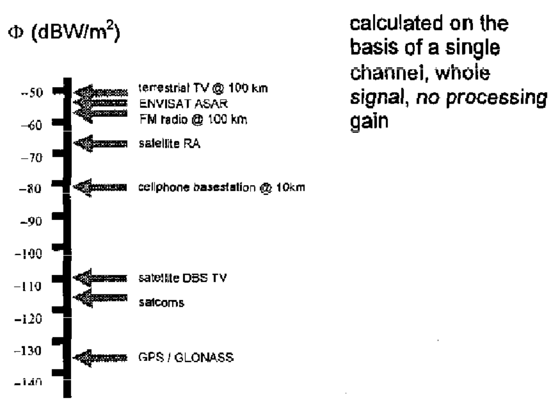


Fig. 5. Power density Φ for various PCL illuminators.

The waveform parameters of interest are the frequency, bandwidth, ambiguity function, and stability. In some cases it may be appropriate only to use a portion of the available signal (for example, to avoid ambiguities associated with the line and frame repetition rate of analogue TV modulation). In such cases the transmit power value used in equation (4) should be appropriate.

Figure 5 shows the values of Φ for various PCL illuminators, under various assumptions. These are calculated on the basis of a single channel, the whole signal bandwidth, and no processing gain.

The detection performance can then be estimated from:

$$(r_2)_{max} = \left(\frac{\Phi \sigma_b \lambda^2 G_p}{(4\pi)^2 (S/N)_{min} kT_0 BF} \right)^{1/2} \tag{5}$$

where G_p is the processing gain, which is the product of the waveform bandwidth and the integration dwell time. The integration dwell time in turn depends on the waveform coherence and the target dynamics. As a rule of thumb, the maximum integration dwell time is given by:

$$T_{max} = \left(\frac{\lambda}{A_R} \right)^{1/2} \tag{6}$$

where A_R is the radial component of target acceleration. From these equations the coverage can be predicted in terms of Ovals of Cassini around transmitter and receiver.

The waveform properties of a variety of PCL illuminators (VHF FM radio, analogue and digital TV, digital audio broadcast (DAB) and GSM at 900 and 1800 MHz) have been assessed by digitizing off-air waveforms and calculating and plotting their ambiguity functions [14]. The receiving system was based on a HP8565A spectrum analyzer, digitizing the 21.4 MHz IF output by means of an Echotek ECDR-214-PCI digitizer card mounted in a PC. The system has the advantage of great flexibility, since the centre frequency and bandwidth of the receiver can be set by the controls of the spectrum analyzer. The rather high noise figure of the spectrum analyzer is not a disadvantage, since all of the signals are of high power and propagation is line-of-sight.

Figure 6 shows typical ambiguity functions derived using this system of (a) BBC Radio 4 at 93.5 MHz, for which the programme content is speech (an announcer reading the news), and (b) a digital audio broadcast (DAB) signal at 222.4 MHz. Both show range resolution appropriate to their instantaneous modulation bandwidths (9.1 and 78.6 kHz respectively), though the difference in the sidelobe structure is very evident, showing that the digital modulation format is far superior because the signal is more noise-like.

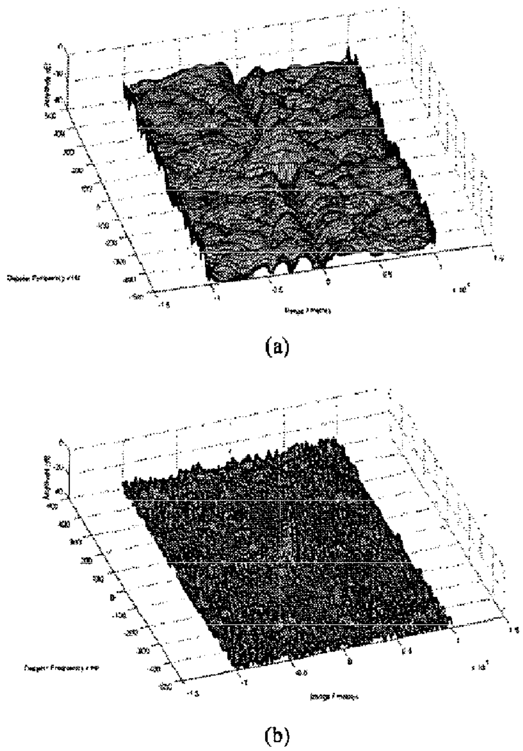


Fig. 6. Typical ambiguity functions: (a) BBC Radio 4 transmission (93.5 MHz) and (b) digital audio broadcast transmission (222.4 MHz).

Table 1 summarizes the measured ambiguity function performance of the various signals captured.

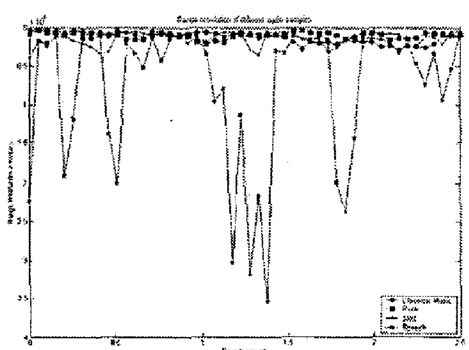


Fig. 7. Variation in range resolution against time for four types of VHF FM radio modulation.

signal	frequency (MHz)	range resolution (km)	effective bandwidth (kHz)	peak range sidelobe level (dB)	peak Doppler sidelobe level (dB)
FM radio: speech (BBC Radio 4)	93.5	16.5	9.1	–19.1	–46.5
FM radio: classical music	100.6	5.8	25.9	–23.9	–32.5
FM radio: rock music (XFM)	104.9	6.55	22.9	–12.0	–26.0
FM radio: reggae (Choice FM)	107.1	1.8	83.5	–27.0	–39.5
DAB	219.4	1.54	97.1	–11.7	–38.0
Analogue TV: chrominance sub-carrier	491.55	9.61	15.6	–0.2	–9.1
Digital TV (DVB-T)	505.0	1.72	87.1	–18.5	–34.6
GSM 900	944.6	1.8	83.3	–9.3	–46.7
GSM 1800	1833.6	2.62	57.2	–6.9	–43.8

Table 1. Properties of ambiguity functions of various types of broadcast and communications signals.

It is also important to know how these properties vary with time, as variations in the form of the ambiguity function will determine the radio system performance. Fig. 7 shows variation in range resolution of four VHF FM radio transmissions, calculated from the –3 dB width of the zero Doppler cut through the ambiguity function, over a 2.5 second interval.

It is evident that for the three types of music the range resolution varies by a factor of two or three, but for the speech modulation the range resolution is badly degraded during pauses between words, by a factor of ten or more.

IV. EXAMPLES OF SYSTEMS

A. Amateur radio forward scatter experiments

An interesting early example of PCL was given by a radio amateur, the Rev. Dr P.W. Sollom, who had noticed a fluttering effect on VHF amateur signals due to the interference between direct signals and Doppler-shifted echoes from aircraft [24]. The same effect may easily be observed with VHF FM radio and VHF or UHF TV, and works best when the direct signal and scattered signal are of comparable amplitude.

He devised an elegant set of experiments using a VHF TV signal located in northern France as illuminator, and built a two-Yagi interferometer, such that a moving target would pass through the interferometer grating lobes; allowing the target motion to be estimated from the amplitude modulation.

B. Non-co-operative radar illuminators

The first work on bistatic radar at University College London was undertaken in the late 1970s. Schoenenberger and Forrest designed and built a system using a UHF Air Traffic Control radar at Heathrow airport as illuminator, and investigated particularly the problems of synchronization between receiver and transmitter [28]. Figure 8 shows a typical PPI display from this system. A real-time co-ordinate correction scheme was also developed for this system.

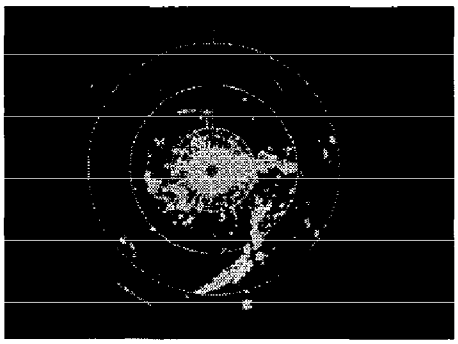


Fig. 8. PPI display from UCL bistatic radar system.

Further developments included a digital beamforming array [9] for pulse chasing experiments (Fig. 9) and a coherent MTI system using clutter from stable local echoes as a phase reference [10].

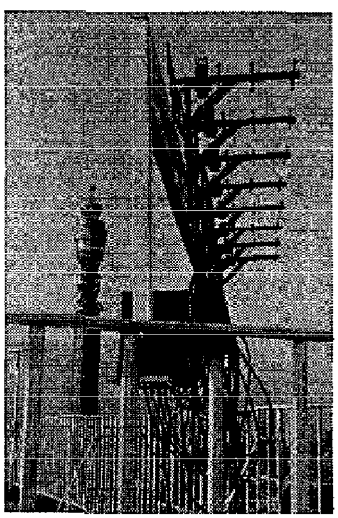


Fig. 9. Digital beamforming array used for pulse chasing experiments with UCL bistatic radar system.

C. Television-based bistatic radar

Subsequent work at UCL attempted to use UHF television transmissions as illuminators of opportunity, to detect aircraft targets landing and taking off from Heathrow airport, to the west of London [11]. Figure 10 shows the geometry. The results showed that although the television waveforms are very suitable in terms of power and coverage, the analogue television modulation format suffers from ambiguities at the 64 μs line repetition rate, which correspond to a bistatic range of 9.6 km.

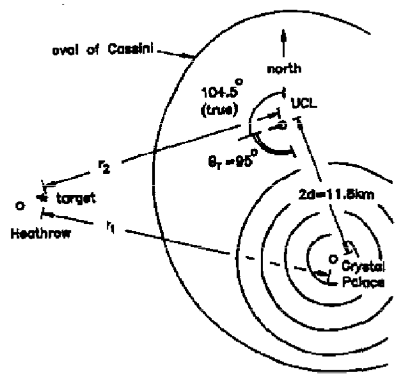


Fig.10. Horizontal-plane geometry of Crystal Palace television transmitter and Heathrow. Indicated Oval of Cassini is the locus $r_1 r_2 = 2 \times 10^8$ m.

D. TV-based forward scatter system

Howland [16] developed a UHF forward scatter system based on television transmissions. Because a forward scatter system is not able to provide range information, he adopted a different approach, measuring angle of arrival (from a two-element interferometer) and Doppler shift of the vision carrier of the television signal. Target tracking was done by an extended Kalman filter algorithm.

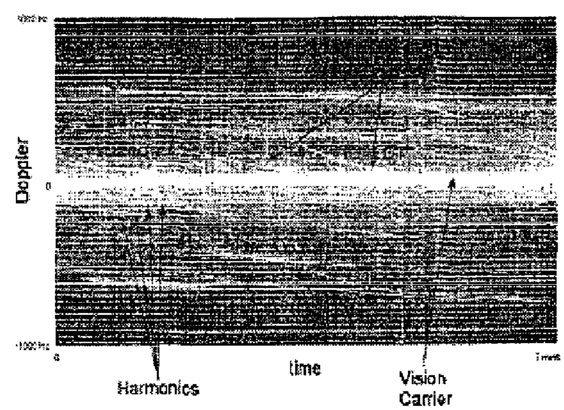


Fig. 11. Example power spectrum against time, around TV vision carrier (after Howland [16]).

He was able to demonstrate tracking of aircraft targets at ranges well in excess of 100 km (Fig. 12).

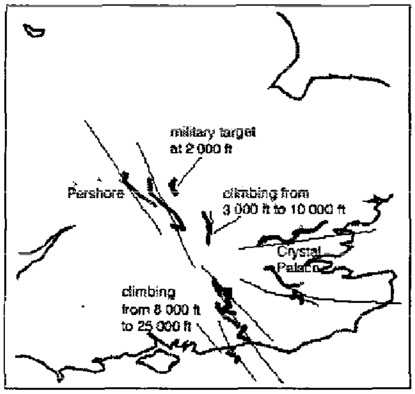


Fig. 12. Track estimates formed on 21 February 1997 between 14:00 and 14:07, compared with secondary radar tracks for the same aircraft (after Howland [16]).

E. Silent Sentry

Silent Sentry is a PCL system developed by the Lockheed Martin company, based on multiple VHF FM radio and television transmissions. In its present version (SSIII) it has demonstrated tracking of aircraft and space targets at impressive ranges. It is advertised as being applicable to:

- air surveillance and tracking in areas of limited coverage – a 'gap filler;
- capable of tracking low flying, non-cooperative, slow moving targets;
- continuous total volume surveillance of air breathing and ballistic objects;
- low acquisition and operations cost, unattended remotely managed.

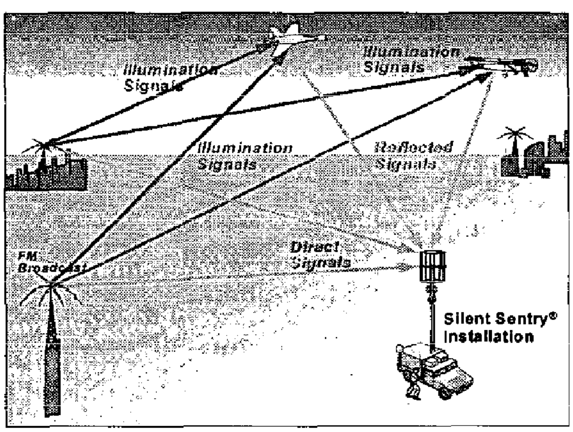


Fig. 13. Principle of operation of Silent Sentry (figure courtesy of Lockheed Martin).

V. CONCLUSIONS

This paper has attempted to present a review of bistatic radar systems, with particular emphasis on Passive Coherent Location (PCL) techniques. The introduction indicated that the question of whether the present interest is just another peak in the cycle will be addressed. There are several reasons why the answer to this is 'no', and that there is reason to believe that practical bistatic radar systems may now be developed and used.

Firstly, there is ever greater spectral congestion. Military operations are likely to be carried out close to centres of population, where there are numerous broadcast and communications signals. For most purposes this spectral congestion is a problem, but for PCL it is a positive advantage. Furthermore, the VHF and UHF frequencies used by high power FM radio and television transmissions are in many senses optimum for PCL.

Secondly, as has already been pointed out, bistatic receivers are potentially simple and cheap.

Thirdly, the advent of GPS solves many of the synchronization and timing problems that have previously limited the performance of bistatic systems.

Fourthly, the inexorable increases in signal processing power mean that many of the signal digitization and processing operations are now feasible in real time. Moore's law predicts that these advances will continue for many years.

Fertile areas for new work are: (i) the use of phased array antennas and antenna signal processing techniques for 'pulse chasing', particularly in the context of multistatic systems, (ii) development of advanced tracking algorithms for multistatic geometries, and (iii) experimental programmes to gather bistatic clutter data, and to develop bistatic clutter models.

ACKNOWLEDGEMENTS

I acknowledge invaluable discussions with many people from whom I have learned much about bistatic radar over the years. I would particularly like to mention Nick Willis, Paul Howland, John Sahr, DEN Davies, Chris Pell, Chris Baker, and also Ken Milne and Dick Lodwig, both of whom are no longer with us and who are sorely missed. I am grateful to Wendy Underwood and Dennis Freeman of Lockheed Martin, for information on the Silent Sentry PCL system, and I thank my students Hesham Ghaleb, Eero Willman and Rajaram Ramakrishnan for obtaining the results shown in Figure 6 and 7 and Table 1.

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Sensing Requirements for Unmanned Air Vehicles

Engineers develop requirements and metrics to ensure integration of future autonomous unmanned aircraft into manned airspace.

AFRL's Air Vehicles Directorate, Control Sciences Division, Systems Development Branch, Wright-Patterson AFB OH

Engineers from the Air Vehicles Directorate transferred unmanned air vehicle (UAV) sensing system requirements for airspace operations to civilian UAV users and developers. These requirements represent design goals on which to base future sensing subsystem designs, filling an omission in UAV technology planning. Directorate engineers are continuing to develop the technologies that will enable future UAVs to coexist with manned aircraft in both military and civilian airspace. Incorporating these requirements will ensure that engineers design future UAVs to detect possible conflicts, such as midair collisions or runway incursions, and take action to avoid them.

Present UAVs cannot detect manned aircraft and conflict situations and, therefore, they cannot share airspace with manned aircraft. To overcome this obstacle, UAVs need to sense the presence of other aircraft in their operating environment (see figure on next page). In other words, UAVs need to at least replicate a human pilot' s ability to see and avoid problems before they will be accepted into the national air space (NAS). Since some aircraft do not have air traffic transponders, UAVs must use onboard sensors to detect aircraft and coordinate that information with available transponder information. With this level of capability, UAVs and operators will have the situational awareness of the airspace around the vehicle to ensure safety at the same level as manned aircraft.

With this goal in mind, directorate engineers worked with Northrop Grumman Corporation (NGC) engineers to establish, iterate, and finalize sensing system performance requirements for the broad range of future Air Force missions. During this collaborative process, directorate engineers noted that many mission elements were similar to civilian airspace operations tasks, and that the requirements they were developing were directly applicable to civilian UAV technology. They also found no report that defined and expressed these requirements for nonmilitary use. To help fill this void, directorate engineers coordinated their research results with the American Institute for Aeronautics and Astronautics UAV airspace operations' focal point, North Atlantic Treaty Organization' s Standards Committees, the National Aeronautics and Space Administration, and industry organizations working the same topics from the civilian side. Incorporation of the directorate' s technology into civilian requirements' definitions and standards will directly impact airspace operations' sensing systems for current and future UAVs.

The coordinated effort of directorate and NGC engineers that resulted in the sensing system requirements represents the first stage of work on the Autonomous Flight Control Sensing Technology (AFCST) program. This program' s long-term goal is to develop the upfront portion of the UAV virtual pilot capability. During this first phase, NGC engineers analyzed midair and near-midair collision data, along with runway incursion data, to generate lessons learned. Then, the NGC engineers combined the lessons learned from aircraft mishap data with sensing performance specifications and good engineering judgment to establish conventions for operating aircraft in the NAS. Next, they examined airspace tasks for operation in NAS and grouped them into deconfliction, collision avoidance, autonomous landing, and ground operations. The UAV functional requirements resulting from this effort are shown in the table.

As shown in the table, the threshold values represent the nearterm requirements (year 2007), while objective values are far-term requirements (year 2013). Engineers consider the forward vision threshold values equivalent to or slightly better than human performance. Federal Aviation Administration data indicates the dominant cause for midair collision is when an aircraft is overtaken by a faster aircraft because a pilot' s position in the cockpit limits rear visibility. In the UAV, rear visibility is not restricted because designers can locate sensors anywhere on the aircraft. Objective values contain UAV rear vision capability to improve safety in this scenario.

Directorate and NGC engineers are currently working on the second phase of AFCST– the preliminary design of the sensor hardware architecture. The AFCST design strategy for all UAV situational awareness functions is to minimize hardware and software quantity and maximize use of multifunction sensors and common image processing software components. Most of the design efforts are completed satisfactorily. NGC engineers are continuing detailed sensor reliability analyses, capturing the individual and combined effects of sensor field-of-view coverage, sensor failure rates, and exposure rates.

During the final stage of the AFCST program, engineers will run simulations emphasizing landing and collision avoidance-tasks with demanding sensing and processing requirements. The engineers will develop landing and see-and-avoid strategies of operation as well as a detailed software architecture design. The simulations should determine if the preferred electrooptic/ infrared and radar sensors meet the specifications identified in the first phase of the AFCST program and the number of false alarms and false negatives that will be encountered. The engineers will also compare various image-processing solutions to determine the most reliable. The ideal system design will be free of nuisance faults caused by system error and will include software designed to minimize such faults. Reliability analysis studies will eventually combine software reliabilities with hardware reliabilities to meet the overall UAV system reliability.

In the near future, directorate and NGC engineers plan to publish the results of the detailed sensor reliability analysis. Program managers are also planning a follow-on hardware-in-the-loop simulation effort to address and demonstrate the integrated system design. In this realistic simulation, engineers will study concepts such as the integration of AFCST sensors with instrument flight rules avionics for see-and-avoid maneuvers, landing, and automated traffic collision avoidance. Real-time simulation will stress the detailed sensor architecture design, allowing the engineers to assess its adequacy and determine its readiness for technology transition to flight test. These efforts will ensure the safe incorporation of UAVs into the NAS.

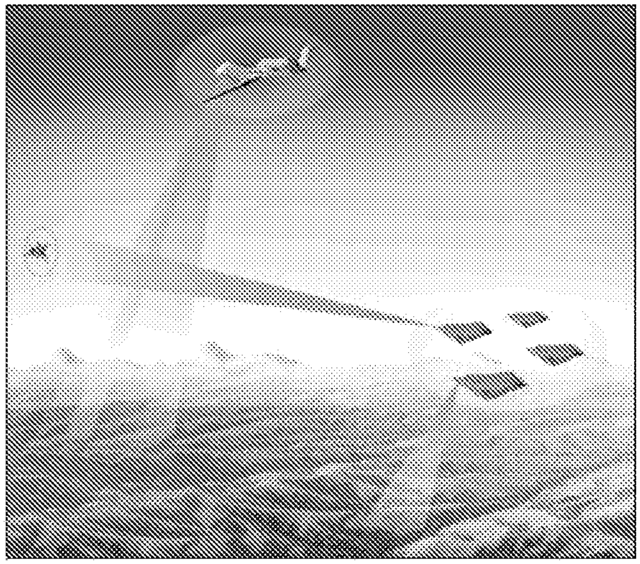


Figure. UAV senses presence of other aircraft

AIRSPACE OPERATIONS SENSING REQUIREMENTS FOR UAVs		
Functional Requirements	**Threshold Values**	**Objective Values**
Field of View	Azimuth: 60° Elevation: 30°	4 π steradians
Field of Regard	Azimuth: +/-100° Elevation: +30°, -90°	4 π steradians
Ranging	0.5 ft CEP* @ 100 ft 700 ft CEP* @ 6 nm	0.25 ft CEP* @ 100 ft 770 ft CEP* @ 13.2 nm
Imaging	Varies from 30 ft to 3 nm	Varies from 30 ft to 13.2 nm
Data Rate	30 Hz	60 Hz
Weather Capability	Visual Meteorological Capability	Visual and Instrument Meteorological Capability
Criticality	Safety Critical	Safety Critical
Emission Constraints	Various Federal Aviation Administration Limitations	Various Federal Aviation Administration Limitations
	*CEP = circular error probability	

Table. Near- and far-term UAV sensing requirement

Mr. Tom Molnar and Mr. Bruce Clough, of the Air Force Research Laborator y' s Air Vehicles Directorate, and Mr. Won-Zon Chen, of Northrop Grumman Corporation, wrote this article. For more information contact TECH CONNECT at (800) 203-6451 or place a request at http://www.afrl.af.mil/techconn/index.htm. Reference document VA-03-06

DISTRIBUTION A
PUBLIC RELEASE

Developing Sense & Avoid Requirements for Meeting an Equivalent Level of Safety

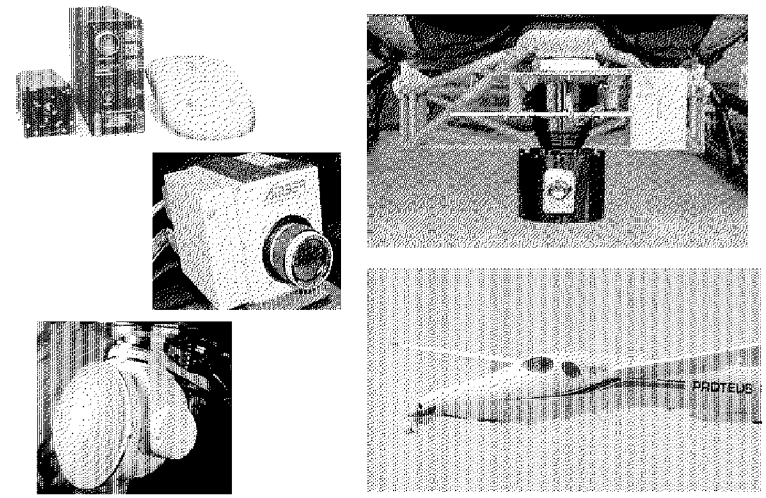
UVS Tech 2006
Salon-de-Provence, France
17-19 January 2006

Presenter: Russell Wolfe
Access 5 Technology IPT Lead
Modern Technology Solutions, Inc

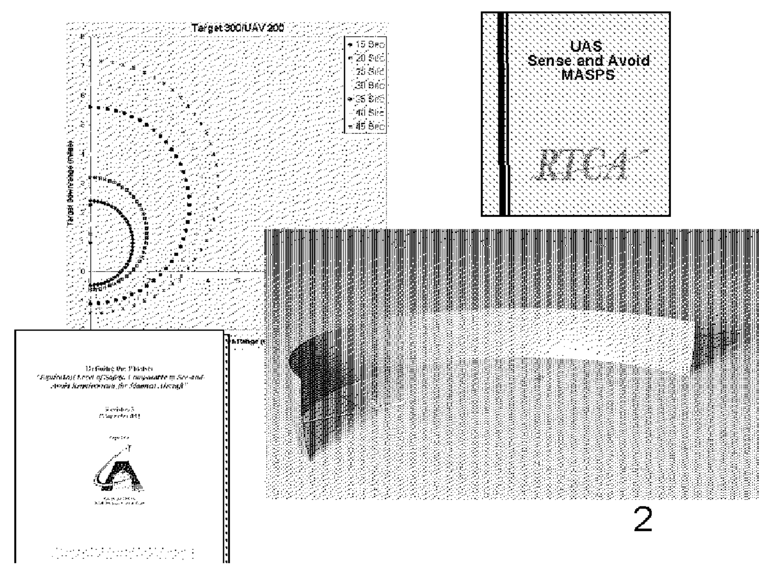
UAS Collision Avoidance Initiatives

NASA Dryden Flight Research Center

- ERAST: 1993 - 2003
  - Sensor Requirements
  - Sensor Concept Development
  - Flight Test Demonstrations
    - Cooperative
    - EO / IR
    - Radar

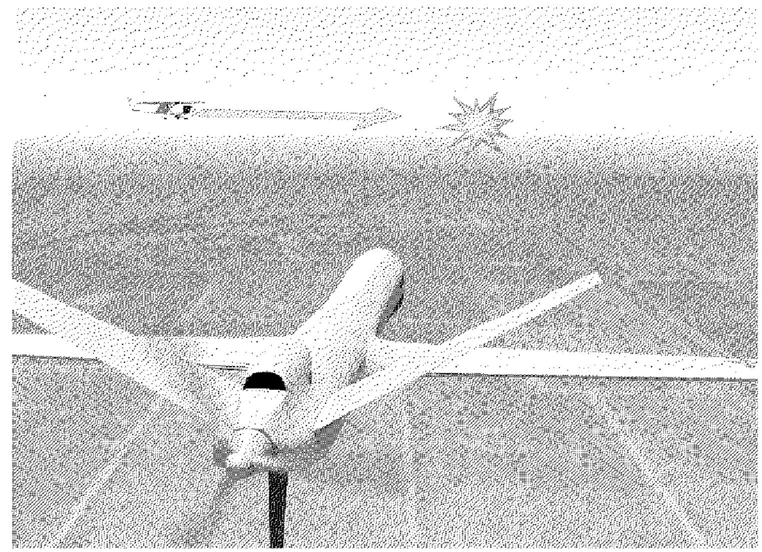


- ACCESS 5: 2004 - present
  - Requirements Development
  - Safety Analysis
  - Simulation Tools
  - Flight Test Demonstrations
  - Standards Development



ACCESS 5
Collision Avoidance Work Package

- Work Package Objectives:
  - Define Equivalent Level of Safety (ELOS) for Sense and Avoid.
  - Develop collision avoidance (CA) requirements for Unmanned Aircraft Systems (UAS); validated through analysis, simulation, and flight demonstration.
  - Provide inputs to the FAA and RTCA Special Committee 203 "Unmanned Aircraft Systems"

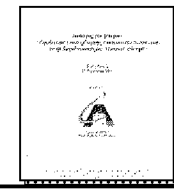


- Team Members:
  - NASA Dryden & Langley
  - Northrop Grumman
  - Lockheed Martin (Ft. Worth)
  - MITRE
  - Modern Technology Solutions
  - Aurora Flight Sciences
  - Federal Aviation Administration

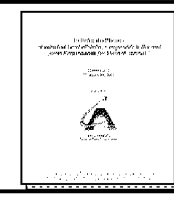
ACCESS 5 Collision Avoidance Work Package

5 Major Task Areas

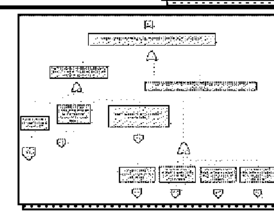
– CA Task 1:
Define ELOS for See & Avoid



– CA Task 2:
Develop CA Requirements

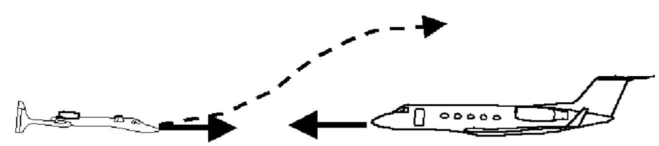


– CA Task 3:
Perform CA Safety Analysis



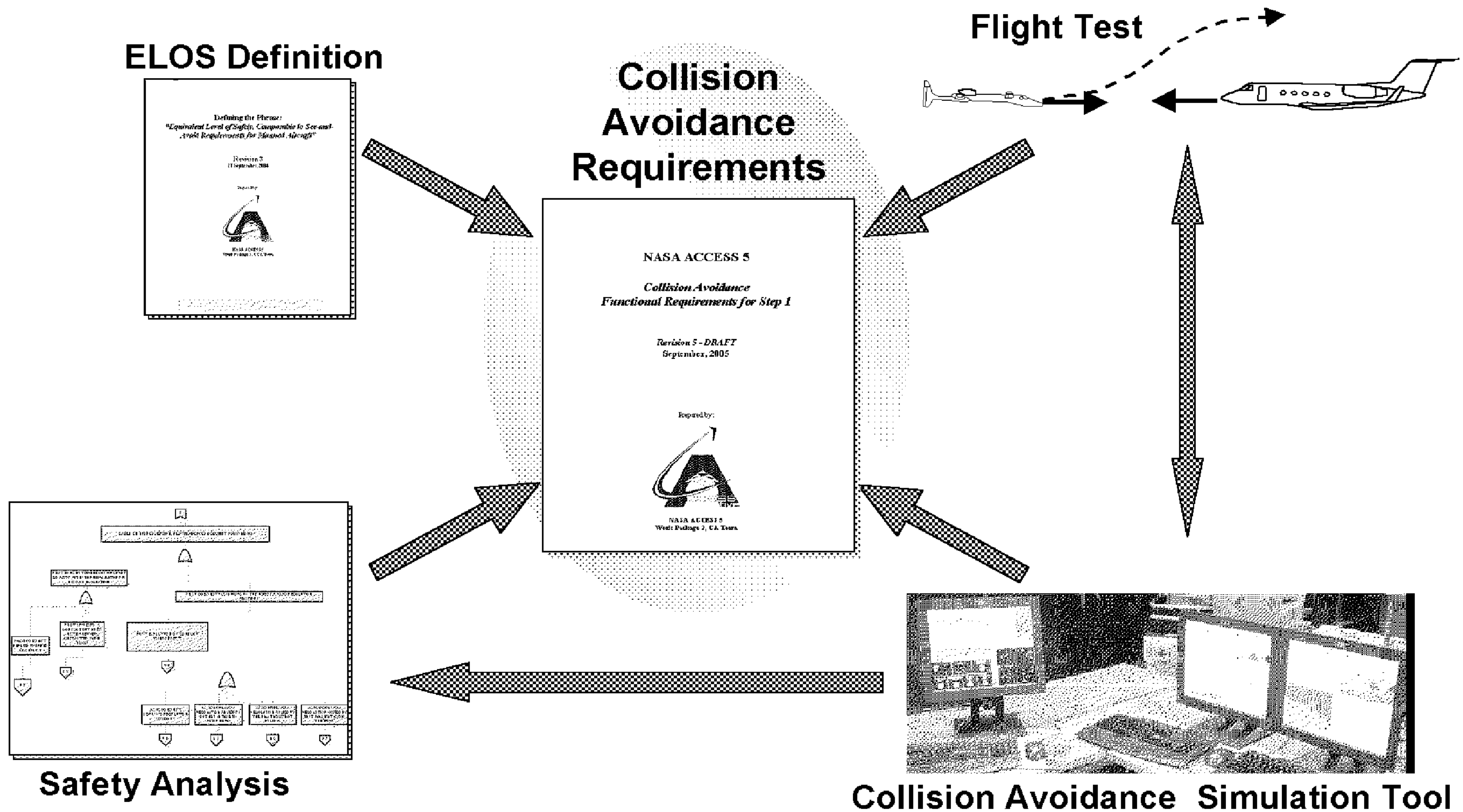
– CA Task 4:
Develop CA Simulation Tool

– CA Task 5:
Perform CA Flight Test



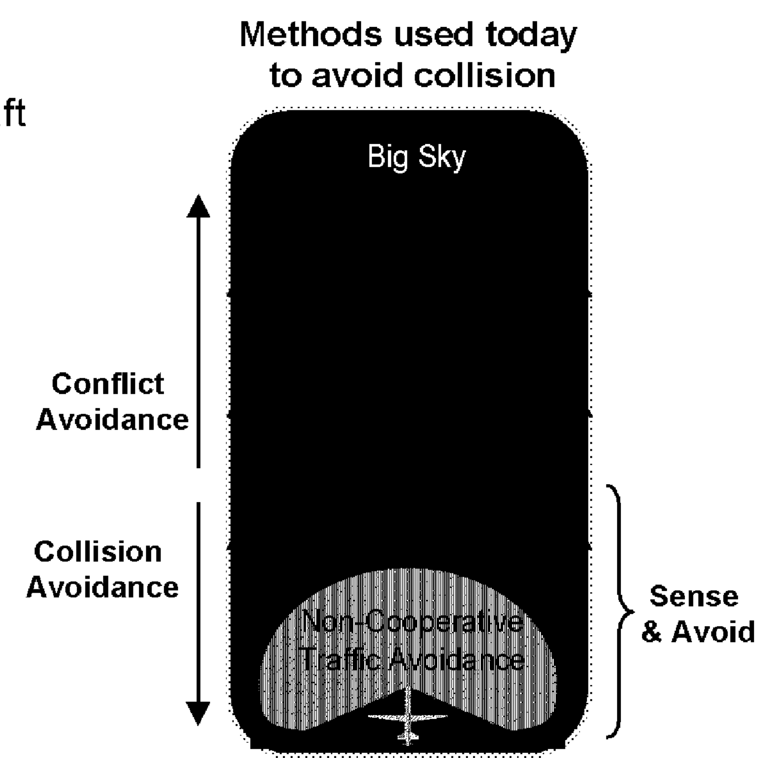
Collision Avoidance Work Package

Task Relationships



Task 1: ELOS Definition Document

- Objective: To present a recommended approach for defining an equivalent level of safety, as it pertains to see and avoid.
- Deliverable Content:
  - Current regulatory / operational environment
    - 14 CFR 91.113(b), Right of Way Rules
    - 14 CFR 91.111, Operating near other aircraft
  - Basis for having to meet an Equivalent Level of Safety
    - 14 CFR 21.21(b), Certification Procedures
    - FAA Order 8110.4C, Equivalent Level of Safety Findings
  - Potential Approaches & Methodologies for defining ELOS
    - 1) Statistical Approach
    - 2) Performance / Rule Based Approach
  - Recommended Definition and Measures of Performance for Sense and Avoid ELOS



- Status: Delivered to FAA on 23 Nov 2004

Task 1: ELOS Definition Document

Definition and Measures of Performance

- Definition: *"Equivalent level of safety to manned aircraft see-and-avoid" is the capability to provide situational awareness with adequate time to detect conflicting traffic and the ability to take the appropriate action necessary to avoid collisions."*

- Measures of Performance:

ELOS for See & Avoid

Surveillance
- Minimum Detect Time
- Field of Regard
- Track Capability
- . . .

Avoidance
- Minimum Miss Distance
- Miss Distance Probability
- System Reaction Time
- . . .

System Quality
- System Integrity
- System Continuity
- System Interoperability
- . . .

Task 2: Develop Collision Avoidance Reqmts

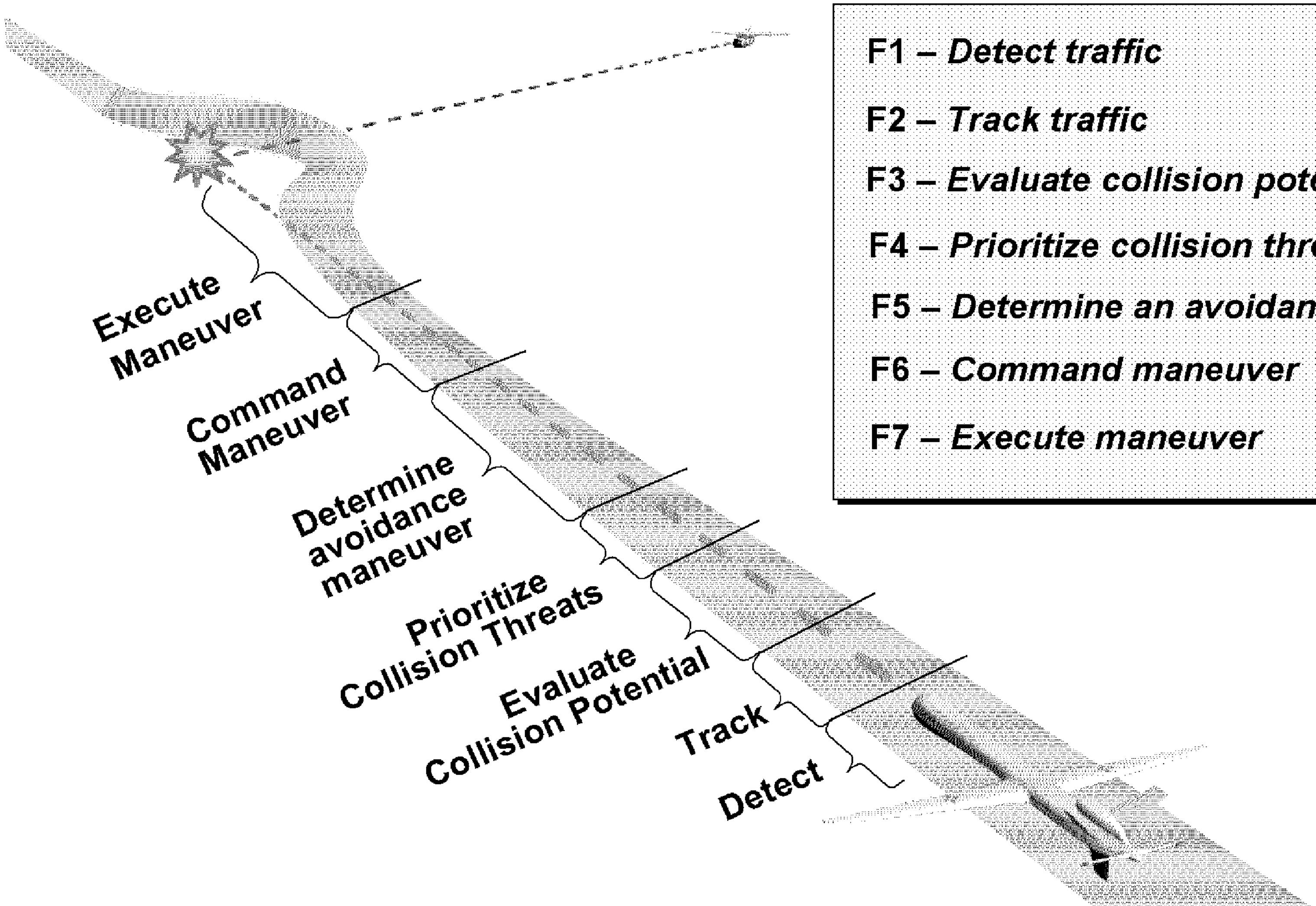
- Objective: To develop the collision avoidance operational, functional, and performance requirements for HALE UAS.

- Deliverable Content:
  - Notional CA Subsystem Description
    - Subsystem Architecture
    - Interfaces
  - Operational Requirements
  - Functional Analysis
    - List of Collision Avoidance Functions
    - Functional Flow Block Diagram
    - Functional Requirements
  - Performance Requirements
    - Design Guidelines
    - Performance Trade-offs
  - Verification Method (Analysis, Inspection, Simulation/Modeling, Demo, Test)

- Status: Intend to release Revision 6.0 in February 2006
  (All previous revisions have included FAA input and review)

Task 2: Develop Collision Avoidance Reqmts

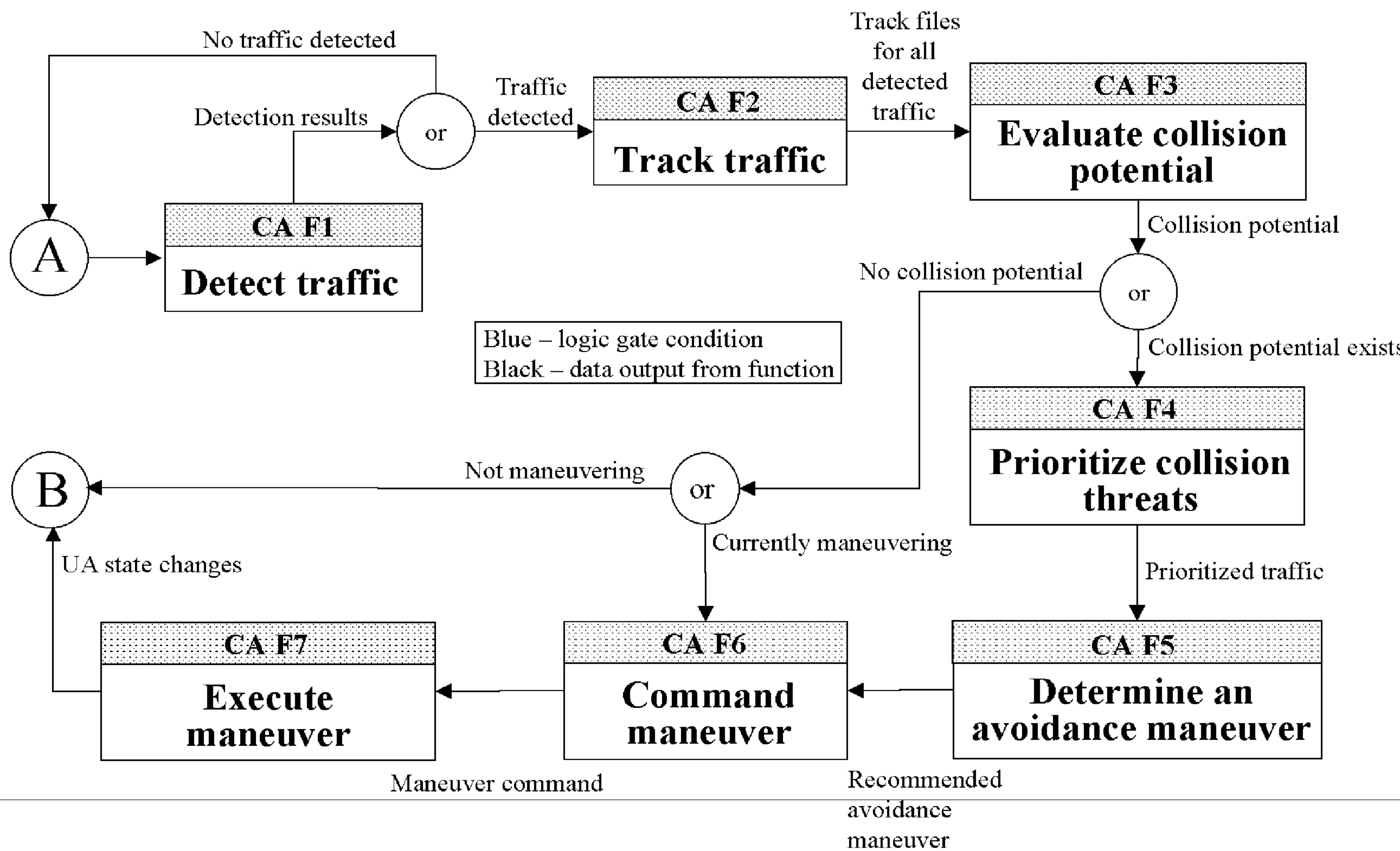
Collision Avoidance Functions



- F1 – *Detect traffic*
- F2 – *Track traffic*
- F3 – *Evaluate collision potential*
- F4 – *Prioritize collision threats*
- F5 – *Determine an avoidance maneuver*
- F6 – *Command maneuver*
- F7 – *Execute maneuver*

Task 2: Develop Collision Avoidance Reqmts

Functional Flow Block Diagram



Task 2: Develop Collision Avoidance Reqmts

Function 1: Detect Traffic Requirements (Example)

- **F1: Detect Traffic - The UAS shall detect traffic within its surveillance volume.**
  - **F1.1: Minimum Detect Time** - The CAS shall detect traffic with sufficient time remaining for successful performance of all required collision avoidance functions.
  - **F1.2: Detection Range** - The CAS shall detect cooperative traffic at a range of at least xx nautical miles. (*see Table F1.2*)
  - **F1.3: Azimuth Field of Regard** - The CAS shall detect cooperative traffic within an azimuth FOR of at least +/-110° referenced from the flight path of the UA.
  - **F1.4: Elevation Field of Regard** - The CAS shall detect cooperative traffic within an elevation FOR of at least +/-15° referenced from the flight path of the UA.
  - **F1.5: Detection Probability** - The CAS shall detect cooperative traffic in the surveillance volume at a rate that supports the track probability guideline (*see F2.3*).
  - **F1.6: Detection Rate** - The average CAS detection rate shall be equal to or greater than xx hertz. (*see Table F1.6*)
  - **F1.7: Detection Accuracy** - The CAS shall detect cooperative traffic with an accuracy of TBD ft for range determinations, and TBD ft for altitude determinations
  - **F1.8: False Detection/Nuisance** - False detections shall account for less than TBD% of all detected traffic.

Task 3: Perform Safety Analysis

- Objective: To develop a method for evaluating the safety of collision avoidance for UAS.
  - Establish equivalent level of safety to manned aircraft using event/fault trees and logic risk ratios

$$\text{Risk Ratio} = \frac{\text{P(collision UAS)}}{\text{P(collision manned AC)}} \leq 1$$

- Accomplishments:
  - Developed visual acquisition model based on Lincoln Lab's SEE1 model
  - Developed surveillance error models for GPS/ADS-B
  - Performed multiple assessments using results from the CA simulation tool for the primary event tree probabilities.
  - Supported requirements development in the areas of Surveillance, Effectiveness, Detection Accuracies, Detection times, Reaction times, Maneuver times, etc.

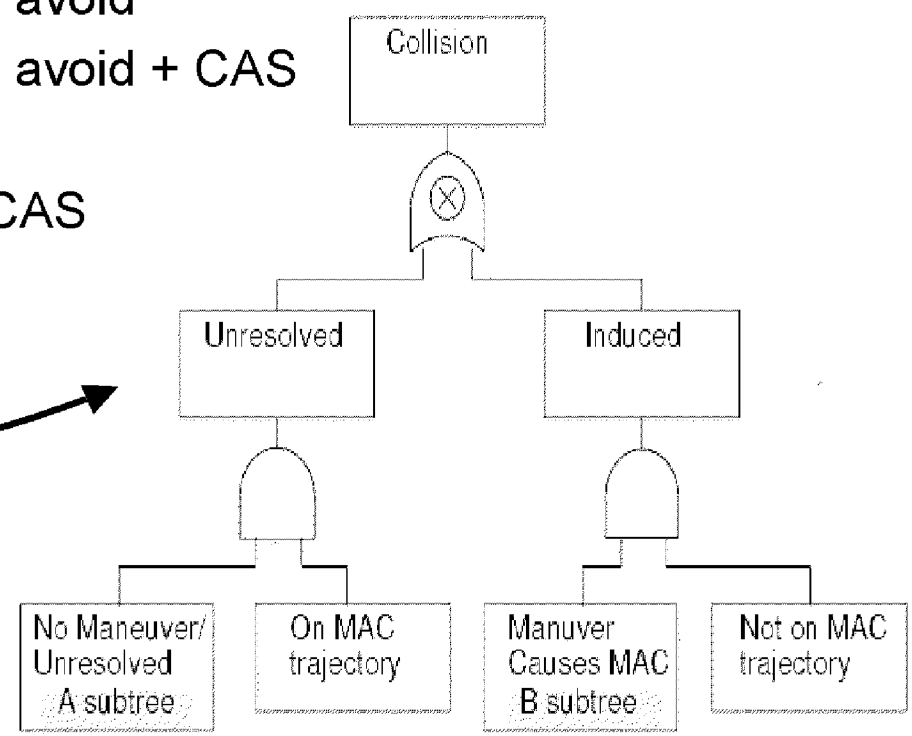
- Status: Currently finalizing final report and lessons learned

Task 3: Perform Safety Analysis

Generic Event/Fault Tree for Collision Probability Estimation

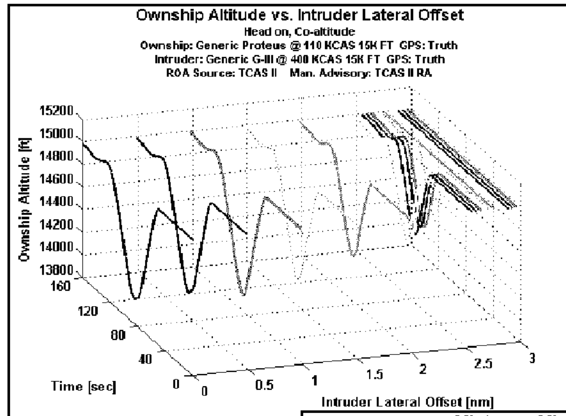
- Generic Event/Fault Tree established to provide a consistent basis for comparison:
  - 1. Manned aircraft using see & avoid
  - 2. Manned aircraft using see & avoid + CAS
  - 3. UAS with Sense & Avoid
  - 4. UAS with Sense & Avoid + CAS

Simplified Fault Tree
(actual tree is several pages long)

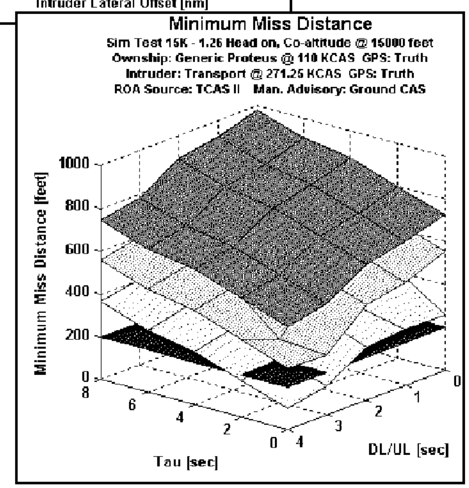


Task 4: Develop CA Simulation Tool

- Objective: To assess the validity of the proposed CA Functional Requirements via Simulation as well as support the CA Flight Test activities.
  - Allows characterization of:
    - Ownship Vehicle Dynamics
    - CA Equipment and Software
    - Encounter Scenarios



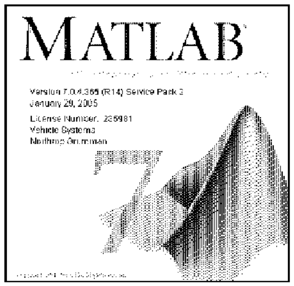
- Accomplishments:
  - Duplicated Tech Demo Scenarios
    - Flight Test Risk Reduction
    - Improve Probability of Obtaining Useful Data
  - Validated Against the System Integration Lab (SIL)
    - Flight Test Risk Reduction
    - CCA Component Models
  - Sensitivity Analyses performed



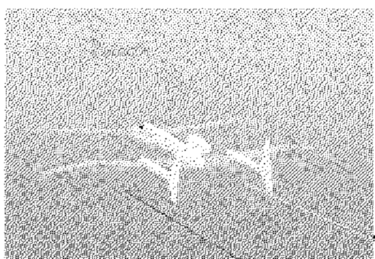
- Status: Currently analyzing flight test data and validating the CA simulation tool.

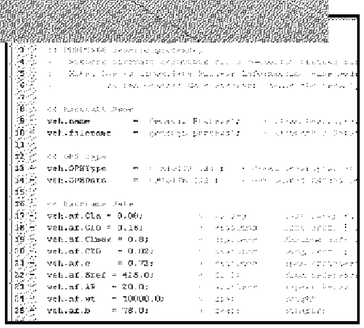
Task 4: Develop CA Simulation Tool

Simulation Features



- MATLAB™/Simulink® Simulation Environment
- Multi-Vehicle Simulation (4 Aircraft Max)
- Generic Aircraft Models Represent Any Fixed Wing Aircraft
  - Each Aircraft = 1 Parameter File
  - Scripts Trim & Initialize Aircraft to Any Encounter Geometry

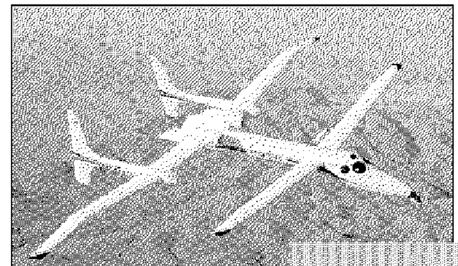




- Modular Components
  - Blocks Can be Copied and/or Swapped Out for Software Upgrades (e.g. CA Sensors, Maneuver Advisory)
- Capable of Batch Runs for Parametric Variation Studies
  - Uses Microsoft Excel Input Dataset
  - Multiple Plot Outputs Available
- PC Portable (< 37 MB)
- Can Run in Both Fast Sim-Time & Soft Real-Time

Task 5: Perform CA Flight Test

OPV - Proteus



Intruder – Gulfstream III

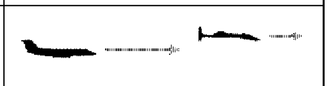
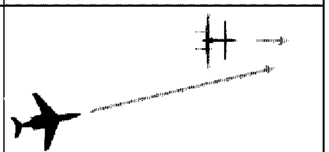
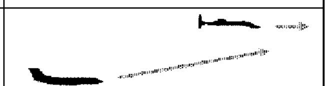
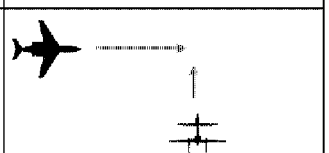
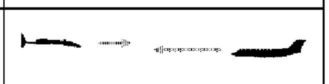
- Objective: To collect cooperative collision avoidance data to validate the CA simulation tool

- Accomplishments:
  - Developed Interface Control Document
  - Developed System Integration Lab (SIL)
  - Developed CA algorithms
  - Developed CA software and human interface tool
  - Procured CA sensors and integrated them onto Proteus platform
  - Developed CA scenarios and test cards
  - Post-processed flight data and prepared for data analysis effort

- Status: Successfully completed over 50 collision scenarios during the last two weeks of September 2005.

Task 5: Perform CA Flight Test

Test Scenarios

	HOST	INTRUDER		PICTORIAL
Scenario #	Climb Rate (fpm)	Δψ (degrees)	Climb Rate (fpm)	
1	0	0	0	
2	0	10	0	
3	0	0	500	
4	0	-90	0	
5	0	180	0	
6	-500	180	0	

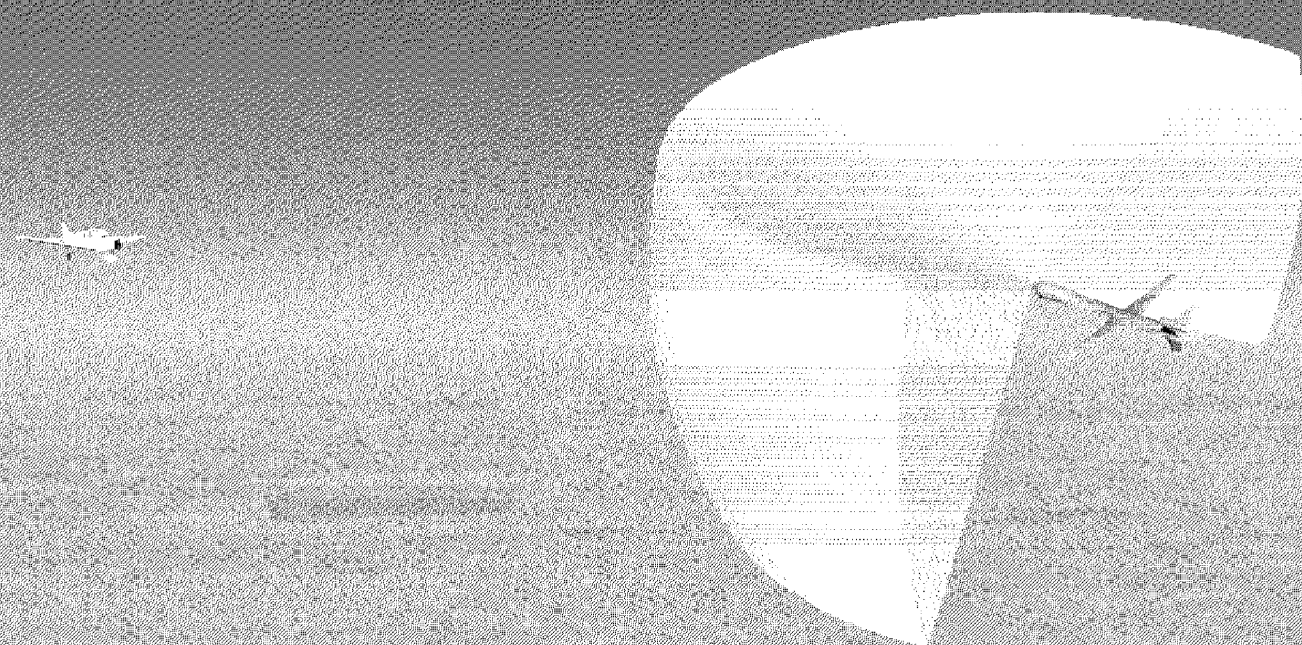
- Test scenarios included multiple collision geometries:
  - Co heading, Intruder overtaking
  - Low aspect, co-altitude
  - Co heading, Intruder climbing
  - Abeam, co-altitude
  - Head-on, co-altitude
  - Head-on, descending

	Configuration						
	TGC & AGA					TRT	
Buffer	6	4	2	0	4	0	0
Link Delay	0	0	0	0	2	0	2
Scenario							
1. Co-Heading, Co-Alt, Intruder Overtaking				1		2	
2. Low Aspect, Co-Alt				1		2	
3. Co-Heading, Intruder Climbing				1		2	
4. Abeam, Co-Alt	1	1	1	2	1	1	1
5. Head-On, Co-Alt	1	1	1	2	1	1	1
6. Head-On, Descending	1	1	1	2	1	1	1

Next Steps

- Document the results and lessons learned from the Safety Analysis and Flight Test Activities
- Complete validating the CA Simulation tool
- Derive practical values/ranges for the TBDs in the performance requirements
  - Utilize the validated CA Simulation tool
  - Utilize the safety analysis results
- Begin Non-cooperative Collision Avoidance Activities
  - Derive unique Non-cooperative performance requirements
  - Perform Trade Studies and Concept Assessments
  - Conduct Non-cooperative Simulation Runs and Flight Demos
- Support RTCA SC-203 on developing the Sense & Avoid Minimum Aviation System Performance Standards (MASPS)

QUESTIONS ?



MTSI

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Zone Ready for Drone

(from FAA Air Traffic Organization Employees web site)

April 7 – The desolate landscape of the southwestern U.S. border with Mexico is widely known for illegal and unseen nocturnal activity. Now, the Department of Homeland Security is keeping watch from restricted airspace between 14,000 and 16,000 feet that extends from Organ Pipe Cactus National Monument in Arizona to New Mexico's Potrillo Mountains. Their unprecedented vantage point is the result of close cooperation with the FAA and the controllers who will keep the sky clear for a remote roving eye.

Since March 29, a temporary flight restriction (view the pdf) has limited access to the airspace along almost 350 miles of the border, expanding an earlier TFR near Nogales. The restriction is in effect nightly from 6 p.m. to 9 a.m., although that time can be expanded by issuance of a Notice to Airmen. Aircraft wishing to fly in the TFR when it is active must receive authorization from air traffic control prior to entry. Once in, pilots are required to maintain two-way communication with ATC and transmit a discrete transponder code.

Though not stated outright in the NOTAM that created the restriction, the reason behind the TFR is no secret. For some time both the White House and the Department of Homeland Security have advocated the use of unmanned aerial systems to increase the Secure Border Initiative's surveillance capability. The TFR makes it possible to fit the operation of those UASs into airspace traditionally occupied by manned military and civilian aircraft.

Predator-B, UAS. Photo: General Atomics Aeronautical Systems

"This is an extreme situation that has been presented to us," states Stephen Glowacki, a Systems Safety and Procedures specialist with the FAA's Air Traffic Organization, stressing the nation's security. "We have been working with U.S. Customs and Border Protection to try and answer this situation."

Inserting UASs into the National Airspace System is not a simple feat. According to Glowacki, the technology and certification that will permit unmanned aircraft to "see and avoid" other air traffic is still eight to ten years away. In the mean time, a carefully controlled environment is needed.

Until the advent of this TFR and its smaller forerunner, border surveillance using UASs was limited to airspace in restricted military areas. Tests conducted there helped develop the procedures now being used to safely conduct flights within the TFRs in New Mexico and Arizona.

Keeping a Homeland Security UAS separated from manned aircraft not participating in its mission requires positive control of aircraft movement within the restricted airspace. In the weeks leading up to the original TFR's issuance, ATC personnel at Albuquerque ARTCC and Tucson ATCT were briefed on procedures for handling UAS operations in airspace that includes non-participating aircraft. IFR control standards are applied and no change in separation minima is involved.

Controllers maintain communication with all manned aircraft operating in the TFR, while simultaneously monitoring the path of the UAS and talking to its ground-based pilot. The controllers' focus is on keeping non-participating aircraft away from the UAS, which flies under an IFR clearance within the TFR boundaries. Should the need arise to temporarily re-direct the UAS, the directions are delivered through secure communication with its pilot.

Although the TFR's Notice to Airmen states that ATC may provide flight advisories concerning UAS operation in the TFR, doing so is neither desired nor expected to be necessary. Only aircraft with ATC permission are allowed to enter the TFR, making it possible to control non-participating aircraft in ways that eliminate the need for such an advisory.

The TFR was not created without opposition. Even though the impact of its presence is expected to be minimal, the Aircraft Owners and Pilots Association feels that long-term operations are inappropriate for temporary restrictions. The TFR is in effect until Feb. 28, 2007. At the local level, airport management at Nogales International Airport reported a drop in business after the first, smaller TFR was created in January. However, because the restrictions are at an altitude well above that flown by aircraft using the airport, pilots may have been avoiding the area out of fear based on misunderstanding the restriction's boundaries.

ATO's Glowacki points out that the TFR was designed to cause the least amount of impact to pilots. The restricted airspace is relatively narrow vertically and is active primarily at night. Aircraft that operate at night are required to have all the equipment needed to communicate with ATC and transmit a discrete beacon code. All that is required for a pilot to enter the airspace, beyond that equipment, is permission from ATC. By flying above or below the restricted altitudes, pilots don't have to worry about what's going on in the TFR.

"It has been an amazing and ingenious way of temporarily resolving an incredible situation," Glowacki says. "Airspace studies and known aviation operations were reviewed and balanced against national security needs."

Now the challenge is to ensure safety while a relatively new technology is introduced to the NAS. Long-term TFRs like those along the southern border allow DHS time to carefully plan missions, without interruption or unexpected changes to the rules that govern them. However, fine tuning may be needed as the program continues. TFRs are flexible enough to be changed quickly based on anything new that is learned, unlike more rigid airspace restrictions such as Air Defense Identification Zones.

As Glowacki says, "the TFR is the best tool to fit the situation."

Related Information:

- Temporary Flight Restriction (PDF)

TMS320C6713B Status: ACTIVE

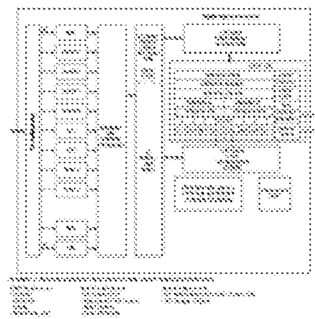
Floating-Point Digital Signal Processors

Datasheet

TMS320C6713B Floating-Point Digital Signal Processor (Rev. B) (PDF 2227 KB)
30 Jun 2006

TMS320C6713, TMS320C6713B DSPs Silicon Errata (Silicon Revisions 2.0, 1.1) (Rev. J) (PDF 319 KB) 6917 views
12 Aug 2005

Functional Block Diagram



Enlarge

	TMS320C6713B-167	TMS320C6713B-200	TMS320C6713B-225	TMS320C6713B-300
CPU	1 C67x	1 C67x	1 C67x	1 C67x
Peak MMACS	334	400	450	600
Frequency(MHz)	167	200	225	300
On-Chip L1/SRAM	8 KB	8 KB	8 KB	8 KB
On-Chip L2/SRAM	64 KB Cache/192 KB SRAM	64 KB Cache/192 KB SRAM	64 KB Cache/192 KB SRAM	64 KB Cache/192 KB SRAM
EMIF	1 32-Bit	1 32-Bit	1 32-Bit	1 32-Bit
External Memory Type Supported	Async SRAM,SBSRAM,SDRAM	Async SRAM,SBSRAM,SDRAM	Async SRAM,SBSRAM,SDRAM	Async SRAM,SBSRAM,SDRAM
DMA	16 (EDMA)	16 (EDMA)	16 (EDMA)	16-Ch EDMA
HPI	1 16-Bit	1 16-Bit	1 16-Bit	1 16-Bit
McBSP	2	2	2	2
McASP	2	2	2	2
I2C	2	2	2	2
Timers	(2) 32-bit	(2) 32-bit	(2) 32-bit	2 32-Bit GP
Core Supply (Volts)	1.2	1.2/1.26	1.26	1.4 V
IO Supply (Volts)	3.3 V	3.3 V	3.3 V	3.3 V

Operating Temperature Range (°C)	-40 to 105	0 to 90,-40 to 105	0 to 90	0 to 90
Rating	Catalog	Catalog	Catalog	Catalog
	Samples	Samples	Samples	Samples
	Inventory	Inventory	Inventory	Inventory

Customers Who Evaluated This Product Also Evaluated

TMS320C6727B: Floating-Point Digital Signal Processor
TMS320DM642: Video/Imaging Fixed-Point Digital Signal Processor
TMS320VC5509A: Fixed-Point Digital Signal Processor
TMS320C6747: Floating-Point Digital Signal Processor
OMAP-L137: Low-Power Applications Processor
TMS320F28335: Delfino Microcontroller

More Related Products

Product Information

Features

- Highest-Performance Floating-Point Digital Signal Processor (DSP): TMS320C6713B
  - Eight 32-Bit Instructions/Cycle
  - 32/64-Bit Data Word
  - 300-, 225-, 200-MHz (GDP and ZDP), and 225-, 200-, 167-MHz (PYP) Clock Rates
  - 3.3-, 4.4-, 5-, 6-Instruction Cycle Times
  - 2400/1800, 1800/1350, 1600/1200, and 1336/1000 MIPS/MFLOPS
  - Rich Peripheral Set, Optimized for Audio
  - Highly Optimized C/C++ Compiler
  - Extended Temperature Devices Available
- Advanced Very Long Instruction Word (VLIW) TMS320C67x™ DSP Core
  - Eight Independent Functional Units:
    - 2 ALUs (Fixed-Point)
    - 4 ALUs (Floating-/Fixed-Point)
    - 2 Multipliers (Floating-/Fixed-Point)
  - Load-Store Architecture With 32 32-Bit General-Purpose Registers
  - Instruction Packing Reduces Code Size
  - All Instructions Conditional
- Instruction Set Features
  - Native Instructions for IEEE 754
    - Single- and Double-Precision
  - Byte-Addressable (8-, 16-, 32-Bit Data)
  - 8-Bit Overflow Protection
  - Saturation; Bit-Field Extract, Set, Clear; Bit-Counting; Normalization
- L1/L2 Memory Architecture
  - 4K-Byte L1P Program Cache (Direct-Mapped)
  - 4K-Byte L1D Data Cache (2-Way)
  - 256K-Byte L2 Memory Total: 64K-Byte L2 Unified Cache/Mapped RAM, and 192K-Byte
  - Additional L2 Mapped RAM
- Device Configuration
  - Boot Mode: HPI, 8-, 16-, 32-Bit ROM Boot
  - Endianness: Little Endian, Big Endian
- 32-Bit External Memory Interface (EMIF)
  - Glueless Interface to SRAM, EPROM, Flash, SBSRAM, and SDRAM
  - 512M-Byte Total Addressable External Memory Space
- Enhanced Direct-Memory-Access (EDMA) Controller (16 Independent Channels)
- 16-Bit Host-Port Interface (HPI)
- Two McASPs
  - Two Independent Clock Zones Each (1 TX and 1 RX)
  - Eight Serial Data Pins Per Port: Individually Assignable to any of the Clock Zones
  - Each Clock Zone Includes:
    - Programmable Clock Generator
    - Programmable Frame Sync Generator
    - TDM Streams From 2-32 Time Slots
    - Support for Slot Size:

- 8, 12, 16, 20, 24, 28, 32 Bits
- Data Formatter for Bit Manipulation
- Wide Variety of I2S and Similar Bit Stream Formats
- Integrated Digital Audio Interface Transmitter (DIT) Supports:
  - S/PDIF, IEC60958-1, AES-3, CP-430 Formats
  - Up to 16 transmit pins
  - Enhanced Channel Status/User Data
- Extensive Error Checking and Recovery
- Two Inter-Integrated Circuit Bus (I^2C Bus™) Multi-Master and Slave Interfaces
- Two Multichannel Buffered Serial Ports:
  - Serial-Peripheral-Interface (SPI)
  - High-Speed TDM Interface
  - AC97 Interface
- Two 32-Bit General-Purpose Timers
- Dedicated GPIO Module With 16 pins (External Interrupt Capable)
- Flexible Phase-Locked-Loop (PLL) Based Clock Generator Module
- IEEE-1149.1 (JTAG †) Boundary-Scan-Compatible
- 208-Pin PowerPAD™ PQFP (PYP)
- 272-BGA Packages (GDP and ZDP)
- 0.13-µm/6-Level Copper Metal Process
  - CMOS Technology
- 3.3-V I/Os, 1.2 ‡ -V Internal (GDP/ZDP/ PYP)
- 3.3-V I/Os, 1.4-V Internal (GDP/ZDP) [300 MHz]

TMS320C67x and PowerPAD are trademarks of Texas Instruments.
I^2C Bus is a trademark of Philips Electronics N.V. Corporation
All trademarks are the property of their respective owners.

† IEEE Standard 1149.1-1990 Standard-Test-Access Port and Boundary Scan Architecture.

‡ These values are compatible with existing 1.26-V designs.

TMS320C6000, eXpressDSP, Code Composer Studio, and DSP/BIOS are trademarks of Texas Instruments.

† Throughout the remainder of this document, TMS320C6713B shall be referred to as C6713B or 13B.

Description

The TMS320C67x™ DSPs (including the TMS320C6713B device †) compose the floating-point DSP generation in the TMS320C6000™ DSP platform. The C6713B device is based on the high-performance, advanced very-long-instruction-word (VLIW) architecture developed by Texas Instruments (TI), making this DSP an excellent choice for multichannel and multifunction applications.

Operating at 225 MHz, the C6713B delivers up to 1350 million floating-point operations per second (MFLOPS), 1800 million instructions per second (MIPS), and with dual fixed-/floating-point multipliers up to 450 million multiply-accumulate operations per second (MMACS).

Operating at 300 MHz, the C6713B delivers up to 1800 million floating-point operations per second (MFLOPS), 2400 million instructions per second (MIPS), and with dual fixed-/floating-point multipliers up to 600 million multiply-accumulate operations per second (MMACS).

The C6713B uses a two-level cache-based architecture and has a powerful and diverse set of peripherals. The Level 1 program cache (L1P) is a 4K-byte direct-mapped cache and the Level 1 data cache (L1D) is a 4K-byte 2-way set-associative cache. The Level 2 memory/cache (L2) consists of a 256K-byte memory space that is shared between program and data space. 64K bytes of the 256K bytes in L2 memory can be configured as mapped memory, cache, or combinations of the two. The remaining 192K bytes in L2 serves as mapped SRAM.

The C6713B has a rich peripheral set that includes two Multichannel Audio Serial Ports (McASPs), two Multichannel Buffered Serial Ports (McBSPs), two Inter-Integrated Circuit (I2C) buses, one dedicated General-Purpose Input/Output (GPIO) module, two general-purpose timers, a host-port interface (HPI), and a glueless external memory interface (EMIF) capable of interfacing to SDRAM, SBSRAM, and asynchronous peripherals.

The two McASP interface modules each support one transmit and one receive clock zone. Each of the McASP has eight serial data pins which can be individually allocated to any of the two zones. The serial port supports time-division multiplexing on each pin from 2 to 32 time slots. The C6713B has sufficient bandwidth to support all 16 serial data pins transmitting a 192 kHz stereo signal. Serial data in each zone may be transmitted and received on multiple serial data pins simultaneously and formatted in a multitude of variations on the Philips Inter-IC Sound (I2S) format.

In addition, the McASP transmitter may be programmed to output multiple S/PDIF, IEC60958, AES-3, CP-430 encoded data channels simultaneously, with a single RAM containing the full implementation of user data and channel status fields.

The McASP also provides extensive error-checking and recovery features, such as the bad clock detection circuit for each high-frequency master clock which verifies that the master clock is within a programmed frequency range.

The two I2C ports on the TMS320C6713B allow the DSP to easily control peripheral devices and communicate with a host processor. In addition, the standard multichannel buffered serial port (McBSP) may be used to communicate with serial peripheral interface (SPI) mode peripheral devices.

The TMS320C6713B device has two bootmodes: from the HPI or from external asynchronous ROM. For more detailed information, see the *bootmode* section of this data sheet.

The TMS320C67x DSP generation is supported by the TI eXpressDSP™ set of industry benchmark development tools, including a highly optimizing C/C++ Compiler, the Code Composer Studio™ Integrated Development Environment (IDE), JTAG-based emulation and real-time debugging, and the DSP/BIOS™ kernel.

Pricing / Packaging / CAD Design Tools / Samples

		Price	Packaging		CAD Design Tools		Samples
Device	**Status**	**Price | Quantity**	**Package | Pins**	**Package QTY | Package Carrier**	**Symbols**	**Footprints**	**Samples**
TMS320C6713BGDP225	ACTIVE	25.45 | 100u	BGA (GDP) | 272	40	View	View	Purchase Samples
TMS320C6713BGDP300	ACTIVE	33.75 | 100u	BGA (GDP) | 272	40	View	View	Purchase Samples
TMS320C6713BPYP200	ACTIVE	19.45 | 100u	HLQFP (PYP) | 208	36	View		Purchase Samples
TMS320C6713BZDP225	ACTIVE	25.45 | 100u	BGA (ZDP) | 272	40	View	View	Purchase Samples
TMS320C6713BZDP300	ACTIVE	33.75 | 100u	BGA (ZDP) | 272	40	View	View	Purchase Samples
TMS32C6713BGDPA200	ACTIVE	25.90 | 100u	BGA (GDP) | 272	40	View	View	Purchase Samples
TMS32C6713BPYPA167	ACTIVE	19.45 | 100u	HLQFP (PYP) | 208	36	View		Purchase Samples
TMS32C6713BPYPA200	ACTIVE	23.25 | 100u	HLQFP (PYP) | 208	36	View		Purchase Samples
TMS32C6713BZDPA200	ACTIVE	25.90 | 100u	BGA (ZDP) | 272	40	View	View	Purchase Samples
TMX320C6713BGDP	OBSOLETE		BGA (GDP) | 272				Not Available

* Suggested Resale Price per unit (USD) for BUDGETARY USE ONLY. For higher volume price quotes,prices in local currency or delivery quotes, please contact your local Texas Instruments Sales Office or Authorized Distributor.

Inventory

Reported Distributor Inventory as of 9:05 AM GMT, 30 Oct 2009			
Region	**Company**	**In Stock**	**Purchase**
TMS320C6713BGDP225			**TI Lead Time*: 20 Weeks**
Americas	Rochester Electronics	>1k	Add to Cart
TMS320C6713BGDP300			**TI Lead Time*: 20 Weeks**
Europe	Compel	2	Add to Cart
TMS320C6713BPYP200			**TI Lead Time*: 20 Weeks**
Americas	Arrow	50	Add to Cart

Europe	Avnet-SILICA	>1k	Add to Cart
TMS320C6713BZDP225			**TI Lead Time*: 20 Weeks**
Americas	Arrow	117	Add to Cart
Europe	Avnet-SILICA	216	Add to Cart
TMS320C6713BZDP300			**TI Lead Time*: 20 Weeks**
Americas	Arrow	114	Add to Cart
Asia	WPI	49	Add to Cart
Europe	Avnet-SILICA	69	Add to Cart
TMS32C6713BGDPA200			**TI Lead Time*: 20 Weeks**
Americas	Arrow	239	Add to Cart
	Avnet	50	Add to Cart
Worldwide	Mouser Electronics	53	Add to Cart
TMS32C6713BPYPA167			**TI Lead Time*: 6 Weeks**
Americas	Arrow	734	Add to Cart
	Avnet	16	Add to Cart
	Rochester Electronics	78	Add to Cart
TMS32C6713BPYPA200			**TI Lead Time*: 23 Weeks**
Americas	Rochester Electronics	103	Add to Cart
Worldwide	Mouser Electronics	7	Add to Cart
TMS32C6713BZDPA200			**TI Lead Time*: 20 Weeks**
Americas	Arrow	80	Add to Cart
Europe	Avnet-SILICA	217	Add to Cart

View all Distributors Choose a Region Go

** Lead time information is not available at this time. However, our information is updated daily so please check back with us soon. Please contact your preferred TI Authorized Distributor for additional information.

Quality & Lead (Pb)-Free Data

	Product Content				DPPM / MTBF / FIT Rate
Device	**Eco Plan***	**Lead / Ball Finish**	**MSL Rating / Peak Reflow**	**Details**	**Details**
TMS320C6713BGDP225	TBD	SNPB	Level-3-220C-168 HR	View	View
TMS320C6713BGDP300	TBD	SNPB	Level-3-220C-168 HR	View	View
TMS320C6713BPYP200	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-4-260C-72 HR	View	View
TMS320C6713BZDP225	Pb-Free (RoHS)	SNAGCU	Level-3-260C-168 HR	View	View
TMS320C6713BZDP300	Pb-Free (RoHS)	SNAGCU	Level-3-260C-168 HR	View	View
TMS32C6713BGDPA200	TBD	SNPB	Level-3-220C-168 HR	View	View
TMS32C6713BPYPA167	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-4-260C-72 HR	View	View

TMS32C6713BPYPA200	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-4-260C-72 HR	View	View
TMS32C6713BZDPA200	Pb-Free (RoHS)	SNAGCU	Level-3-260C-168 HR	View	View

* The planned eco-friendly classification: Pb-Free (RoHS) or Pb-Free (RoHS Exempt) or Green (RoHS & no Sb/Br) - please click on the Product Content Details "View" link in the table above for the latest availability information and additional product content details.

If the information you are requesting is not available online at thi contact one of our Product Information Centers regarding the ava this information.

Tools & Software

Name	Part #	Company	Tool / Software Type
Code Composer Studio IDE Subscription Service for v3.3	CCSTUDIOSUBSCRIPTIONS	Texas Instruments	Code Composer Studio(TM) IDE
Code Composer Studio Integrated Development Environment (IDE) - v4.x	CCSTUDIO	Texas Instruments	Code Composer Studio(TM) IDE
C6701 EVM bundled with Code Composer Studio	TMDSEVM6701-4	Texas Instruments	Development Boards/EVMs
C6701 Evaluation Module (EVM) Bundle	TMDS32600C6701	Texas Instruments	Development Boards/EVMs
SMT374-300 DSP Module		Sundance Multiprocessor Technology LTD	Development Boards/EVMs
ORS-112		Traquair Data Systems, Inc.	Development Boards/EVMs
ORS-114		Traquair Data Systems, Inc.	Development Boards/EVMs
ORS-116		Traquair Data Systems, Inc.	Development Boards/EVMs
Multichannel Vocoder Demonstration Software for C6211 or C6711 DSK	MCVTDK6211	Texas Instruments	Development Platforms
XDS510 Class Emulators	XDS510	Texas Instruments	Emulators/Analyzers
Blackhawk™ LAN560 JTAG Emulator		Blackhawk	Emulators/Analyzers
Blackhawk™ PCI560 JTAG Emulator for TI DSPs		Blackhawk	Emulators/Analyzers
Blackhawk™ USB560 JTAG Emulator		Blackhawk	Emulators/Analyzers
Blackhawk™ USB560BP JTAG Emulator		Blackhawk	Emulators/Analyzers
JTAGjet USB 2.0 Emulator for TMS320		Signum Systems	Emulators/Analyzers
XDS510PP PLUS JTAG Emulator		Spectrum Digital, Inc.	Emulators/Analyzers
XDS510USB JTAG Emulator		Spectrum Digital, Inc.	Emulators/Analyzers
XDS510USB PLUS JTAG Emulator		Spectrum Digital, Inc.	Emulators/Analyzers
C6711 DSP Starter Kit (DSK)	TMDS320006711	Texas Instruments	Starter Kits
TMS320C6713 DSP Starter Kit (DSK)	TMDSDSK6713	Texas Instruments	Starter Kits
TMS320C6000 Chip Support Library	SPRC090	Texas Instruments	Application Software
Driver Developer's Kit (DDK)	SPRC118	Texas Instruments	Application Software
TMS320C67x DSP Library	SPRC121	Texas Instruments	Signal Processing Libraries
C67x Fast Run-Time Support (RTS) Library	SPRC060	Texas Instruments	Signal Processing Libraries

Related Products

Part #	Name	Product Family	Comments
TMS320C6727B	Floating-Point Digital Signal Processor	C6000 FLOATING/FIXED-POINT DSPS - TMS320C672X DSPS	The device has SIMILAR FUNCTIONALITY but is not functionally equivalent to the compared device.

PCM4204	118dB SNR 4-Channel Audio ADC	AUDIO CONVERTERS AND CODECS - AUDIO A TO D CONVERTERS	4ch 118dB ADC
PCM4202	118dB SNR Stereo Audio ADC	AUDIO CONVERTERS AND CODECS - AUDIO A TO D CONVERTERS	4ch 118dB DAC
PCM4104	118dB SNR 4-Channel Audio DAC	AUDIO CONVERTERS AND CODECS - AUDIO D TO A CONVERTERS	PWM POWER SUPPLY CONTROLLERS
SRC4392	High-end Combo Sample Rate Converter	DIGITAL AUDIO INTERFACE - SAMPLE RATE CONVERTERS	144dB Combo SRC & S/PDIF Transciever
SRC4382	Combo Sample Rate Converter	DIGITAL AUDIO INTERFACE - SAMPLE RATE CONVERTERS	128dB Combo SRC & S/PDIF Transciever
TPS2110A	Autoswitching Power Mux	POWER MUXES AND CURRENT LIMITED SWITCHES - POWER MUXES	POWER MUXES
TPS3808G33	Low Quiescent Current, Programmable-Delay Supervisory Circuit	POWER MANAGEMENT - SUPERVISORY CIRCUITS(VOLTAGE SUPERVISORS)	SUPERVISORY CIRCUITS(VOLTAGE SUPERVISORS)
BQ2002C	NiCd/NiMH Charge Controller with Negative dV and Peak Voltage Detection Termination	BATTERY MANAGEMENT - BATTERY CHARGE MANAGEMENT	BATTERY CHARGE MANAGEMENT
Customers Who Evaluated This Product Also Evaluated...			
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OMAP-L138	Low-Power Applications Processor	OMAP™ Applications Processors-OMAP-Lx Processors	TI customers also evaluated this product.

TMS320F2812	32-Bit Digital Signal Controller with Flash	C2000™ 32-BIT MICROCONTROLLERS-28X FIXED-POINT SERIES	TI customers also evaluated this product.
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TMS320C6748	Fixed/Floating Point Digital Signal Processor	C6000 FLOATING/FIXED-POINT DSPS-TMS320C674X LOW POWER DSPS	TI customers also evaluated this product.
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Simple Solutions for Hyperbolic and Related Position Fixes

BERTRAND T. FANG
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Navigation fixed from range differences to three stations plus an additional piece of information are investigated. It is shown that if the additional information is the navigator altitude, or the range difference to a fourth station, the computation of the navigation fix is reduced to finding the roots of a quadratic. If the additional information is the range to another station, or that the navigator is on the Earth ellipsoid, the fix can be obtained by solving a quartic. By emphasizing the underlying geometric interpretations, these fixes and their simple solutions are made clear. The derivations also show that the same solution algorithms are applicable if the basic navigation measurements are range sums instead of range differences.

Manuscript received October 18, 1989; revised December 18, 1989.

IEEE Log No. 38444.

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0018-9251/90/0900-0748 $1.00 © 1990 IEEE

INTRODUCTION

Navigation systems such as LORAN or DECCA [1] use differences in the times of arrival of a radio signal at different stations to determine a navigation position. It is well known that time of arrival differences at a pair of stations locate the navigator on a hyperboloid of revolution with foci at the stations; that time arrival differences at three stations place the navigator ont he curve of intersection of two such hyperboloids. To fix the position at a point on this curve of intersection requires additional information. Some examples of such information are: the position is on the surface of an ellipsoidal Earth or another station exists which provides additional signal time of arrival differences. Navigation positions located in this way at the intersections of hyperboloids and other surfaces may be called hyperbolic position fixes. Usually, computing a hyperbolic position fix requires an iterative algorithm with its attendant inefficiency and convergence problem [1]. It is shown in the following that the computation of these hyperbolic position fixes can be reduced to the solution of a quadratic or a quartic equation. The simplicity of these solutions comes from the use of station baseline planes as references and from exploring the geometrical properties of intersection of hyperboloids. The advantages of such references was first noted in a related navigation problem [2].

Measurements which are sums of signal times of arrival are also common. These measurements involve ellipsoids and lead to the elliptic position fixes. It is obvious from our derivation below that the algorithms derived for hyperbolic position fixes are also applicable to elliptic position fixes.

NAVIGATION POSITION RELATIVE TO THREE STATIONS

Fig. 1 shows a navigation position relative to three stations A, B, and C. A set of local right-handed orthogonal axes is chosen as shown. The origin is at one of the stations, one axis is along a station baseline, and another axis is orthogonal to the two station baselines, or the station plane.

Let V be the signal velocity, $T_{ab} = T_a - T_b$ and $T_{ac} = T_a - T_c$ be the differences in the times of signal arrival at the station pairs A, B and A, C, respectively. From Fig. 1, one has

$$\sqrt{x^2+y^2+z^2} - \sqrt{(x-b)^2+y^2+z^2} = V*T_{ab} = R_{ab} \quad (1)$$

$$\sqrt{x^2+y^2+z^2} - \sqrt{(x-c_x)^2+(y-c_y)^2+z^2} = V*T_{ac} = R_{ac} \quad (2)$$

where R_{ab} and R_{ac} are range differences from the navigation position to the stations, converted from

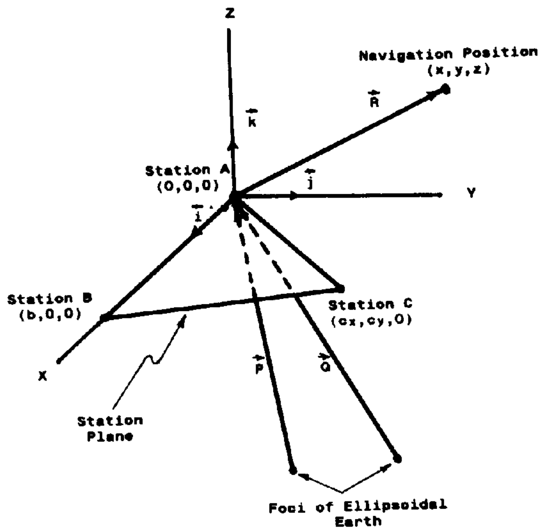

Fig. 1. Navigation position referenced to local coordinates defined by station baselines.

the measured time of arrival differences. Transposing the first terms to the right-hand sides of (1) and (2), squaring and simplifying, one obtains

$$R_{ab}^2 - b^2 + 2b*x = 2R_{ab}\sqrt{x^2+y^2+z^2} \quad (3)$$

$$R_{ac}^2 - c^2 + 2c_x*x + 2c_y*y = 2R_{ac}\sqrt{x^2+y^2+z^2} \quad (4)$$

where b and $c = \sqrt{c_x^2 + c_y^2}$ are the lengths of station baselines. These two equations, when squared, can be readily recognized as representing two hyperboloids of revolution with foci at A, B and A, C, respectively.

Note that for measurements consisting of sums instead of differences of times of arrival, one would have a set of equations similar to (1) and (2) with positive signs between the radicals and with R_{ab} and R_{ac} interpreted as range sums instead of range differences. Squaring these new equations would give a set of equations identical to (3) and (4), although representing ellipsoids of revolution rather than hyperboloids. Thus all derivations below which originate from (3) and (4) are applicable to range sum measurements as well as range difference measurements.

Let us consider, without loss of generality, that the range difference R_{ab} is not equal to zero.[1] Then equating (3) and (4) and simplifying, one obtains

$$y = g*x + h \quad (5)$$

where

$$g = \{R_{ac}*(b/R_{ab}) - c_x\}/c_y \quad (6)$$

$$h = \{c^2 - R_{ac}^2 + R_{ac}*R_{ab}(1-(b/R_{ab})^2)\}/2c_y. \quad (7)$$

Substituting (5) into (3), one obtains

$$z = \pm\sqrt{d*x^2 + e*x + f} \quad (8)$$

or

$$z^2 = d*x^2 + e*x + f \quad (9)$$

where

$$d = -\{1 - (b/R_{ab})^2 + g^2\} \quad (10)$$

$$e = b*\{1 - (b/R_{ab})^2\} - 2g*h \quad (11)$$

$$f = (R_{ab}^2/4)*\{1-(b/R_{ab})^2\}^2 - h^2. \quad (12)$$

These equations admit the following geometric interpretations. Equation (5) defines a plane orthogonal to the station baselines. The navigation position must lie in this plane, or the curve of intersection of the two hyperboloids is a plane curve. Equation (8) says this curve must be symmetrical with respect to the station plane. Equation (9) says the projection of this curve onto the $X-Z$ plane is an ellipse ($d < 0$) or a hyperbola ($d > 0$). A simple expression for this curve of intersection can be obtained by a straightforward transformation of coordinate axes such that the new origin is on the plane defined by (5) and the new Y-axis is orthogonal to the plane. We do not go into the details but will point out that, as its projection discussed above, this curve is an ellipse or a hyperbola depending on whether $d < 0$ or $d > 0$. From (10) it can be seen that for range sum measurements, $d < 0$ and the curve is an ellipse, being the intersection of a plane and an ellipsoid of revolution. For range difference measurements this curve is the intersection of a plane and a hyperboloid of revolution, and may be a hyperbola, or an ellipse. It can be seen from (6) and (10) that an ellipse would result if the angle subtended by the two baselines is small.

One may now write the navigation position vector as follows which depends on a single unknown parameter x,

$$\vec{R} = x*\vec{i} + (g*x+h)\vec{j} \pm \sqrt{d*x^2+e*x+f}\vec{k}. \quad (13)$$

As discussed above, this vector defines a hyperbola ($d > 0$) or an ellipse ($d < 0$) with mirror symmetry with respect to the station plane.

POSITION FIX WITH ADDITIONAL INFORMATION

The preceding section shows that when time of arrival differences or sums to three stations are known, an ellipse or a hyperbola on which the navigator lies can be computed. To fix the navigation position on this

[1] $R_{ab} = 0$ implies $x = b/2$. In that case one can follow a similar procedure and express (13) below in terms of y instead of x. But a separate treatment is unnecessary because one can choose a baseline such that $R_{ab} = 0$, unless $R_{ab} = R_{ac} = 0$. In the latter situation the problem is trivial since the navigation position will be at an equal distance to the three stations.

ellipse or hyperbola, additional information is required. Among the commonly available information, some will restrict the position on another plane; others will place it on a second degree surface. For the former, the navigation position becomes the solution of a quadratic equation. This is easy to understand from geometry. The intersection of this new plane with the plane of the hyperbola or ellipse is a straight line. And the intersection of this first degree straight line with a coplanar second degree curve such as a hyperbola or an ellipse is a root of a quadratic equation. For the latter, the intersection of the plane of the hyperbola or ellipse with a second degree surface is a second degree planar curve. Thus the navigation position is at the intersection of two coplanar second degree curves, or the root of a quartic equation.

Expressions for these quadratic and quartic equations are derived below. Before proceeding, however, it is to be noted that in the derivations that led to (13) we removed radicals by squaring appropriate expressions. This process can introduce extraneous solutions. Only those roots which satisfy the measurement equations (1) and (2) are admissible navigation solutions. That extraneous roots may exist can be seen from (6), (7), (10)–(12) that the parameters d, e, f, g, h and therefore the vector R as given in (13) remain unchanged if R_{ab} and R_{ac} are replaced by $-R_{ab}$ and $-R_{ac}$.

A. Altitude of Navigator Above Station Plane Known

An example of this situation is the local (flat Earth approximation) navigation of an aircraft equipped with an altimeter. Since the altitude z is known, x is obtainable as the solution of (9), i.e.,

$$d*x^2 + e*x + (f - z^2) = 0. \tag{9a}$$

Geometrically the navigation position is at the intersection of the plane z =known altitude with a hyperbola or an ellipse and where two admissible solutions corresponding to the two roots of (9a) generally exist. This two-fold ambiguity can often be resolved if some knowledge of the general location of the navigator is available.

B. Signal Arrival Time Difference or Sum to Another Station Known

This is the problem of the hyperbolic or elliptic position fix; i.e., the navigation position is at the intersection of three hyperboloids or ellipsoids. For this case, consider another station C′ and the associated timing measurement T'_{ac} are available. The stations A, B, C′ provide another set of reference and the timing measurements T'_{ac} and T_{ab} define another plane on which the navigator lies. An alternative expression for the navigation position vector referenced to the stations A, B and C′ is, similar to (13),

$$\vec{R} = x*\vec{i} + (g'*x + h')*\vec{j}' \pm \sqrt{d'x^2 + e'*x + f'}\vec{k}' \tag{14}$$

where the primed quantities are computed just like the corresponding unprimed quantities, with the station C replaced by the station C′. Taking the scalar product of (13) and (14) with the unit vector $\vec{j}'$ and equating the results, one obtains

$$g'*x + h' = (g*x + h)(\vec{j}*\vec{j}') \pm \sqrt{d*x^2 + e*x + f}*(\vec{k}*\vec{j}')$$

or, squaring and simplifying

$$p*x^2 + q*x + r = 0 \tag{15}$$

where

$$p = d*(\vec{k}*\vec{j}')^2 - \{g' - g*(\vec{j}*\vec{j}')\}^2 \tag{16}$$

$$q = e*(\vec{k}*\vec{j}') - 2\{g' - g*(\vec{j}*\vec{j}')\}\{h' - h*(\vec{j}*\vec{j}')\} \tag{17}$$

$$r = f*(\vec{k}*\vec{j}')^2 - \{h' - h*(\vec{j}*\vec{j}')\}^2. \tag{18}$$

With x known as the solution of (15), y and z follow from (5) and (8), respectively. As discussed already, for the present situation, the navigation position is at the intersection of a straight line and a hyperbola or an ellipse, and generally has two solutions. If the fourth station C′ is not in the plane of the stations A, B and C, these two solutions correspond to two values of x which are the two roots of (15). The $\pm$ sign of z in (8) can be resolved, because symmetries with respect to the A, B, C and A, B, C′ planes are incompatible. On the other hand, if the four stations are coplanar, the two planes containing the navigation position and defined by the two sets of references must intersect at a line parallel to the Z-axis, (15) must have double roots and the two possible navigation positions are mirror images with respect to the station plane corresponding to the $\pm$ signs of z in (8).

C. Navigator on Ellipsoid of Revolution

To a very good approximation, the surface of the ocean is an ellipsoid of revolution. Thus this is the situation for the navigation of ships. Since a sphere is a special case of an ellipsoid, this also includes the special case that the range of the navigator to another location is known, the location of interest may be another station or the center of the Earth. As discussed already, the navigation position is now at the intersection of an ellipse with a coplanar hyperbola or another ellipse, and it is obvious from geometry that two or four points of intersection may exist. The quartic that governs these intersections can be derived as follows. Let the position vectors from the two foci of the ellipsoid to Station A be $\vec{P}$ and $\vec{Q}$, respectively (Fig. 1). From the defining property of an ellipsoid of revolution, one must have

$$\sqrt{(\vec{P}+\vec{R})*(\vec{P}+\vec{R})}+\sqrt{(\vec{Q}+\vec{R})*(\vec{Q}+\vec{R})}=2a \quad (19)$$

where a is the semimajor axis of the ellipsoid. Transposing and squaring twice, one obtains

$$\{(P^2-Q^2-4a^2)+2(\vec{P}-\vec{Q})*\vec{R}\}^2$$
$$=16a^2*(Q^2+2\vec{Q}*\vec{R}+R^2)$$

where P, Q, and R are the lengths of the vectors $\vec{P}$, $\vec{Q}$, and $\vec{R}$, respectively. By expressing the known vectors $\vec{P}$ and $\vec{Q}$ in terms of their components along the $X-Y-Z$ axes defined in Fig. 1, it can be readily seen that the above equation can be rearranged as follows

$$u*x^2+v*x+w=\pm\sqrt{d*x^2+e*x+f}*(n*x+m) \quad (20)$$

where

$$u=\{(\text{beta})^2+d*s_z^2\}/4a^2-(1+g^2+d)$$
$$v=\{(\text{alpha})*(\text{beta})+e*s_z^2\}/4a^2$$
$$-(2q_x+2g*q_y+e+2g*h)$$
$$w=\{(\text{alpha})^2+4f*s_z^2\}/16a^2$$
$$-(Q^2+2h*q_y+h^2+f)$$
$$m=-s_z*(\text{alpha})/4a^2+2q_z$$
$$n=-s_z*(\text{beta})/2a^2$$
$$\text{alpha}=P^2-Q^2-4a^2+2s_y*h$$
$$\text{beta}=s_x+g*s_y$$

q_x, q_y, q_z and s_x, s_y, s_z are components of vector $\vec{Q}$ and $\vec{S}=\vec{P}-\vec{Q}$ along X, Y, and Z axes, respectively.

Notice that if the ellipsoid becomes a sphere, i.e., for the special case that the range of the navigator to a known location is given, then $n=0$, $m=2q_z$, the first terms in the expressions for u and v vanish, that for w becomes a^2, and the algebra simplifies considerably. Squaring (20), one obtains the following quartic for x

$$x^4(u^2-d*n^2)+x^3(2u*v-e*n^2-2d*m*n)$$
$$+x^2(v^2+2u*w-f*n^2-d*m^2-2e*m*n)$$
$$+x(2v*w-2f*m*n-e*m^2)+(w^2-f*m^2)=0 \quad (21)$$

When x is known, y and z follow from (5) and (8). Note that the quartic may have four distinct real roots. These, together with the $\pm$ values of z means there are eight possible combinations. However, as discussed before, only two or four of these are admissible navigation positions. The others are extraneous solutions which do not satisfy the measurement equations (1) and (2), or the auxiliary information (19).

INDEPENDENT BASELINES

Sometimes different station baselines are independent, i.e., the station clocks are synchronized only in pairs. In that case, although two sets of time of arrival differences, say T_{ab} and T_{cd} still constrain the navigation position at the intersection of two hyperboloids, the curve of intersection is no longer a planar curve, and the simple results obtained in previous sections no longer apply. However, as long as there is a set of three synchronized stations, additional measurements from independent baselines do provide simple solutions. Obviously, if an additional set of three synchronized stations exists, the navigation fix is again given by the roots of a quadratic. Likewise, if an additional independent baseline exists, the navigation fix is given by the roots of a quartic. The derivations parallel those in B and C above and are not reported here.

COMPUTATION FLOW

To illustrate the solution algorithm, the computational flow for a navigation fix on the Earth ellipsoid is presented in Fig. 2. The computations for other fixes are similar, but simpler, particularly when the solution is governed by a quadratic instead of a quartic.

DISCUSSION

It is shown in the above that several problems of interest in computing hyperbolic (elliptic) navigation fixes can be reduced to the solution of a quadratic or quartic equation. The solution of a quadratic is trivial. Analytic solution of a quartic is available, although some algebra is involved, but it is a simple matter to program the algorithm on a computer, as has been done by the author. The simplicity of the solutions results from the recognition that the intersection of two hyperboloids (ellipsoids) of revolution with a common focus is a hyperbola or an ellipse symmetrical with respect to the plane of the foci. By exploring the geometrical interpretations the nature of the navigation fixes are clarified. When the navigation position is governed by the quadratic, generally two admissible navigation positions exist and the ambiguity must be resolved from other information such as knowledge of the general whereabouts of the navigator. The quartic may have four distinct real roots corresponding to four possible navigation positions. Frequently some are extraneous roots which can be rejected by showing that

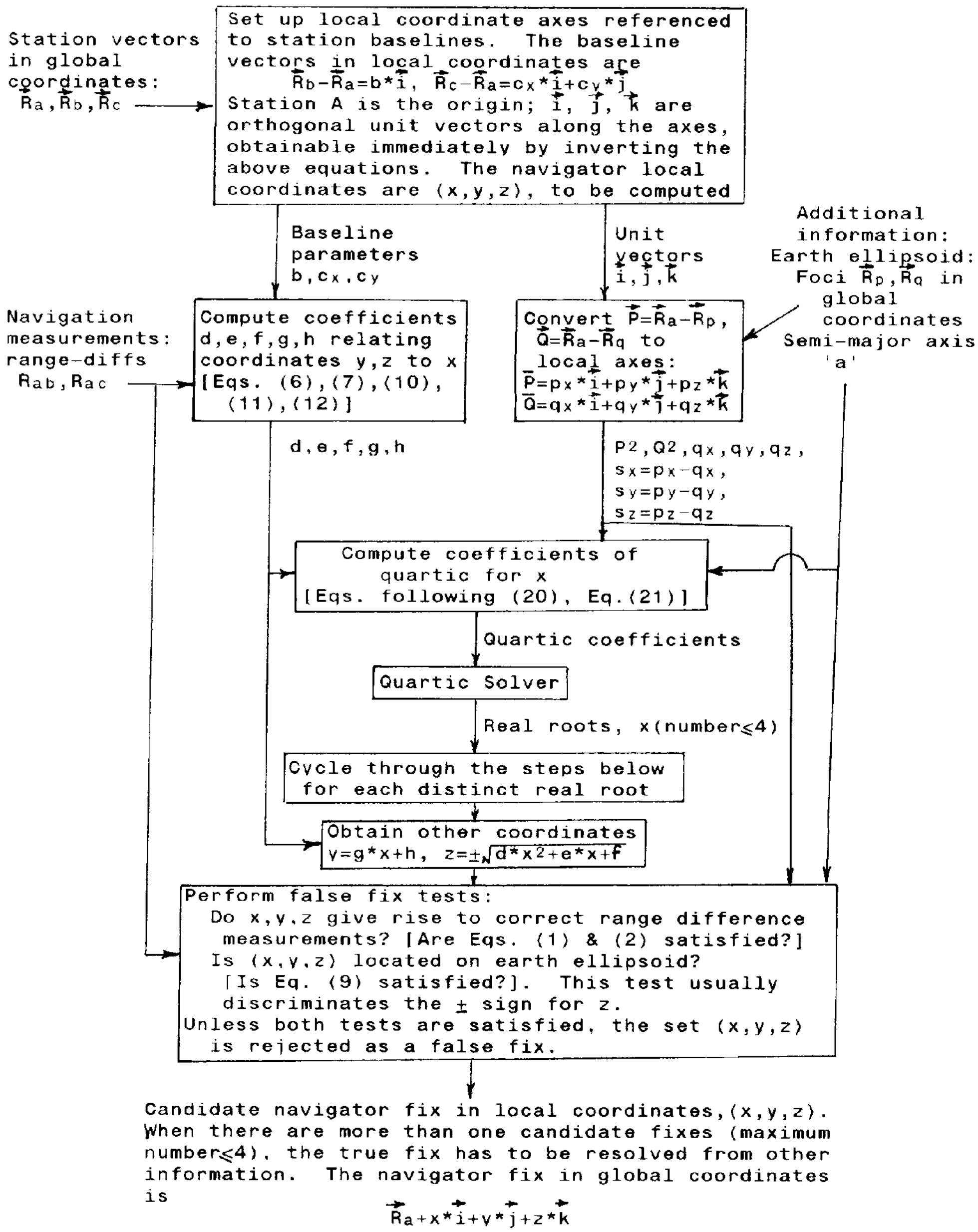

Fig. 2. Computation flow.

they do not produce the correct measurements. If a navigation position exists, it must be one of the real roots of the quadratic or the quartic, as the case may be. The nonexistence of an admissible root indicates a gross measurement error.

The navigation fixes discussed are based on range difference or range sum information, converted from time difference and time sum measurements. For terrestrial navigation systems that rely on ground wave propagation such conversion can be complicated. For line-of-sight wave propagation, or navigation in space, the conversion is straightforward. Very long baseline interferometry (time difference) and bilateration using a remote ground transponder (time-sum) are examples of such space navigation systems [3].

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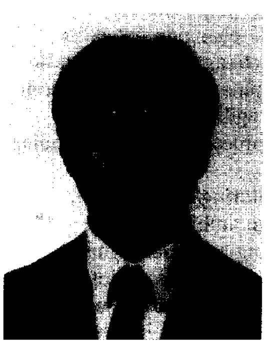


Bertrand T. Fang was born in China on February 2, 1932. He received the B.S. degree in mechanical engineering from National Taiwan University, Taiwan, in 1952, the M.S. degree in theoretical and applied mechanics from Iowa State University, Ames, in 1957, and the Ph.D. in aeronautical engineering from University of Minnesota, Minneapolis, in 1962.

Dr. Fang taught aerospace engineering at the Catholic University of America in Washington, DC for eleven years. His industrial experience includes employment at the General Electric Company, E G & G Washington Analytic Service Center, Inc., and Computer Sciences Corporation. Since 1985 he has been with The Analytic Sciences Corporation.

Lissajous Figures

by Jed Margolin

In the old days, whenever they showed an engineer working, there was usually an oscilloscope nearby with a pattern on the screen. Most often, the pattern was a Lissajous Figure.

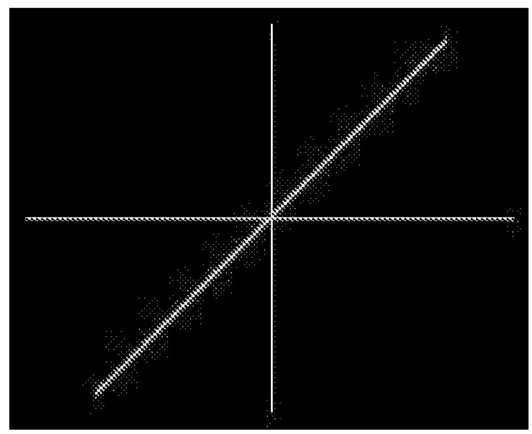
Jules Antoine Lissajous (1822-1880) was a French physicist who was interested in waves, and around 1855 developed a method for displaying them optically by reflecting a light beam from a mirror attached to a vibrating object such as a tuning fork.

You might wonder why he didn't just use an oscilloscope. It was probably because the Cathode Ray Tube hadn't been invented yet. (It was invented in 1897 by Karl Ferdinand Braun).

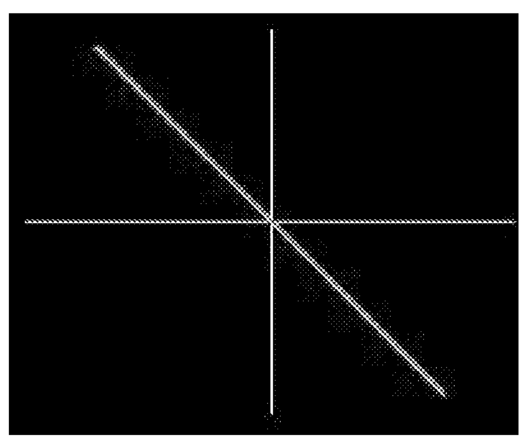
A Lissajous figure is produced by taking two sine waves and displaying them at right angles to each other. This is easily done on an oscilloscope in XY mode.

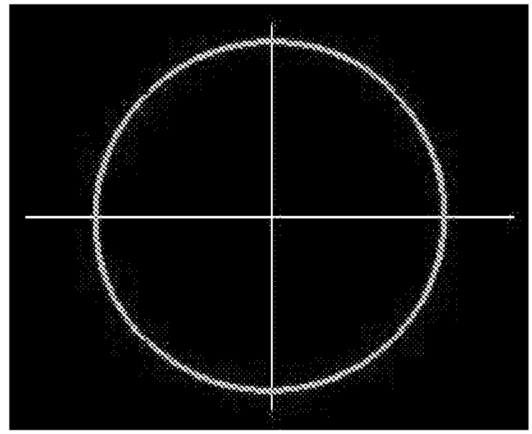
In the following examples the two sine waves have equal amplitudes.

When the two sine waves are of equal frequency and in-phase, you get a diagonal line to the right .



When the two sine waves are of equal frequency and 180 degrees out-of-phase you get a diagonal line to the left.





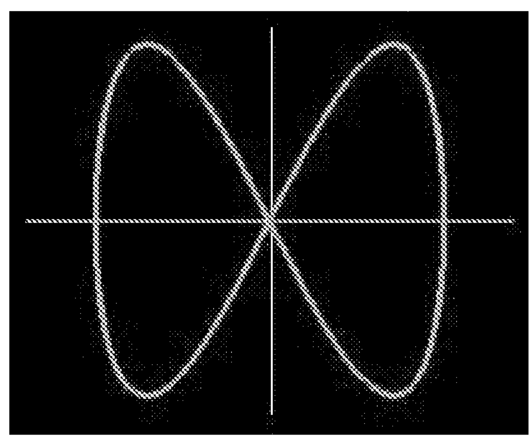
When the two sine waves are of equal frequency and 90 degrees out-of-phase you get a circle.

This should not be a big surprise, because when

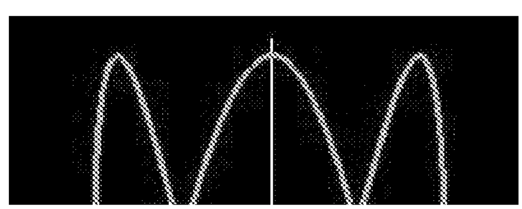
X = sin(a) and **Y = sin(a + 90) = cos(a)**

X*X + Y*Y = sin(a) * sin(a) + cos(a) * cos(a) = 1

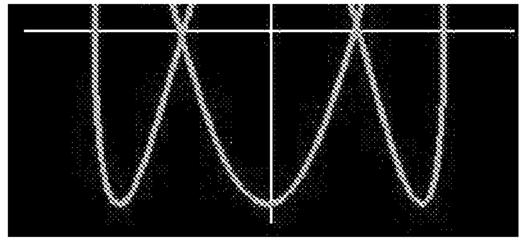
which is the parametric equation for a circle having a radius of 1.



If the two sine waves are in phase but the frequency of the horizontal sine wave is twice the frequency of the vertical sine wave you get the pattern shown here.



This shows the sine wave 90 degrees out-of-phase with the frequency of the horizontal sine wave three times the frequency of the vertical sine wave.



Mere static pictures do not do justice to Lissajous Figures.

When the horizontal and vertical sine wave frequencies differ by a fixed amount, this is equivalent to constantly rotating the phase between them.

The figure produced by this rotating phase appears to be a rotating 3D figure.

In addition, as in 3D wireframe images, the figure can appear to rotate in either direction, depending on how your brain interprets it. It can also spontaneously reverse the direction of rotation. (In a real 3D wireframe image the image can also appear to rotate around a different axis.)

The rotation of Lissajous Figures is something you need to see, so I am posting a program to do this.

Because the sine function is computationally intensive, the program starts out by calculating a table of sine values for a complete cycle of 360 degrees. Changing the address at which the table lookup is begun produces a sine wave with a different phase. The table address is wrapped so that the value is always valid.

By constantly increasing or decreasing the phase we produce the equivalent of having a small frequency difference. Technically, this is phase modulation. Large differences in frequency to produce integer multiples of frequencies are produced by multiplying the step size of the angles used to look up the sine value.

It is part of a program of Monitor Test Patterns that also produces Color Bars, a Crosshatch Pattern, a Dot Pattern, and a Monitor High Voltage Test.

The Color Bars are used to evaluate how well the Monitor reproduces colors.

The Crosshatch and Dot patterns are used to evaluate and adjust monitor convergence. (Don't try to adjust monitor convergence unless you know what you're doing and you have an enormous amount of patience.)

The Crosshatch pattern is also used to evaluate Geometric Distortion in the Monitor.
A Monitor should produce a crosshatch pattern with nice regular squares. A distorted pattern means either something is wrong or you have a crappy monitor. I once had a moderately expensive Sony TV (not a computer monitor) that exhibited noticeable geometric distortion. When I brought it to the Sony Service Center they gave me quite a run-around. It finally came down to:

Sony: *This TV meets all of our specifications for Geometric Distortion.*
Me: *I would like a copy of your specifications for Geometric Distortion.*
Sony: *We have no specifications for Geometric Distortion.*

Eventually, they saw the wisdom of buying the TV back from me. (I bought an inexpensive Daytron Korean

TV that was my primary TV for many years and still works even now.)

The High Voltage Test changes the screen brightness in order to see how well the High Voltage is regulated. When the High Voltage changes, so does the deflection sensitivity. (See my article on *The Secret Life of XY Monitors* if you would like an explanation.) When you are watching a TV program, it is really annoying to have the picture noticeably change size when the brightness of the scene changes. I have a newer model Magnavox TV whose High Voltage regulation sucks. I am betting on Organic LED (OLED) Displays to finally allow me to have an affordable flat panel TV with none of the design compromises that make TVs with CRTs so annoying.

I have done two versions of the program:

Version 1 uses OpenGL. It was compiled by Microsoft Visual C++ 6.0 and runs under Windows 9X. Support for OpenGL is built into Windows 9X. You don't have to install anything or screw around with the Operating System. All you do is run the program.

There are two versions of the Lissajous Patterns: one for fast machines and one for slow machines. The reason for this is that the Timer functions available in Windows are pathetic. The fastest you can get (without special gyrations) is 50 ms. Incredibly, there appears to be no way of determining when Vertical Retrace occurs, which is the best time for switching the display buffers.

My preference is that you examine the code until you understand it, then compile it yourself before running it. (Visual C++ 6.0 contains the OpenGL files you need to compile the program.)

This is my first real Windows program. I adapted the framework for the program from Jeff Molofee's excellent OpenGL tutorial available at www.nehe.gamedev.net/opengl.asp .

The framework is in *Mtest.cpp* . Any bugs are probably mine.

My part of the program is in *Mprog.cpp* . Any bugs are definitely mine.

If you do not have Visual C++, I suggest you run a virus checker on *Mtest.exe* before you run it. It will give us both some piece of mind.

Given the problems with viruses these days, I also suggest you download it *only* from my Web site (www.jmargolin.com).

Download Mtest.zip for Windows

It should consist of the following files:

Name	Modified	Size	Ratio	Packed	Path
Mprog.cpp	5/21/01 7:27 PM	29,487	82%	5,291	
Mprog.h	5/21/01 7:29 PM	3,401	64%	1,236	
Mtest.aps	5/13/01 1:29 PM	4,096	70%	1,215	
Mtest.cpp	5/21/01 7:27 PM	17,992	66%	6,180	
Mtest.dsp	5/17/01 10:39 AM	4,643	74%	1,200	
Mtest.dsw	5/13/01 1 18 PM	533	61%	210	
Mtest.exe	5/21/01 7:29 PM	53,248	57%	22,801	

Mtest. h	5/13/01	1 17 PM	323	51%	157
Mtest. ico	5/13/01	1:17 PM	1,078	83%	180
Mtest. ncb	5/21/01	7:32 PM	66,560	85%	10,299
Mtest.opt	5/21/01	7:32 PM	53,760	92%	4,357
Mtest. plg	5/21/01	7:29 PM	6,154	86%	880
Mtest. rc	5/13/01	1:17 PM	3,056	70%	931
Readme.txt	5/13/01	1 17 PM	2,055	64%	741
Resource.h	5/13/01	1 17 PM	777	54%	357
Small.ico	5/13/01	1 17 PM	318	71%	91
Stdafx.cpp	5/13/01	1 17 PM	292	34%	192
Stdafx. h	5/13/01	1 17 PM	936	49%	476
18 file(s)			248,709	77%	56,794

Version 2 of the program is from the original DOS version that I developed using Borland Turbo C, which was a good way to learn C. Borland Turbo C has a nice Integrated Development Environment (IDE) but it is very forgiving and allows one to develop sloppy programming habits. Its main drawback is that the best it can produce is 286 code.

The version I am making available here has been updated somewhat. Mtest386.exe was compiled under Borland C 4.5 as a DOS program to produce 386 code. Mtest286.exe was compiled under Borland Turbo C to produce 286 code.

You can even put it on a boot disk.

I could have had the compiler produce 486 code but if you have an old 286 or 386 machine around you can keep the Lissajous Pattern running on it so people will know you are a real engineer.

Download Mtest.zip for DOS

It should consist of the following files:

Name	Modified		Size	Ratio	Packed
Chatch.c	12/10/98	9:27 PM	8,137	83%	1,386
Colors.c	12/9/98	8:58 PM	6,357	80%	1,271
Colors.h	12/7/98	12:24 AM	1,750	67%	578
Main.c	5/21/01	8:04 PM	6,697	71%	1,960
Msine.c	5/21/01	11:34 PM	5,334	66%	1,827
Msine2.c	5/19/01	10:36 AM	4,417	68%	1,406
Mtable.h	5/19/01	10:50 AM	2,508	64%	892
Mtest286.exe	5/21/01	11:34 PM	81,715	43%	46,700
Mtest386.exe	5/21/01	11:44 AM	118,974	48%	62,410
9 file(s)			235,889	50%	118,430

Before there were frequency counters and phase locked loops, Lissajous Figures were used to compare two frequencies (such as a reference signal to an unknown signal) that were within a few integer multiples apart.

You could even get a rough estimation of the phase between the signals.

Even today, there is value in taking the two channels of a stereo audio signal and connecting them to an oscilloscope in XY mode, especially if you are an FM Broadcast Station.

Not everyone who listens to an FM Station is listening in stereo; it is essential to produce a compatible monaural signal. (The process by which an FM Stereo signal is produced creates a monaural signal that is the sum of the Left and Right Channels.)

If, somewhere along the audio chain, the phase of one of channels is reversed, instead of getting a L+R signal, a monaural listener will hear the L-R channel. Since most announcers are placed in the center channel (L=R), the announcer will disappear.

This can go completely unnoticed by operators listening with a pair of stereo monitors.(The stereo image will be screwed up as well, but is easily missed in the pressure of a broadcast operation).

Connecting the Left and Right channels to an oscilloscope in XY mode will give an instant indication of the phases between the channels, since much of the material in a stereo signal is in-phase. If, when the announcer comes on, you see a 45 degree line to the right (as in the first figure in this article) you are ok. If you get a 45 degree line to the left (as in the second figure) one of your channels is out of phase. It's easy to make that kind of error when wiring a radio station. I heard one FM station broadcast for the first several hours of its first day on the air with a channel out of phase. (No, it wasn't my station.) I called them up but the operator on duty didn't know what I was talking about.)

It might be interesting to program a PC to take the inputs from the sound card and display them on the screen in XY mode. Then connect the channels to an stereo FM radio and tune across the dial.

It might also be interesting to program Lissajous figures and play them through the sound card.

And, finally, even today with all the sophisticated graphics that people do, Lissajous Figures are still compelling to look at.

Run the program in full-screen mode with the lights out and you will see why.

Jed Margolin
San Jose, CA
May 23, 2001

Please send comments here

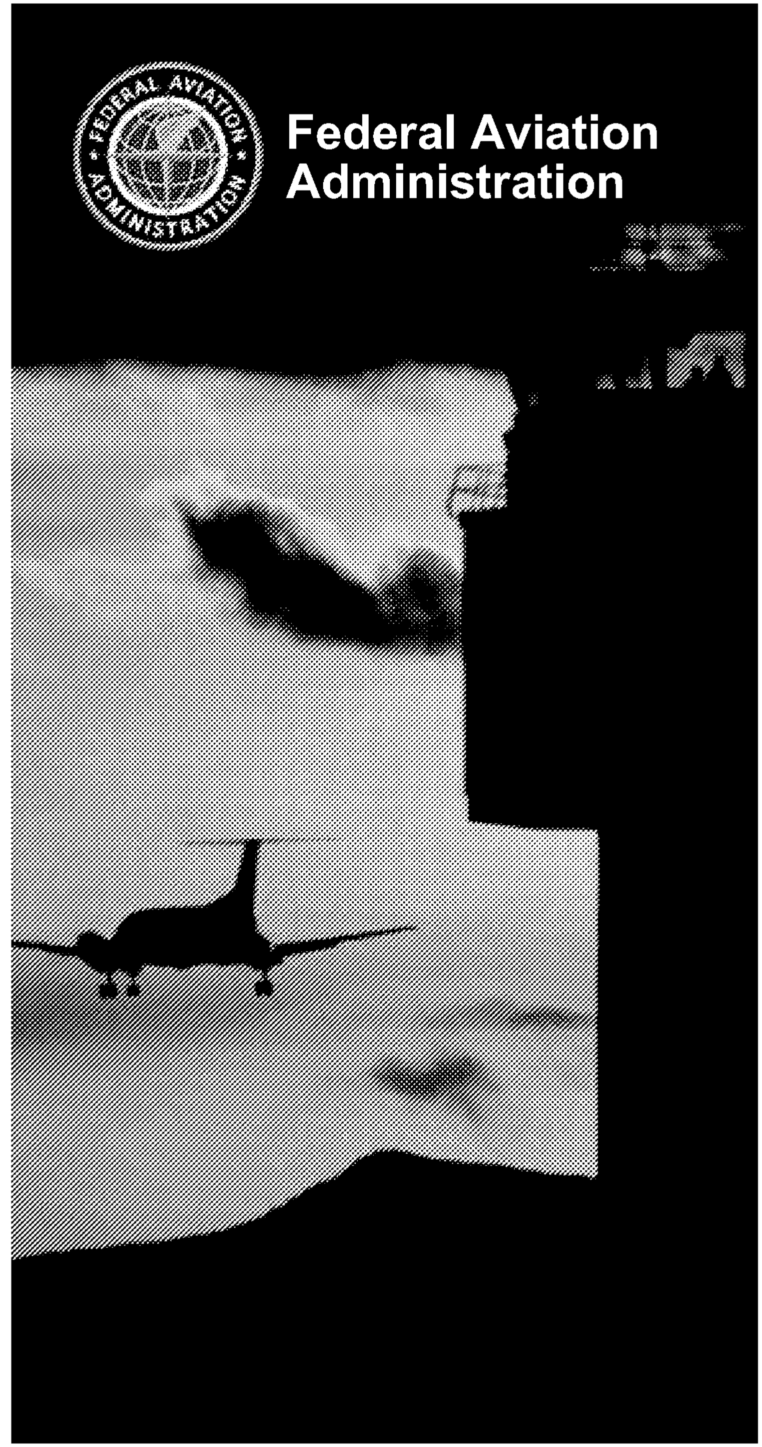
Unmanned Aircraft Systems

Integration into the National Airspace System (NAS)

Presented to: Access5

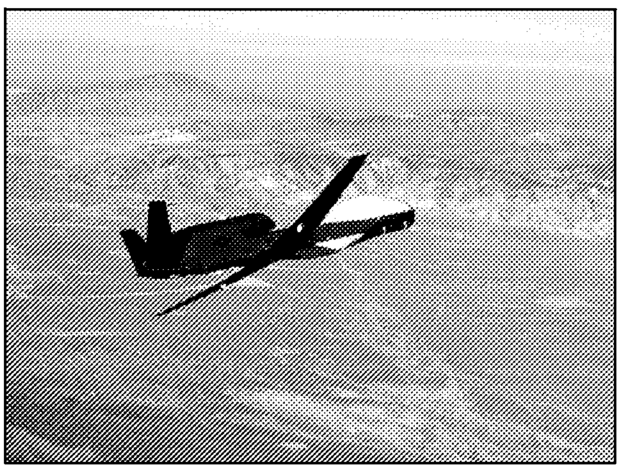
By: John Timmerman

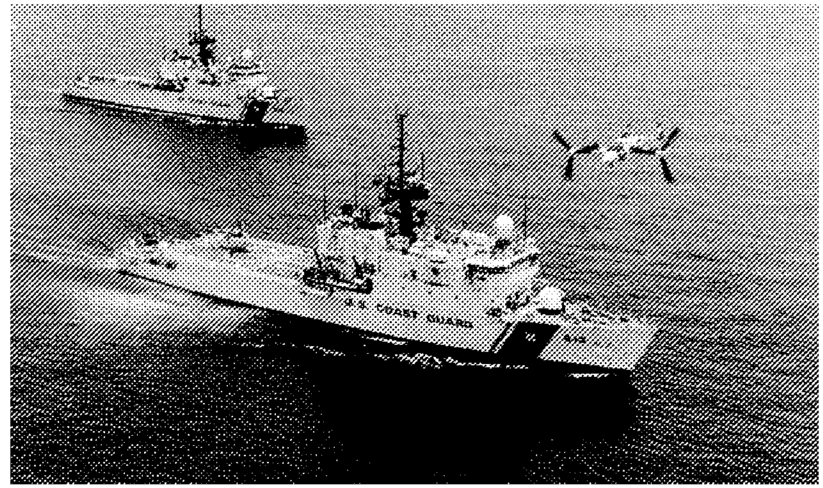
Date: July 12, 2005

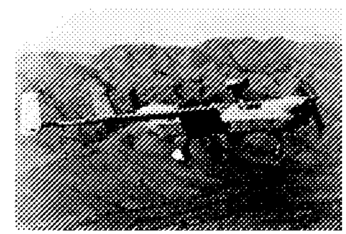


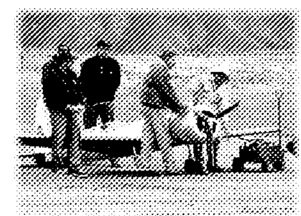
What is UAS?

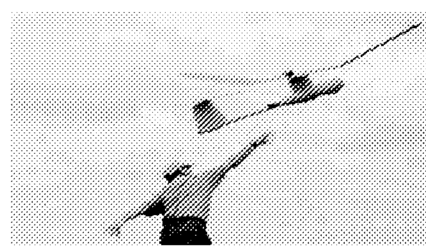
- Unmanned Aircraft Systems (UAS) historically called by various terms:
  - Drone/ROA/RPV/UAV/Model/R-C
- Includes:
  - Unmanned Aircraft (UA)
  - Aircraft Control Station
  - Command & Control Link/s
- Operated or flown by a “pilot”

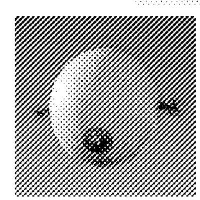


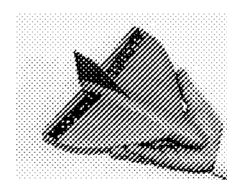












Current UAS Operations in the NAS

- Within "segregated" airspace
  - Includes Special Use Airspace (SUA) & Air Traffic Control Assigned Airspace (ATCAA)
  - Primarily by DOD
- In non-segregated airspace
  - "Public" UAS – through Certificate of Authorization (COA) process
    - Includes initial "trials" in support of DHS
  - "Civil" UAS – using experimental / type certification process
  - "Model" aircraft – with guidance from AC 91-57, dated June 1981
  - Variety of other operations believed to be occurring by both the public and private sector
    - Some based on interpretations of "model" aircraft guidance
    - Others with a lack of knowledge of aviation environment requirements
- While ensuring "no harm" to other NAS customers and public

Expected Changes - Next 5-10 years

- Many UAS's transitioning from R&D to operational status
  - Routine UAS flight - both VFR and IFR and in all airspace classes
- Wider scale development and uses for UAS
  - R&D activities in public and civil sectors continue to grow
  - New uses and applications – innovative customers and providers
- Increased demands on the NAS
  - Greater numbers and diversity of requests to operate in the NAS
  - UAS operations "mushrooming" in an increasingly busy NAS
  - Additional airspace and access requested for UAS flight
    - Including security and surveillance
      - Border and harbor patrol
      - Broad spectrum of law enforcement activities
  - Pressure for quicker access - "file and fly"
  - Conflicting interests among aviation stakeholders
- International efforts to "harmonize out of the box"

2015 and Beyond

- UAS operations dominate some aviation sectors
  - Particularly those “dirty, dull or dangerous”
- Commercial UAS applications steadily grow
  - Driven by “business cases” for reduced costs
- Consumers becoming increasingly receptive to reduced human presence in aircraft cockpits
  - Passenger flights with a single “supervisory” pilot
  - Cargo operations without an on-board pilot
- Increased “cooperation” needed between aviation segments to efficiently manage finite airspace resources
- Increased expectations for higher levels of safety

GOAL

&

RESPONSIBILITY!

A Safe NAS for All

www.ato.faa.gov

Test Results from a Novel Passive Bistatic GPS Radar Using a Phased Sensor Array

Alison Brown and Ben Mathews, *NAVSYS Corporation*

BIOGRAPHY

Alison Brown is the Chief Visionary Officer of NAVSYS Corporation. She has a PhD in Mechanics, Aerospace, and Nuclear Engineering from UCLA, an MS in Aeronautics and Astronautics from MIT, and an MA in Engineering from Cambridge University. In 1986, she founded NAVSYS Corporation. She was a member of the GPS-3 Independent Review Team and the Interagency GPS Executive Board Independent Advisory Team, and is an Editor of GPS World Magazine. She is an ION Fellow and an Honorary Fellow of Sidney Sussex College, Cambridge.

Ben Mathews is a Program Manager and Digital Signal Processing Section Manager at NAVSYS Corporation. His work includes the design and development of advanced GPS and integrated navigation systems and digital signal processing systems. He holds a BSEE from the University of Illinois at Urbana-Champaign and a MSEE from Virginia Tech.

ABSTRACT

GPS bistatic signals have applications for remote sensing in collecting data such as soil moisture content, surface altitude or wave speed. Prior research using these signals has been limited by the low signal power of the bistatic GPS signals. Leveraging off of a previous effort that used a 15-element array, NAVSYS Corporation has developed an advanced bistatic GPS receiver that uses a 109-element GPS antenna array and digital beam steering to provide gain to increase the ability to detect the weak bistatic GPS signals. The enhanced 109-element array offers 20 dB of gain over previous receivers, which use single element tracking and offers promise of retrieving usable return data from a much higher altitude.

In this paper, the design of the digital beam-steering receiver is described and data collected during flight tests with the array are presented. The data was collected with the antenna array installed on a Cessna aircraft. Flights were conducted over terrain and water and the data was recorded for post-test analysis. The results of the flight test show the increase in fidelity and observability of the bistatic GPS signals by using digital beam steering. The digital scanning capability of the receiver also increases the area of coverage over which data can be collected from a single aircraft pass. The enhanced data collected will be of benefit for all remote sensing applications using bistatic GPS signals.

INTRODUCTION

Early experimentation using NAVSYS' advanced Global Positioning System (GPS) receiver technology demonstrated the ability to track the reflected GPS signals from the surface of the earth in the early 90's [1]. Since then, further research has demonstrated the utility of these signals for applications such as surface altimetry [2], wave motion detection and wind sensing [3], and observing surface water content [4, 5] for mapping ice fields or wetlands.

Because of the extremely low power level of the returned bistatic GPS signals, this previous research has focused primarily on the strong specular bistatic signals. NAVSYS has developed a digital beam-steering GPS receiver, the High-gain Advanced GPS Receiver (HAGR), which can be used to increase the received signal/noise ratio from these weak bistatic signal returns allowing improved detection of both specular and diffuse GPS signals (Figure 1). The theoretical basis for the GPS bistatic sensing using these signal returns is included in Reference [6].

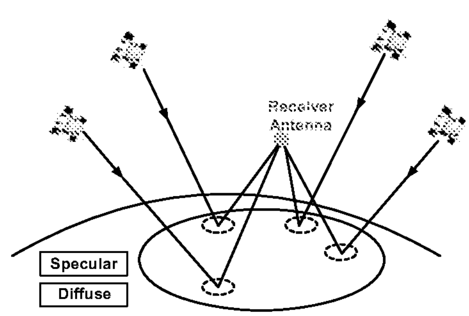


Figure 1 GPS Bistatic Geometry with Specular Reflection Points

DIGITAL BEAM-STEERING GPS RECEIVER

The NAVSYS High-gain Advanced GPS Receiver is a digital beam steering receiver designed for GPS satellite radionavigation and other spread spectrum applications.

This is installed in a rugged Compact PCI chassis (Figure 2) suitable for aircraft flight tests (Figure 2 through Figure 5).

The HAGR system architecture is shown in Figure 6. The signal from each antenna element is first digitized using a Digital Front-End (DFE). Each DFE card includes the capability to sample signals from 8 antenna inputs. These can be cascaded together to allow beam steering to be performed from a larger antenna array. The complete set of DFE digital signals is then used to create the composite digital beam-steered signal input by applying a complex weight to combine the antenna array outputs.

The HAGR can be configured with a variable number of antenna elements up to a total of 109-elements, as shown in Figure 6. For the first flight test a 15-element array was used; while the second flight test used 96 elements, with the elements shown in blue in Figure 7. Figure 8 shows the beam pattern created by the 96-element array. The advantage of digital beam steering can be seen in Figure 9, where we compare the CN0 values obtained from 5 individual elements with the CN0 value obtained using 96-element beam steering. Through the HAGR digital control, these beams can be directed at any point on the surface of the earth for data collection. The area they cover is a function of the beam width and the aircraft altitude, as illustrated in Figure 10. Up to 5 beams each, with +20 dB gain, can be independently directed by the HAGR signal processor.

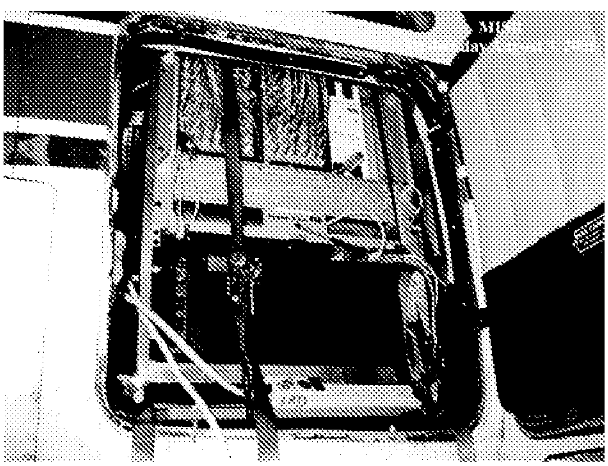


Figure 2 HAGR Receiver and Digital Recorder Installed on the Aircraft

Figure 3 96-Element Antenna Array before Installation

Figure 4 96-Element Antenna Array Installation

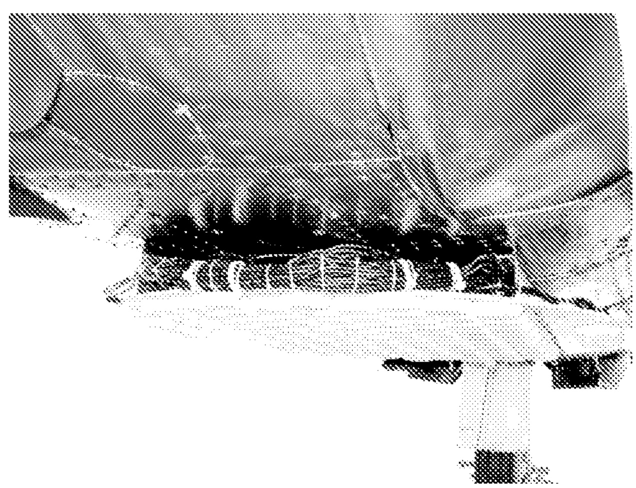


Figure 5 96-Element Antenna Array Mounted on the Aircraft

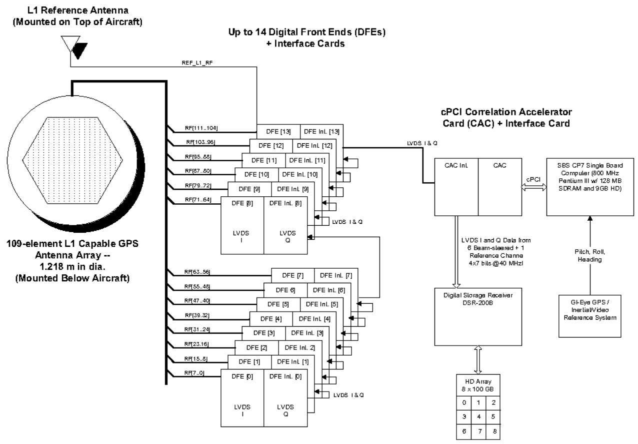


Figure 6 HAGR System Architecture

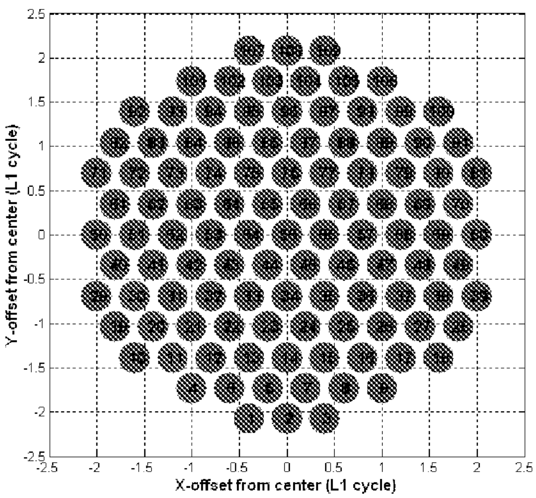


Figure 7 96-Element Phased Array

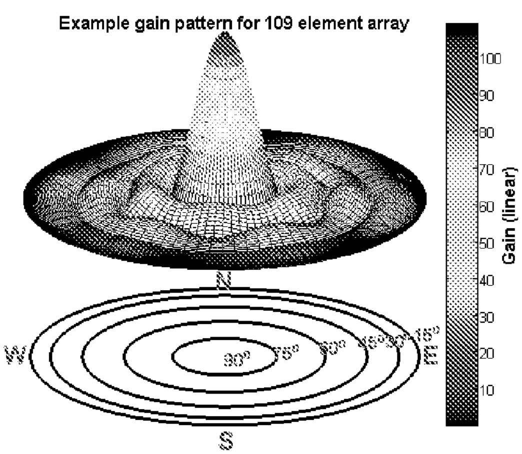


Figure 8 Beam Pattern of 109-Element Array

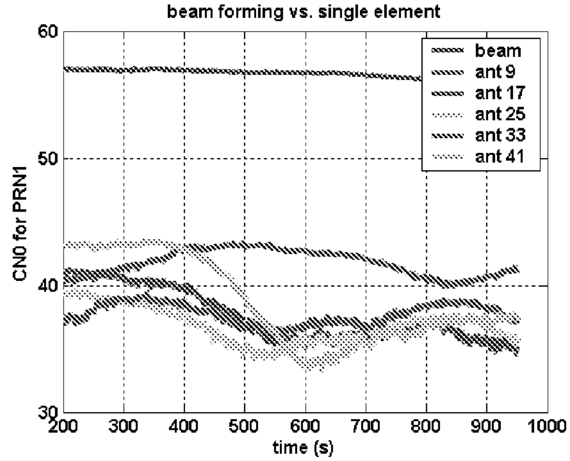


Figure 9 Beam forming Gain

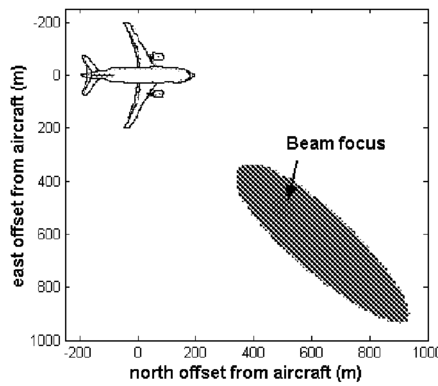


Figure 10 109-Element Beam Footprint (3dB contour from 500 m altitude)

BISTATIC GPS FLIGHT TEST

The flight test was conducted with the digital beam-steering receiver and the 96-element HAGR antenna array. The antenna array was installed on the underside of a Cessna test aircraft, Figure 11, and a reference antenna was installed on the upper-side of the aircraft. A similar flight test was previously flown using a 15 element array. During these flight tests, the HAGR was used to track the GPS satellites, and our digital storage receiver [7, 8] was used to record the raw broadband data from each beam and from the roof-mounted reference antenna. Approximately one hour of bistatic maritime data and one hour of bistatic land data was collected during each flight. This data was then played back into the HAGR from the digital storage receiver for signal processing post-test.

Figure 11 Cessna Test Aircraft before Flight

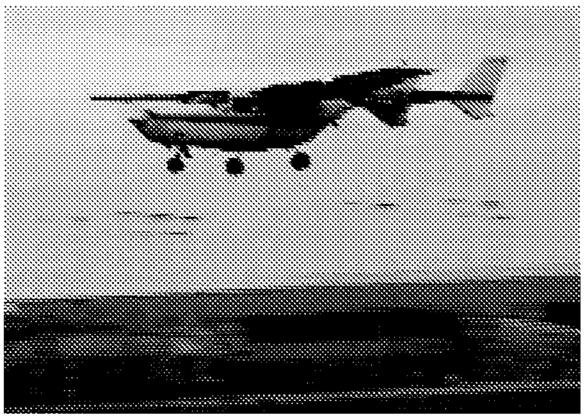


Figure 12 Test Aircraft with 96-Element Array in Flight

SPECULAR DATA ANALYSIS

Analysis of the specular returns over water are expected to be stronger than over land and can be used to provide information on vehicle detection, wave motion detection, wind sensing, and observing surface water content. For example, Figure 13 shows that using the 96-element array without post-processing, the HAGR receiver was able to track much more frequently off of the specular points on water than it was off of specular points off of land.

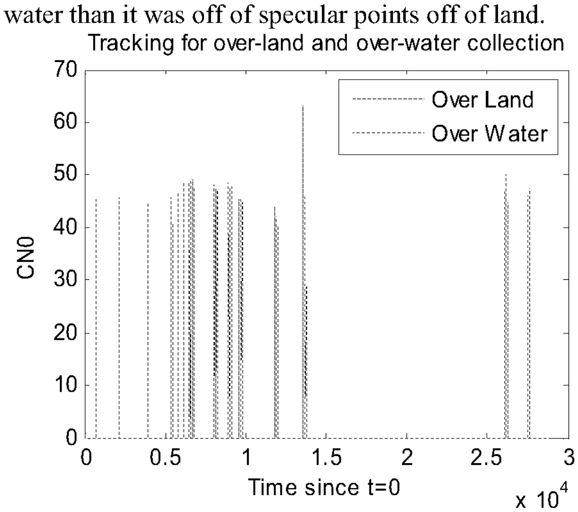


Figure 13 Bistatic Tracking over Land and Water

In Figure 14 an example of the kind of returns is shown. In this case, the HAGR receiver is able to track off of the two specular points that occur over the water (SV11 and SV27), while the specular points that occur over land (SV8 and SV31) do not return sufficient power to be tracked without additional post processing.

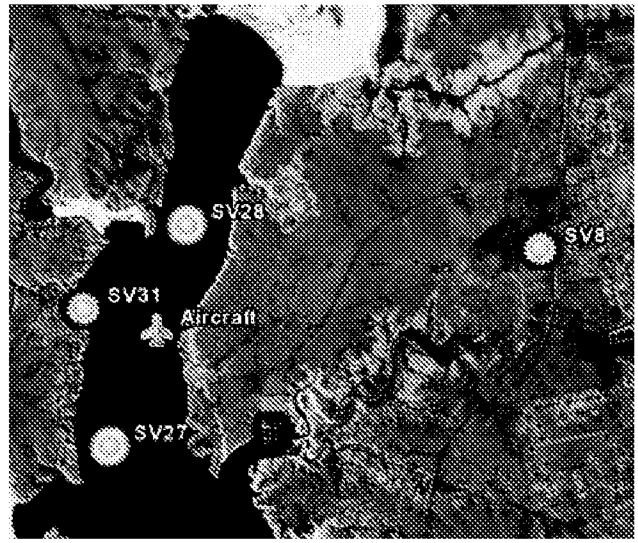


Figure 14 Aircraft and Specular Points over Land and Water

Figure 15 shows a dramatic increase in return power during the first flight test with a 15-element array when the specular point crosses the Pearl River in a forest on the Mississippi-Louisiana border. The rough surface formed by the treetops provides a low specular return whereas the smooth river surface provides a very strong return.

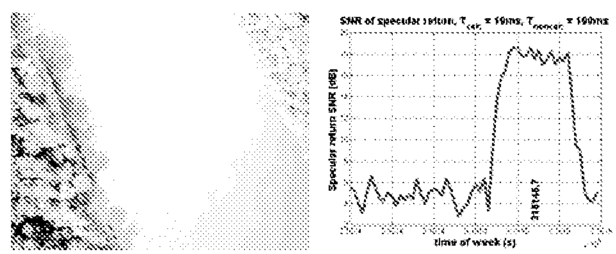


Figure 15 Pearl River Crossing, Specular Power Increase

An analysis on the data shown in Figure 13 was conducted. We examined the difference between the CN0 values obtained when we tracked off of the specular points and the expected CN0 values calculated, considering factors such as the beam forming gain, the satellite power and elevation, and the loss associated with the type of terrain that the specular point is reflecting off. These results are shown in Table 1. Using digital beam forming, the HAGR receiver was able to track off of the specular points with typical CN0 values comparable to those of single element tracking directly off of the satellite.

Table 1 Comparison of Expected and Actual CN0 values

Case	Expected CN0 (db-Hz)	Actual CN0 (db-Hz)
1	49	45
2	48	46
3	48	45
4	42	46
5	51	47
6	54	48
7	56	49
8	53	49
9	50	49
10	46	48
11	53	48
12	55	45
13	49	40
14	52	49
15	51	50
16	55	47

In Figure 16 and Figure 17 the expected and actual bistatic returns are shown from a point located in an urban area of Monument, Colorado. The characteristic horseshoe shape of the return can be seen in both images. With the gain provided by the use of beamsteering, sufficiently strong returns are obtained to provide useful measurements for a variety of remote sensing applications.

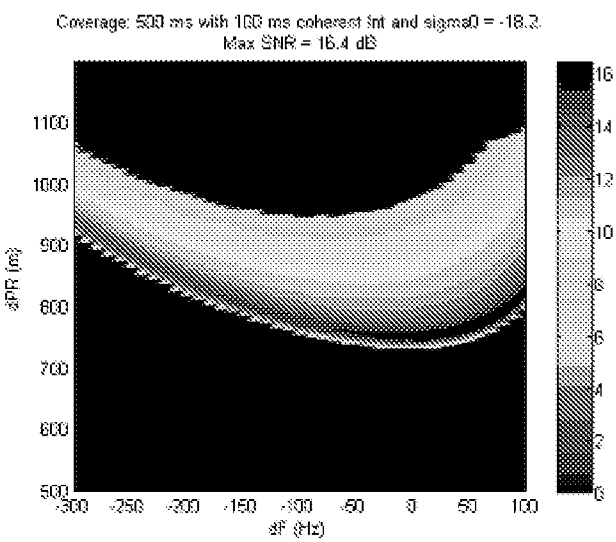


Figure 16 Expected Bistatic Returns

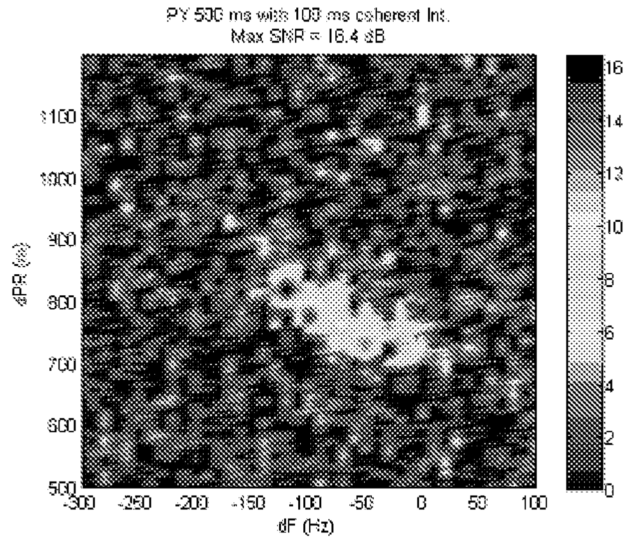


Figure 17 Actual Bistatic Returns

CONCLUSIONS

Test results and analysis described in this paper have demonstrated the ability of the HAGR receiver to improve the GPS bistatic remote sensing capability by using digital beam steering, to allow the weak bistatic GPS signal returns to be detected over a larger area. The test data taken has successfully shown that with the +20 dB gain provided by the ISR array and receiver, we are able to robustly track the specular and some diffuse signal bistatic GPS returns that were not trackable under previous efforts that used only a single antenna [9]. Using the ISR array, we were able to reliably detect signals returned from surfaces with clutter coefficients as low as -21 dB, which would have been undetectable using single antenna approaches.

We have demonstrated the following advantages of the ISR array for GPS bistatic signal tracking:

- Provides a wide-area, passive, intelligence, surveillance, and reconnaissance capability
- Provides fine resolution range/Doppler data using encrypted P(Y) code signal processing
- Allows robust detection of weak GPS specular and diffuse signal returns over a variety of terrain
- Passive operation enables use for covert detection operations.

Higher power GPS signals planned for the GPS IIF and GPS-3 satellite constellation will extend the range of operation of this system.

ACKNOWLEDGMENTS

The authors would like to acknowledge the support of The Office of Naval Research for sponsoring this activity. This work was funded under SBIR Contract No. N00014-00-C-0552.

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[8] http://www.navsys.com/Products/agbs.htm

9 D. Masters, V. Zavorotny, and S.J. Katzberg, "Data Summary Presentation," CLPX 2003 Workshop, Boulder, CO, May 2003

Quadrennial Roles and Missions Review Report

Department of Defense
January 2009

Quadrennial Roles and Missions

Review Report

January, 2009

Front Cover Image Credits

Top Row
#1 A fully armed MQ-9 Reaper taxis before a mission in Afghanistan.
U.S. Air Force photo by Staff Sergeant Brian Ferguson

#2 U.S. Coast Guard Cutter Bainbridge Island stands watch over the Statue of Liberty in New York Harbor.
U.S. Coast Guard photo by Petty Officer Mike Lutz

#3 An Afghan engineer talks with a member of the Nangarhar Provincial Reconstruction Team in the Nangarhar province of Afghanistan.
Photo by Staff Sergeant Joshua T. Jasper, U.S. Air Force

Second Row
#4 Wideband Global SATCOM satellite.
Air Force Image

#5 SEALs in from the water.
U.S. Navy SEALs Photo

Third Row
#6 The first Joint Cargo Aircraft presented to the U.S. Army.
L3, Alenia North America, Global Military Aircraft Systems

#7 Operations center in Qatar.
U.S. Air Force photo by SrA Brian Ferguson

#8 Soldiers in their M1A1 Abrams tank in Iraq.
Photo by Pvt. Brandi Marshall

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AP Photo/ U.S Marine Corps, Cpl Michael R McMaugh, 1st Marine Division Combat Camera, HO

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U.S. Navy photo

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FOREWORD

Since September 2001, our Nation has been engaged in a multi-theater, long-term conflict against militant extremists who seek to erode the strength and will of the United States, our partners, and our allies through irregular and asymmetric means. As the Department of Defense continues to engage in ongoing operations, we must also prepare for our future challenges by learning from the past, building on the present, and taking advantage of opportunities to increase the effectiveness and efficiency of our institution. During the inaugural Quadrennial Roles and Missions Review, we have leveraged previous defense reviews and lessons from recent operations to determine how we should change to better meet our institutional responsibilities and improve support to our national security partners.

In accordance with section 941 of the National Defense Authorization Act for Fiscal Year 2008, this report identifies the Department's Core Mission Areas and Core Competencies. Additionally, this report describes how the Department's civilian and military leadership reviewed the rapidly-evolving roles, missions, and capabilities associated with irregular warfare, cyberspace operations, unmanned aircraft systems, and intratheater airlift. Together, we have concluded the Department must improve how we organize, train, and equip our forces for these areas.

Of course, the Department of Defense cannot address our Nation's complex security challenges alone. One of the most important lessons from recent operations is that military success does not equate to victory. As a result, during the Quadrennial Roles and Missions Review we considered opportunities that will help strike a better balance between our Nation's hard and soft power capabilities. The Quadrennial Roles and Missions Review concludes we must improve our soft power: our national ability to promote economic development, institution-building and the rule of law, internal reconciliation, good governance, training and equipping indigenous military and police forces, strategic communications, and more. Doing so requires exploring whole-of-government approaches for meeting complex security challenges.

While the Quadrennial Roles and Missions Review lays a foundation for understanding the Department's roles and responsibilities in today's complex security environment, there is still much work to be done. As we move toward the Quadrennial Defense Review, we must continue initiatives that establish the right balance between winning today's wars and preventing tomorrow's conflicts while improving our whole of government ability to promote stability and security at home and aboard.

Robert M. Gates
Secretary of Defense

I. INTRODUCTION

Quadrennial Roles and Missions Review Objectives. The Quadrennial Roles and Missions Review (QRM) offered a unique opportunity for the Defense Department to further our strategic priorities by assessing responsibilities of individual components and evaluating improvements to the way we do business across our enterprise. Completed toward the end of the 2006 QDR implementation cycle, the 2009 QRM capitalized on changes the Department has made to its responsibilities, processes, and capabilities since 2006 and direction for the future established in our latest strategic guidance documents, including the 2008 *National Defense Strategy.*

From the onset of the Review, teams of senior civilian and military leaders from the Military Services, Joint Staff, Combatant Commands, and Office of the Secretary of Defense worked together to develop a framework that defines and links the Department's Core Mission Areas with its Core Competencies and Functions of the Armed Forces. Additionally, teams of civilian and military experts worked together to assess high-interest issue areas and propose actions to achieve the Department's primary objectives for this inaugural QRM:

- Increase synergy across the Department's Components.
- Improve the effectiveness of joint and interagency operations.
- Ensure the Department continues to efficiently invest the Nation's defense resources to meet the asymmetric challenges of the 21st Century.

This approach stems from our understanding that dealing with long-term security challenges requires the Department to operate with unity, agility, creativity, and in concert with our partners across the U.S. Government.

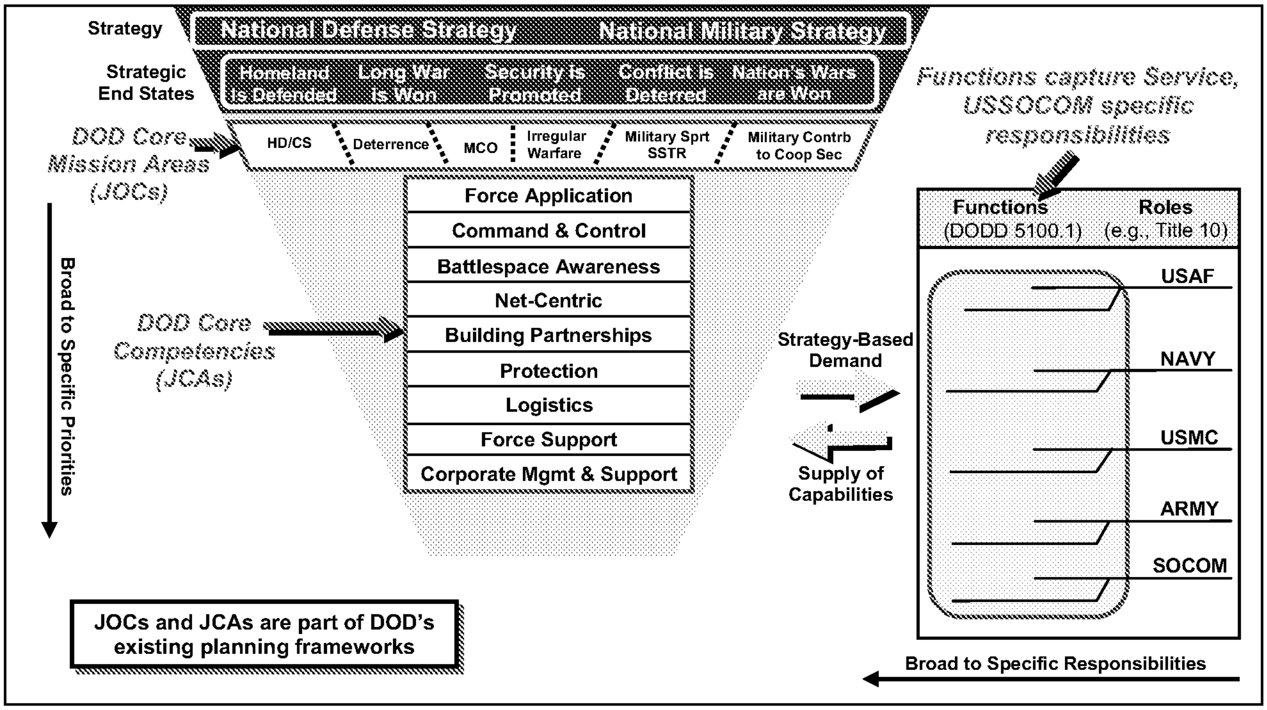
QRM Report Overview. Section II of this report describes a framework developed by the Department for assessing potential future roles and missions changes. This framework, which integrates traditional missions with new and emerging military activities, is the first of its kind developed during a defense review. Section III defines the Department's Core Mission Areas and Core Competencies, as required by section 941 of the 2008 National Defense Authorization Act. Section IV summarizes the Department's insights and initiatives for four specific roles and missions focus areas: Irregular Warfare; Cyberspace; Intratheater Airlift; and Unmanned Air Systems / Intelligence, Surveillance, Reconnaissance. Section V addresses the need for increased emphasis on effective interagency operations to address complex national security challenges.

During the QRM, the cohesive efforts of our civilian and military leaders and their desire to address security challenges from a Departmental perspective provided a solid foundation for continued cooperation in these and other roles and missions issue areas. While this report captures 2009 QRM results, they should not be viewed as the final solution for roles and missions challenges the Department and its partners face in today's dynamic security environment. Continued progress will depend on the capacity of the Department and its partners to take advantage of real-word lessons learned and our ability to work together to better integrate all instruments of national power.

II. ROLES AND MISSIONS FRAMEWORK

The framework in Figure 1 summarizes results of the Department's efforts to define its Core Mission Areas and Core Competencies. As the framework illustrates, Core Mission Areas and Core Competencies provide guidance to the Services and U.S. Special Operations Command on the appropriate mix and scope of roles and functions to meet priorities of the *National Defense Strategy* and *National Military Strategy*:

Figure 1: Department of Defense Framework for the QRM



Core Mission Areas are broad Department of Defense military activities required to achieve strategic objectives of the *National Defense Strategy* and *National Military Strategy*. A Core Mission Area is a mission for which the Department is uniquely responsible, provides the preponderance of U.S. Government capabilities, or is the U.S. Government lead for achieving end states defined in national strategy documents.

- Each of the Department's Core Mission Areas is underpinned by a Joint Operating Concept (see Section III) that identifies desired effects necessary to achieve operational objectives, essential capabilities to achieve these objectives, and relevant conditions under which capabilities must be applied. Joint Operating Concepts (JOCs) are a visualization of future operations. They describe how a commander, using military art and science, might employ capabilities necessary to meet future military challenges. In practice, JOCs establish context for the Department's force development planning and resourcing activities. This helps the Department identify military problems and develop innovative solutions that go beyond merely improving the ability to execute missions under existing standards of performance.

- Although JOCs underpin the Department's Core Mission Areas, they are not entirely Department-centric. For example, the Department informally coordinates with the Department of State and other agencies on concepts for irregular warfare, cooperative security, and stability operations. As we continue to evolve JOCs, there will be additional opportunities for interagency cooperation.

Core Competencies are groupings of functionally-organized capabilities associated with the performance of, or support for, a Department of Defense Core Mission Area. The Department's Components perform tasks and activities that supply these functionally-organized capabilities.

- The QRM determined the Department's Core Competencies correspond to the nine Joint Capability Areas (see Section III) established following the 2006 QDR. Joint Capability Areas (JCAs) are groupings of related capabilities that support strategic decision-making, capability portfolio management, and joint analyses of capability gaps, excesses, and major tradeoff opportunities. JCAs also provide a common capabilities language for use across the Department's activities and processes.

Functions are the appropriate or assigned duties, responsibilities, missions, or tasks of an individual, office, or organization as defined in the National Security Act of 1947, including responsibilities of the Armed Forces as amended. The term "function" includes purpose, powers, and duties. Specific Functions of the Services and U.S. Special Operations Command are captured in Department of Defense Directives.

Roles are the broad and enduring purposes for which the Services and U. S. Special Operations Command were established by law.

III. DEPARTMENT OF DEFENSE CORE MISSION AREAS, CORE COMPETENCIES, AND FUNCTIONS

A. Core Mission Areas

The QRM defined five key attributes for the Department's Core Mission Areas: they represent relatively enduring missions; they are necessary for achieving strategic end states derived from the 2008 *National Defense Strategy;* they constitute a broad military activity; they describe a unique Department of Defense capability and capacity; or they identify a mission for which the Defense Department is the U.S. Government lead and/or provides the preponderance of U.S. Government capabilities. In compliance with section 941 of the 2008 National Defense Authorization Act, the Department has established six Core Mission Areas:

1. **Homeland Defense and Civil Support (HD/CS)** operations help ensure the integrity and security of the homeland by detecting, deterring, preventing, or, if necessary, defeating threats and aggression against the United States as early and as far from its borders as possible so as to minimize their effects on U.S. society and interests. The Department also may be directed to assist civilian authorities in order to save lives, protect property, enhance public health and safety, or to lessen or avert the threat of a catastrophe. The Department provides many unique capabilities that can be used to mitigate and manage the consequences of natural and man-made disasters and must be prepared to provide support to federal, state, and local authorities.

Two UH-60 Black Hawk helicopters from 2nd Battalion, 227th Aviation Regiment, 1st Air Cavalry Brigade, 1st Cavalry Division, fly the commanding general of U.S. Northern Command General Victor Renuart Jr. and his staff over Galveston, Texas and surrounding areas during an aerial assessment of damage left in the wake of Hurricane Ike.

Photo by Sgt. Nathan D. Hoskins, 1st ACB, 1st Cav. Div. Public Affairs

2. **Deterrence Operations** are integrated, systematic efforts to exercise decisive influence over adversaries' decision-making calculus in peacetime, crisis, and war to achieve deterrence.

3. **Major Combat Operations (MCOs)** are the conduct of synergistic, high-tempo actions in multiple operating domains, including cyberspace, to shatter the coherence of the adversary's plans and dispositions and render him unable or unwilling to militarily oppose the achievement of U.S. strategic objectives.

4. **Irregular Warfare** encompasses operations in which the joint force conducts protracted regional and global campaigns against state and non-state adversaries to subvert, coerce, attrite, and exhaust adversaries rather than defeat them through direct conventional military confrontation. Irregular warfare emphasizes winning the support of the relevant populations, promoting friendly political authority, and eroding adversary control, influence, and support.

5. **Military Support to Stabilization Security, Transition, and Reconstruction Operations** is assistance to severely stressed governments to avoid failure or recover

from a devastating natural disaster, or assist an emerging host nation government in building a new domestic order following internal collapse or defeat in war.

6. **Military Contribution to Cooperative Security** describes how Joint Force Commanders mobilize and sustain cooperation, working in partnership with domestic and foreign interested parties, to achieve common security goals that prevent the rise of security threats and promote constructive regional security environments.

B. Core Competencies

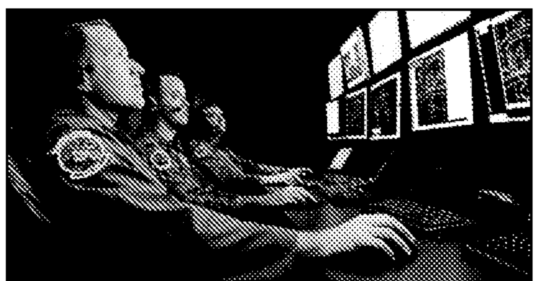
The Department's Core Competencies, expressed as Joint Capability Areas, establish the link between the operational perspectives of our Core Mission Areas and the Department's capabilities development processes. In practice, Joint Capability Areas translate current and future operational needs to capability priorities, and form the functional structure used to prioritize, assess, develop, and manage capabilities across all the Department's Components. In compliance with section 941 of the National Defense Authorization Act for 2008, the Department has defined nine Core Competencies:

1. **Force Application** – The ability to integrate the use of maneuver and engagement in all environments to create effects necessary to achieve mission objectives.

2. **Command and Control** – The ability to exercise authority and direction by a properly designated commander or decision maker over assigned and attached forces and resources in the accomplishment of the mission.

3. **Battlespace Awareness** – The ability to understand dispositions and intentions as well as the characteristics and conditions of the operational environment that bear on national and military decision-making.

4. **Net Centric** – The ability to provide a framework for full human and technical connectivity and interoperability that allows all Defense Department users and mission partners to share the information they need, when they need it, in a form they can understand and act on with confidence, and protects information from those who should not have it.

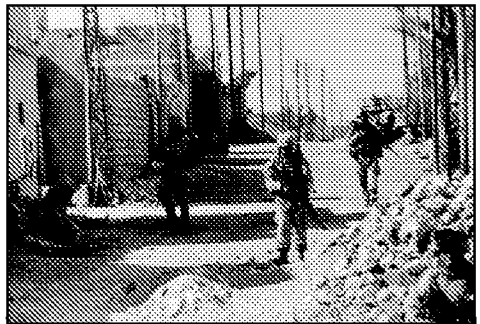


Electronic warfare officers monitor a simulated test in the Central Control Facility (CCF) at Eglin Air Force Base, Florida. The Air Force uses the CCF to oversee electronic warfare flight testing.

5. **Building Partnerships** – The ability to set the conditions for interaction with partner, competitor or adversary leaders, military forces, or relevant populations by developing and presenting information and conducting activities to affect their perceptions, will, behavior, and capabilities.

6. **Protection** – The ability to prevent/mitigate adverse effects of attacks on combatant and non-combatant personnel and physical assets of the United States, our allies, and friends.

7. **Logistics** – The ability to project and sustain a logistically-ready joint force through the deliberate sharing of national and multi-national resources to effectively support operations, extend operational reach, and provide joint force commanders the freedom of action necessary to meet mission objectives.



Marines with 1st Platoon, Echo Company, 2nd Battalion, 1st Marine Regiment conduct a security patrol in Husaybah, Iraq, during Operation Steel Curtain.

8. **Force Support** – The ability to establish, develop, maintain and manage a mission-ready Total Force, and provide, operate, and maintain capable installation assets across the Total Force to ensure needed capabilities are available to support national security.

9. **Corporate Management and Support** – The ability to provide strategic senior level, enterprise-wide leadership, direction, coordination, and oversight through a chief management officer function.

C. Integrating Core Mission Areas & Core Competencies into DOD Processes

As described in the 2006 QDR Report, the Department has expanded its use of integrated capability portfolios to balance risk and conduct strategic-level capability trade-offs. Accordingly, the Department has organized its governance structure for managing its capability portfolios around the nine Core Competencies/Joint Capability Areas. A pilot program started during the Fiscal Year 2009 budget process validated using JCAs as part of an integrated portfolio management framework. The current defense budget development cycle considered all nine JCAs, with specific program elements mapped to appropriate lead and supporting JCA portfolios. Additionally, the Department has assigned oversight responsibility for each of the JCAs to a Senate confirmed official paired with a senior military co-lead. The Core Competencies/Joint Capability Areas structure is now a significant part of the Department's requirements process. For example, the Joint Capability Integration Development System will direct all requirements documents to be associated with appropriate JCAs. As the Department fully integrates the Core Competencies/Joint Capability Areas structure, it will be able to better illustrate capability investments across the Department.

D. Functions of the Services and U.S. Special Operations Command

The QRM examined responsibilities assigned by U.S. Code and the Secretary of Defense to the Services and other Department Components. A major aspect of this assessment was a thorough review of Department of Defense Directive 5100.1, "Functions of the Department of Defense and Its Major Components." This document was modified to ensure functions are identified and assigned to appropriate organizations. These modifications stress the Department's continued emphasis on joint warfighting, and incorporate recent and emerging responsibilities in such areas as special operations and cyberspace operations.

IV. ROLES AND MISSIONS FOCUS AREAS

During the Quadrennial Roles and Missions Review, the Department of Defense assembled teams of experts to address specific roles and missions issues in the areas of Irregular Warfare; Cyberspace; Intratheater Airlift; and Unmanned Aircraft Systems / Intelligence, Surveillance, Reconnaissance.[1] The following sections capture the Department's common vision for each area and initiatives underway to increase synergy across the Department's Components; improve effectiveness of joint and interagency operations; and ensure the Department continues to efficiently invest our Nation's defense resources to meet the asymmetric challenges of the 21st Century.

A. Irregular Warfare

Executive Summary. The Department currently defines irregular warfare as a violent struggle among state and non-state actors for legitimacy and influence over the relevant populations. Irregular warfare favors indirect and asymmetric approaches, though it may employ the full range of military and other capabilities, in order to erode an adversary's power, influence, and will.[2] The Department continues to make steady progress toward incorporating irregular warfare into its force planning construct, influencing the size of the force and the capabilities needed to ensure the joint force is as effective in irregular warfare as it is in conventional warfare. Both the 2008 *National Defense Strategy* and the 2006 QDR codified this commitment to irregular warfare. The Department will continue to inculcate irregular warfare priorities into policy, doctrine, training, and education at all levels, while developing and sustaining a balanced investment strategy to field needed capabilities and capacity. General Purpose Forces (GPF) and Special Operations Forces (SOF) each have roles and responsibilities for irregular warfare missions, with the force composition mix depending largely on the risk and character of the operational environment. To support maturation of our national ability to conduct irregular warfare, the Department, in collaboration with other U.S. Government departments and agencies, will explore alternatives that promote interagency cooperation, and improve the efficiency, flexibility, and responsiveness of funding lines and legislative authorities.

The Department's vision is to shape the future joint force to be as effective in irregular warfare as it is in conventional warfare.

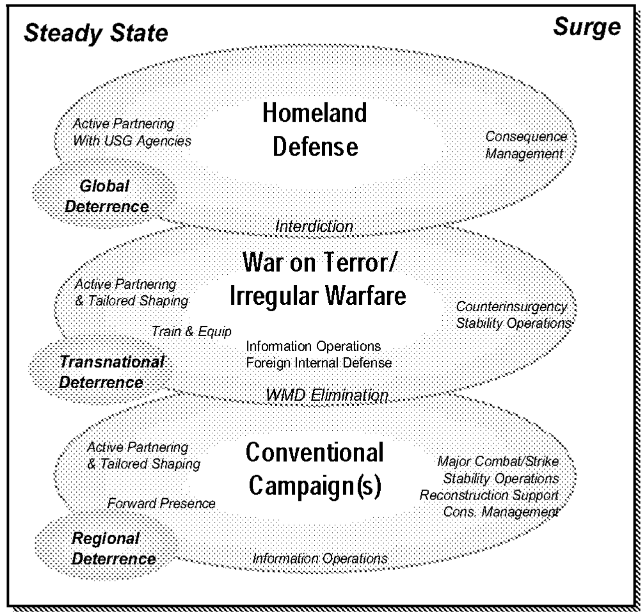
Irregular Warfare Challenges. Historically, the Department has focused its efforts on the ability to defeat a state adversary's conventional military forces. However, the 2006 QDR assessed that while conventional threats will remain and U.S. Armed Forces must maintain the capacity to defeat them, current and future adversaries are more likely to pose irregular and asymmetric threats. The Department therefore developed a force planning construct (Figure 2) that recognizes the need to maintain capabilities to defend the homeland and prevail in conventional campaigns while concurrently developing a mastery of irregular warfare comparable to that which our armed forces have achieved for conventional warfare. This

[1] The Defense Department's leadership and members of the 2008 U.S. House Armed Services Committee Roles and Missions Panel identified these areas as high interest.

[2] In this definition, the term "violent" refers to the nature of the conflict and is not necessarily the prescription for a U.S. response.

assumes added importance, especially during an era when the character of warfare is blurring and military forces are likely to engage adversaries who use hybrid warfare which simultaneously blends conventional and irregular methods. Given this likelihood, the Department must determine the most efficient and effective balance between homeland defense, irregular warfare, and conventional warfare priorities.

Figure 2: DoD Force Planning Construct



The primary irregular warfare activities addressed by this report – foreign internal defense, counterinsurgency, counter-terrorism, unconventional warfare, and stability operations – occur across the spectrum of irregular and conventional warfare operations. None of these activities are new to the Department of Defense. Many of the capabilities required to execute them are resident in some parts of the joint force, but may not exist in sufficient capacity to meet expected demand. In other cases, the Department needs to develop new capabilities, such as foreign language and cross-cultural communication skills, to address emerging and future challenges.

During the QRM, an Irregular Warfare Issue Team led by U.S. Special Operations Command and the Assistant Secretary of Defense for Special Operations/Low Intensity Conflict and Interdependent Capabilities addressed initiatives to improve effectiveness of joint operations and create opportunities for efficient investment of resources for irregular warfare. The team examined irregular warfare roles and missions across Special Operations Forces and General Purpose Forces; the balance of responsibilities across the Active and Reserve Components; identified mechanisms to further institutionalize irregular warfare across the Department; and how to better integrate defense capabilities with those of our interagency partners and allies.

Graduates of the first Ministry of Interior National Police Command Special Forces platoon perform a demonstration during their graduation ceremony at the Iraqi Police Academy in Kirkuk, Iraq. Irregular warfare increases demand for capabilities to organize, train, and equip foreign security forces.

Background. DOD has achieved some success in institutionalizing irregular warfare across the Department in recent years. The Department has established irregular warfare as one of its six Core Mission Areas, and completed a formal Irregular Warfare Joint Operating Concept describing how joint commanders might employ capabilities to meet future irregular warfare operational challenges. The Irregular Warfare Joint Operating Concept recognizes the protracted nature of irregular conflict and how it can occur in both steady-state and surge scenarios, just as partner capacity building can occur in both. At the component level, all Services and several Combatant Commanders have established irregular warfare-related training and education centers. The Office of the Secretary of Defense has initiatives underway to institutionalize irregular warfare in the joint force, working with the Services, Joint Staff and several interagency partners. The Department is currently conducting a study of irregular warfare-relevant requirements in the steady-state, as well as in counterinsurgency and unconventional warfare surge scenarios used for defense planning. Study results will allow the Department to identify and institute additional long-term changes to address irregular warfare capabilities and capacity priorities, resulting in a force that is better trained, equipped, and educated to handle the full range of missions across the spectrum of operations.

While these efforts reflect progress, the Department acknowledges it has more to do to achieve its irregular warfare vision. Gaps still exist in institutionalizing irregular warfare concepts and capabilities needed for future joint operations, and for operating in concert with our interagency partners. The Department will continue to develop a resource investment strategy that achieves the right balance of capabilities to meet future challenges across the spectrum of operations. While more remains to be done, institutional transformation requires time and appropriate resources. With the continued support of Congress, the Department will steadily improve critical irregular warfare capabilities to meet the challenges of a rapidly evolving security environment.

Vision: Responsibilities for Irregular Warfare and Continued Institutionalization. The Department's irregular warfare vision is to equip the joint force with capabilities, doctrine, organization, training, leadership, and operating concepts needed to make it as proficient in irregular warfare as it is in conventional warfare. The Defense Department's goals for the future joint force include two main elements:

1. A Department with increased and balanced capability and capacity to address all future security challenges, including irregular warfare; and

2. A Department that can better integrate with interagency partners to leverage all elements of national power to meet national security objectives.

A 7th Special Forces Group Soldier instructs his Colombian counterparts in urban-warfare techniques. DOD will continue to institutionalize irregular warfare capabilities in SOF and General Purpose Forces.

Decisions and Initiatives.

SOF and GPF Roles and Missions for Irregular Warfare. The Department reviewed the roles and missions for SOF and GPF and concluded each has significant responsibilities for irregular warfare. As a result, the Department is continuing to define how Services develop and apply capabilities in different environments. For example, U.S. Special Operations Command, acting as the Department's joint proponent for security force assistance, is collaborating with the Chairman of the Joint Chiefs of Staff, U.S. Joint Forces Command, Services, and Geographic Combatant Commanders to develop global joint sourcing solutions that recommend the most appropriate forces for validated security force assistance requirements.

- As noted in the 2006 QDR, General Purpose Forces will continue to support and play a leading role in stability operations and counterinsurgency, and a greater role in foreign internal defense. For steady-state operations, GPF will have an increased role in training, advising, and equipping foreign security forces, deploying and engaging with foreign partner security forces, supporting civil-military teams in stability operations, and conducting integrated irregular warfare operations with SOF. To do this effectively, General Purpose Forces will need a greater degree of language and cultural instruction to train and advise indigenous forces.

- The SOF and GPF force mix for conducting future operations will largely depend on the risk and character of the operational environment, not simply by the task at hand. For example, when operational environments dictate that the joint force presence remains unobtrusive, SOF will play a leading role. General Purpose Forces will continue to play a leading role in operational environments where a large-scale presence is warranted to provide security to a population.

Balancing Active and Reserve Components for Irregular Warfare. The global, protracted nature of irregular warfare will continue to place more demands on the Department's Active Component, Reserve Component, and civilian Total Force. To address this challenge, the QRM assessed the appropriate Active/Reserve Component balance to meet future irregular warfare-related operational demand. The Department concluded that persistent presence and sustainment of irregular warfare activities require increasing specific capabilities across the Total Force, including civil affairs and psychological operations capabilities in the Active Component force.

Key Mechanisms to Institutionalize Irregular Warfare.

- Oversight. The Department's Components have matured their understanding and execution of irregular warfare. While the Department assessed the need to designate a lead component for oversight of institutionalizing irregular warfare, we have determined it is more advantageous to use existing oversight structures and mechanisms for institutionalizing irregular warfare across the joint force rather than create new ones.

- Guidance. Despite gains achieved since the 2006 QDR, the Department has determined efforts to transform capabilities are not uniform across all of its elements. As a result, the Department has finalized a Directive that provides a policy framework and designates responsibilities for irregular warfare. This Directive will help lay the foundation for investments that will continue to build capabilities needed to balance near-term risk and long-term force development goals.

- Component Responsibilities. The Department is revising DOD Directive 5100.1, Functions of the Department of Defense and its Major Components, to incorporate irregular warfare responsibilities.

- Planning Construct. In order to further ingrain irregular warfare key elements into planning for the range of military operations, the Department will assess revisions to its current campaign planning construct[3] to account for complexities of the environment and incorporate irregular warfare concepts for influencing relevant populations.

Mechanisms to Integrate with Interagency Partners. Meeting challenges of current and future security environments requires the concerted effort of all instruments of U.S. national power. Achieving unity of effort within the U.S. Government is often complicated by organizational "stove-piping," crisis-driven planning, and divergent organizational processes and cultures. These differences have certain benefits, but are not well-suited for addressing the range of irregular challenges that cut across organizational expertise of different U.S. Government entities. Additionally, many interagency processes are oriented toward responding to crises, or surge scenarios, rather than supporting steady-state activities.

A soldier from the 502nd Infantry Regiment, 2nd Brigade Combat Team, 101st Airborne Division speaks with an Iraqi man while visiting a home for the elderly in Kadhimiya, Iraq. Earning the trust of the local population is critical to successful counter-insurgency operations.

Photo by Staff Sergeant Manuel J. Martinez, U.S. Air Force

- The Department will continue to promote and participate in efforts to institutionalize irregular warfare in interagency planning. Initiatives currently underway include development of the Interagency Management System for Reconstruction and Stabilization led by the Department of State Coordinator for Reconstruction and Stabilization, and the National Counter Terrorism Center's efforts to lead interagency steady-state and surge planning for the war on terrorism.

Looking Forward. While significant progress is being made today toward achieving the Department's vision for irregular warfare, there are still challenges to overcome. The Department must continue to address related issues with the interagency outlined in the "Interagency Opportunities" section of this report. With the continued support of Congress, the Department will achieve its objective of ensuring irregular warfare capabilities are firmly integrated into all aspects of the Department's future force.

[3] The Department's planning construct consists of six phases: Shape; Deter; Seize Initiative; Dominate; Stabilize; and Enable Civil Authority.

B. Cyberspace

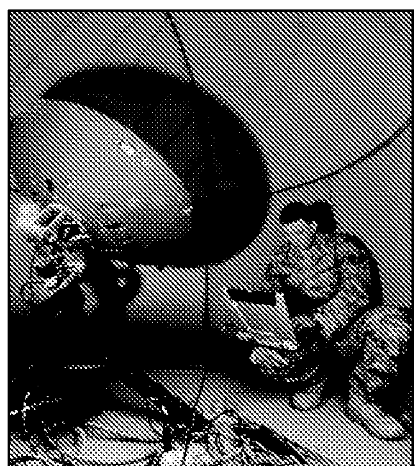
Executive Summary. Cyberspace is a decentralized domain characterized by increasing global connectivity, ubiquity, and mobility, where power can be wielded remotely, instantaneously, inexpensively, and anonymously. Amidst the rush of technological advancement, the Department seeks cyberspace capabilities that maintain our freedom of action and that of our allies and partners while ensuring superiority over potential adversaries in militarily-relevant portions of the domain. This environment presents enormous challenges and unprecedented opportunities to forces charged with defending national interests and advancing U.S. policy.

The Department's vision is to develop cyberspace capability that provides global situational awareness of cyberspace, U.S. freedom of action in cyberspace, the ability to provide warfighting effects within and through cyberspace, and, when called upon, provide cyberspace support to civil authorities.

The Department is continuing to transform to meet the challenges of this dynamic domain. As part of the 2009 QRM, the Department set out to define its roles, missions, and objectives in cyberspace through the year 2030. In particular, the 2009 QRM focused on the Department's roles and missions related to:

- Developing capable forces, equipped with requisite skills, training, education, and experience.
- Structuring forces and associated processes and procedures to effectively and efficiently execute Defense Department policies and priorities in cyberspace.
- Employing those forces to achieve desired effects across the full range of military operations.

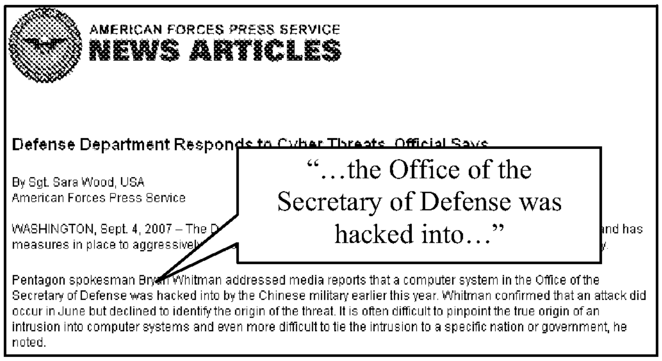
The Department has determined it is appropriate for each Service to develop capabilities to conduct cyberspace operations. Improvements are needed in training and education to field a professional force, and in command and control for cyberspace operations. Initiatives described in this report represent current Defense Department responsibilities and challenges in this evolving domain. More remains to be done before the Department is able to fully meet its vision. Accordingly, decisions and initiatives reported in this section should be considered as waypoints to chart the Department's progress toward achieving our cyberspace vision.



A U.S. Air Force network systems technician reacquires the Global Broadcast System, which is part of keeping an uninterrupted flow of information streaming to a Combined Air Operations Center.

U.S. Air Force photo by Staff Sergeant Christian Skyes, 36th SW

Cyberspace Challenges. Our national security is inextricably linked to the cyberspace domain, where conflict is not limited by geography or time. The expanding use of cyberspace places United States' interests at greater risk from cyber threats and vulnerabilities. Cyber actors can operate globally, within our own borders, and within the borders of our allies and adversaries. The complexity and amount of activity in this evolving domain make it difficult to detect, interdict, and attribute malicious activities.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Defense Department Respon

By Sgt. Sara Wood, USA
American Forces Press Service

WASHINGTON, Sept. 4, 2007 – The D … nd has measures in place to aggressive …

Pentagon spokesman Bry… Whitman addressed media reports that a computer system in the Office of the Secretary of Defense was hacked into by the Chinese military earlier this year. Whitman confirmed that an attack did occur in June but declined to identify the origin of the threat. It is often difficult to pinpoint the true origin of an intrusion into computer systems and even more difficult to tie the intrusion to a specific nation or government, he noted.

"…the Office of the Secretary of Defense was hacked into…"

Although cyberspace presents unique challenges to military operations, the Department has made significant progress in defining its roles, missions, and objectives in cyberspace. Additionally, cyberspace offers the U.S. military unprecedented opportunities to shape and control the battlespace to achieve national objectives. Because adversaries operate in the same shared environment, U.S. forces have the ability to use non-kinetic options with new levels of global reach and immediacy against a variety of targets.

Background. The Department has officially defined cyberspace as a global domain within the information environment consisting of the interdependent network of information technology infrastructures, including the Internet, telecommunications networks, computer systems, and embedded processors and controllers.

Experience from recent operations and global cyberspace incidents underscore the critical role cyberspace capabilities play in preventing conflict when possible, and supporting full-spectrum military operations when necessary. The Department has made significant progress in operations in support of Combatant Commands and in working cyberspace issues collaboratively within the U.S. Government. Interagency forums allow the Department to leverage authorities in an integrated fashion and to understand equities in the earliest stages of planning. These operations are governed by U.S. domestic and international law. Additionally, our understanding of threats to the Global Information Grid and the development of defensive measures has progressed.

The findings of the 2006 Quadrennial Defense Review and the 2006 *National Military Strategy for Cyberspace Operations* (NMS-CO) laid the groundwork for many areas where the Department has made significant progress on cyberspace challenges.

- The 2006 QDR highlighted the Department's ability to operate effectively in cyberspace as a critical facet of our long-term strategy. The QDR set out several imperatives for the Department, including: capabilities to locate, tag, and track terrorists in cyberspace; capabilities to shape and defend cyberspace; and the strengthening of coordination of defensive and offensive missions in cyberspace across the Department.

- The NMS-CO and associated Implementation Plan provide a comprehensive strategy for the U.S. military to achieve military superiority in cyberspace. Combatant Commanders, Military Departments, Defense Agencies, and other Department Components use the NMS-CO as a reference for planning, resourcing, and executing cyberspace operations.

Outside the Department, we continue to work with other U.S. Government departments and agencies to better delineate roles and missions and enhance the Nation's ability to protect and advance national security objectives both in cyberspace and using cyberspace tools. The Comprehensive National Cyber Security Initiative (CNCI) provides an important framework for U.S. Government cooperation and division of labor.

Vision. U.S. national power and security depend on our ability to access and use the global commons. As such, the Department seeks the ability to achieve superiority in military-relevant portions of cyberspace. In an environment characterized by uncertainty, complexity, rapid technological change, vulnerability, and minimal barriers to entry, the Department seeks strategic, operational, and tactical cyberspace capabilities that provide:

- U.S. freedom of action in cyberspace, to include freedom from unwanted intrusions and the ability to deny an adversary's freedom of action in cyberspace.
- Global situational awareness of cyberspace.
- The ability to provide warfighting effects within and through the cyberspace domain that are synergistic with effects within other domains.
- The ability, when called upon, to provide cyberspace support to civil authorities.

Decisions and Initiatives. During the QRM, a Cyber Issue Team co-led by the Office of the Under Secretary of Defense for Policy and U.S. Strategic Command addressed cyberspace issues related to developing, structuring, and employing the cyberspace force. To achieve the desired end states of our cyberspace vision, the Department has decided to pursue the following initiatives.

<u>Developing the Cyberspace Force</u>.

- The Department has decided to develop a professional cyberspace force able to influence and execute cyberspace operations with the same rigor and confidence as traditional Department operations in other domains.
- To mature this force, the Defense Department intends to learn from the new, innovative capabilities and experiences of our counterparts across the U.S. Government, in the private sector, and internationally.
- Internally, the Department is changing its Joint Professional Military Education curricula to include more classes and information on cyberspace to improve knowledge of this domain throughout the force and among civilian employees.
- For Computer Network Operations (CNO) specialists, the Department is increasing basic training capacity in the coming years. Our goal is to double the capacity of Department CNO training facilities to 1,000 students per year.

Employing the Cyberspace Force.

- Internally, the Department is establishing adaptable, agile, and responsive organizational structures and processes that ensure resource coherence, integration of core functions, and optimization of cyberspace capabilities, while preserving Services' ability to field tactical CNO elements into their force structure.

- Externally, the Department will continue its robust cooperation with a broad range of cyberspace stakeholders. Consistent with the objectives of preserving U.S. freedom of action in cyberspace and denying an adversary's freedom of action in the domain, the Department seeks to build stronger partnerships with Congress, Federal Government departments and agencies, alliance and coalition partners, industry, academia, and other non-government organizations. Greater integration of cyber policies, operations and activities into exercises, discussions with allies and partners, within the U.S. Government and with industry is necessary to better understand the requirements and effects of military operations in this domain. The Department has much to build on within the framework of the CNCI and from ongoing international efforts.

Partnerships are a vital component to successful cyberspace operations.

Developing Cyberspace Capabilities.

- The Department has determined its acquisition processes for cyberspace capabilities should be more responsive to warfighter requirements. While we have continuously sought to increase capabilities and capacity for achieving effects in and through cyberspace, we will continue to seek new ideas through diverse venues and forums, including combatant commander senior warfighting forums and experimentation, to define future opportunities and develop creative solutions for warfighters' needs.

Looking Forward. In a cyberspace environment of constant change, the Department must continually review its posture. It is clear we cannot accomplish all we desire in this evolving domain without significant assistance from a broad range of partners from academia, industry, and other governments. Collectively, with the support of Congress, the Department will:

- Continually assess emerging threats and existing vulnerabilities.

- Exercise our abilities to anticipate, predict, prevent and respond to cyberspace attacks.

- Build capacity and capability to take advantage of the opportunities and limit challenges inherent to cyberspace.

- Organize ourselves, within the U.S. Government, to defend national interests and advance national policy through cyberspace.

Thanks to a strong basis for private sector, interagency and international cooperation, the Department's roles and missions in cyberspace will continue to mature. As the U.S., our alliance and coalition partners, and our adversaries learn to employ these capabilities in all phases of collaboration, cooperation, and conflict, we anticipate that the demand for effects in and through cyberspace will grow. This will require corresponding growth of the technical Defense Department workforce, expansion of our scientific and technological capabilities, and potential shifts in our traditional culture. Our approach to cyberspace must remain flexible as our understanding of the domain continues to mature, and as U.S., alliance, coalition partners, and adversary capabilities to operate in cyberspace increase. The Department remains steadfast in our commitment to achieve superiority in the military-relevant portions of cyberspace.

Department of Defense photo by R. D. Ward

Estonian Minister of Defense Jaak Aaviksoo, left, talks about how he views the threat of cyber terrorism during discussions with Secretary of Defense Robert M. Gates in the Pentagon.

C. Intratheater Airlift

Executive Summary. The 2009 QRM assessed alignment of Service responsibilities for conducting intratheater airlift operations. Airlift operations performed within a theater span the traditional division between "general support," which is normally provided for the joint force by an Air Force component commander through a common-user airlift service, and "direct support" conducted by all Service component commanders employing their Services' organic airlift assets. At the conclusion of the QRM, the Department determined Service responsibilities for intratheater airlift operations are appropriately aligned, and the option that provided the most value to the joint force was to assign the C-27J to both the Air Force and Army. However, based on lessons learned from recent operations, there are areas for improvement. By changing internal policy, updating doctrine, and maturing concepts of operations to better reflect our intratheater airlift vision, we will improve effectiveness, increase joint synergy and minimize duplication of effort for this mission

The Department's vision is to provide both general and direct support intratheater airlift by maximizing the use of aircraft that have significant multi-use capabilities and are able to alternate between these missions.

Intratheater Airlift Challenges. Responsibilities for the intratheater airlift mission have evolved over time to respond to the changing operating environment and fielding of enhanced capabilities. Most recently, lessons learned from airlift support to Operations Iraqi Freedom (OIF) and Enduring Freedom (OEF) have reshaped our intratheater airlift vision. During the QRM, an Intratheater Airlift Issue Team co-led by the Office of the Under Secretary for Acquisition, Technology, and Logistics, and U.S. Transportation Command addressed all fixed-wing airlifters with significant theater capabilities, including the C-27J Joint Cargo Aircraft being acquired by the Air Force and Army through a joint program.[4] The team's objective was to identify potential changes to responsibilities, policies, doctrine, and concepts of operation to improve effectiveness, address current and future challenges, increase joint synergy, and minimize duplication of effort between the Services for the intratheater airlift mission.

U.S. Air Force photo by Staff Sgt. Ricky A. Bloom

Airmen finish signing forms after conducting a preflight inspection on a C-5 at Balad Air Base, Iraq. Strategic airlift aircraft effectively support intratheater movements for OIF and OEF.

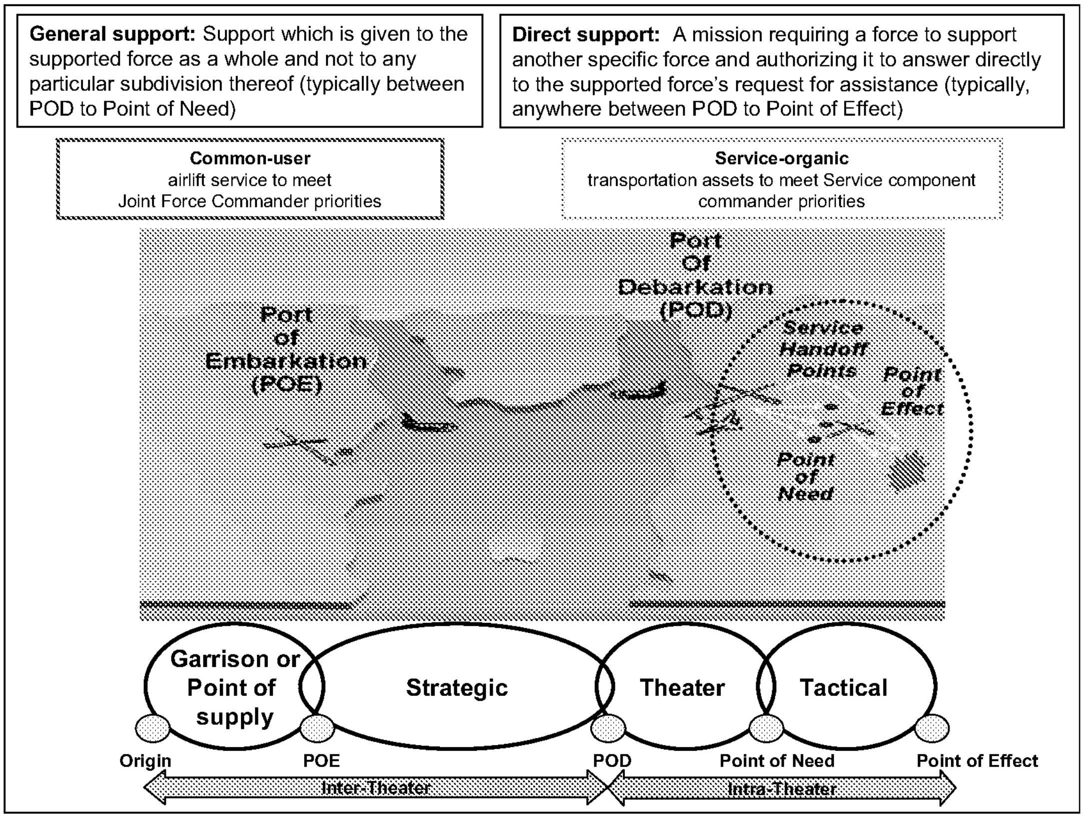
Background.

General and Direct Support Airlift. Intratheater airlift operations span the traditional division between general support, normally provided by an Air Force component commander using a

[4] The QRM assessed intratheater airlift operations conducted under Title 10, including Reserve Component forces operating as gained Title 10 forces. Traditional missions that are clearly organic to a Service component were not addressed (i.e., helicopter or small fixed-wing aircraft operations in direct support of a Service component in a "combat zone").

centrally-managed common-user airlift service, and direct support conducted by Service component commanders usually using Service component organic airlift transportation assets (see Figure 3).

Figure 3: General Support and Direct Support Airlift



Evolution of Airlift Responsibilities. The Army and Air Force first reached agreement on airlift responsibilities in the early 1950s. A series of memoranda removed restrictions on Army helicopter development and allowed the Army to conduct air operations for transport of Army supplies, equipment, and small units within the combat zone. In 1966, the Army and Air Force agreed the Army should fully develop helicopter capabilities, but barred the Service from major fixed-wing airlift roles. In 1986, another Army-Air Force agreement identified the Army as the executive Service for aircraft in units organic to the land force and employed within the land component's area of operations. The Air Force continued as the executive Service for aircraft that are most effective when organized under centralized control for theater-wide employment. Today, Service responsibilities for intratheater airlift missions generally remain aligned along the tenets of the 1986 agreement, as reaffirmed by an Army and Air Force Joint Cargo Aircraft Memorandum of Agreement signed in 2006.

OIF and OEF Observations. Recent operations in OIF and OEF highlighted three airlift issues of relevance to the QRM:

- The operational agility achieved by using airlift aircraft that alternate between intertheater and intratheater missions is a true transformation in airlift employment concepts. This flexibility is achieved by improving the visibility of requirements and exploiting previously untapped capacity gained through arrangements with U.S. Transportation Command to support theater airlift operations as needed. This new, combat-tested approach is a model for improving intratheater airlift across the full range of general and direct support operations.

- Increasing distances in a more dispersed and non-contiguous operational environment challenge our ability to supply distributed forces. While this evolving operational environment challenges the capabilities of helicopters to provide direct support to ground forces, the need for direct support remains unchanged. As a result, the Department has determined it must look for new ways to employ time sensitive/mission critical airlift in theater.

- Starting with U.S. Central Command in 2004, the Department has been integrating a Joint Deployment Distribution Operations Center (JDDOC) into every Combatant Command's operating structure to coordinate and synchronize logistical movements and ensure greater effectiveness and efficiency of intratheater airlift operations. A success story from the U.S. Central Command's JDDOC is the ability to meld commercially contracted intratheater airlift options into the mix of airlift capabilities. Commercial contracts/tenders offer a flexible means to quickly expand and reduce capacity to meet the ebb and flow of movement requirements in theater. Commercial contract and tender options range from short-takeoff and landing aircraft for moving small loads and servicing outlying airfields, to large transport aircraft moving palletized cargo and rolling stock. In collaboration with the Air Force, the U.S. Central Command's JDDOC provides the means to manage airlift requirements and funnel demand to military or commercial lift providers based on expected capacity.[5]

Vision for Future Intratheater Airlift Operations. Future joint operations will continue to require robust general and direct support intratheater airlift. The Air Force, through a common-user airlift service, will provide intratheater general support, while each Service will provide its own direct support using their "organic" transportation assets. The evolving operational environment, characterized by increasingly distributed operations and longer lines of communication, requires a suitable fixed-wing aircraft for intratheater airlift roles traditionally performed by helicopters. Mission-capable fixed-wing aircraft in a direct support role will complement other airlift assets and allow the entire intratheater airlift fleet to be employed more efficiently. Conducting simultaneous general and direct support missions using a fleet of cross-Service airlift capabilities will

The first Joint Cargo Aircraft was presented to the U.S. Army on September 25, 2008. The C-27J offers significant utility to provide both general and direct support to warfighters.

[5] USTRANSCOM provides the contracting oversight for commercial contracts/tenders to ensure compliance with contracting requirements.

take full advantage of aircraft with significant multi-use capabilities. Some fixed-wing direct support aircraft, like the C-23B Sherpa, have limited payload and range and cannot support common-user airlift operations theater-wide. The C-27J, which is replacing the C-23B, has significantly greater capability and will be employed to maximize the overall utility for the joint force in either role.

Decisions and Initiatives. The QRM Intratheater Airlift assessment determined that Service responsibilities for intratheater airlift capabilities are appropriately aligned. However, there are opportunities to improve effectiveness, increase joint synergy and minimize duplication of effort between the Services for this evolving mission.

<u>Supporting Time Sensitive/Mission Critical (TS/MC) Movement Requirements</u>. The Department has determined theater TS/MC movement requirements will continue to drive a need for Service-organic aircraft to conduct direct support missions. These requirements reflect supported commanders' immediate priorities for delivery of equipment, supplies, and personnel. In support of the QRM, the intratheater airlift issue team created a definition of TS/MC movement requirements (see Glossary) that states dedicated airlift capacity must be available and extremely responsive to meet supported commanders' immediate operational or tactical priorities.

- Accordingly, the Department concludes joint force commander direct support airlift requirements for a theater of operations cannot be routinely satisfied through a common-user airlift service.

<u>Maximizing Use of Today's Airlift Assets</u>. The Department evaluated four options for how intratheater airlift responsibilities could be assigned to the Services. These options ranged from assigning all significant fixed-wing airlift (such as the C-27J) to the Air Force for both general and direct support, to the Army employing all Joint Cargo Aircraft exclusively in direct support of Army forces.

- The Department found the option that provided the most value to the joint force was to assign the C-27J to the Air Force and Army. This will allow all C-27J aircraft to conduct operations identified in the Joint Cargo Aircraft Concept of Operations, with the ability to alternate between either role, regardless of Service alignment, similar to how strategic airlift aircraft alternate from intertheater to intratheater airlift.[6] A challenge to this approach is a need to gain requirement visibility and access to available/allocated airlift capacity.

<u>Increasing Visibility of Airlift Requirements and Capacity</u>. U.S. Transportation Command recently conducted an assessment of organizational options for Operational Support Airlift aircraft, which normally perform organic direct support missions.

- An assessment recommendation accepted by the Department is to employ the Joint Airlift Logistics Information System – Next Generation across all Geographic Combatant

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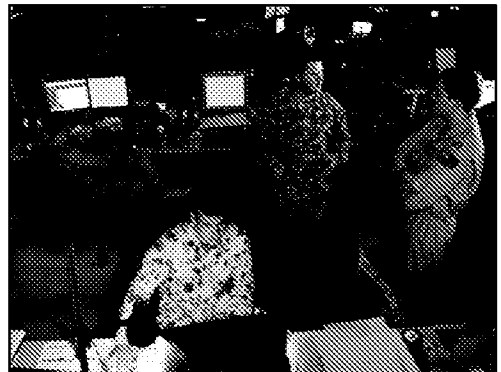
[6] The Joint Cargo Aircraft Concept of Operations specifies the Air Force provides a common-user pool, while the Army provides Time Sensitive/Mission Critical direct support to Army forces.

Command theaters to standardize the airlift process and gain visibility over direct support requirements and available capacity. Shared visibility and joint oversight maximizes potential use of airlift assets while ensuring they remain under Service component control to meet TS/MC movement needs. Although this effort focuses on improving visibility of Operational Support Airlift operations, expanding it to increase the enterprise-wide visibility of *all* airlift requirements and operations is the Department's desired objective.

<u>Common Deployment and Distribution Control Mechanisms</u>. The Department recognizes the need for improving mechanisms to control deployment and distribution operations at the theater level to maximize airlift potential.

- To meet this need, U.S. Transportation Command, in conjunction with the Services and Geographic Combatant Commanders, is pursuing common supporting capabilities to enhance airlift aircraft employment and data visibility as part of a joint, integrated enterprise. One successful initiative is implementation of the Joint Deployment Distribution Operations Centers within Geographic Combatant Command structures to better integrate and optimize distribution operations.



Operations centers, such as this one in Qatar, enable the flexible use of airlift aircraft to alternate between mission areas. The USCENTCOM Joint Deployment Distribution Operations Center in Kuwait has significantly improved the ability to effectively and efficiently coordinate movement operations.

U.S. Air Force photo by SrA Brian Ferguson

<u>Updating the Joint Cargo Aircraft Concept of Operations</u>. As a result of the QRM, the Air Force, Army, and U.S. Transportation Command are updating the Joint Cargo Aircraft Concept of Operations and revising the Services' Joint Cargo Aircraft Memorandum of Agreement to fully embrace multi-use of the C-27J across traditional Service employment roles. Specifically, the Air Force will make necessary adjustments to ensure the Air Force C-27J can conduct Army direct support missions when requested, and the Army will make certain its C-27J variant can be fully integrated into a common-user airlift system when available/allocated.

<u>Adapting Airlift Policy and Doctrine</u>. Finally, the Department will take action to ensure its airlift vision and need to maximize the utility of intratheater airlift aircraft, including contracted airlift, is addressed through changes to policy and doctrine, including Department of Defense Instruction 4500.43 (*Operational Support Airlift);* Joint Publication 3-17 (*Joint Doctrine and Joint Tactics, Techniques, and Procedures for Air Mobility Operations);* and Joint Publication 3-30 (*Command and Control for Joint Air Operations).*

Looking Forward. The 21st Century operational environment demands responsive theater airlift capabilities. The ability to provide a balanced application of airlift across the theater is the key to operational flexibility. Developing common capabilities and processes for sharing movement requirements and accessing airlift capacity provides the means to optimize scarce intratheater airlift assets, and will be a focus in the future. Continuing to bridge traditional boundaries for airlift general support and direct support requires sustaining the ongoing partnership between the Services and Geographic Combatant Commanders, and the support of Congress, to enhance joint operations and maximize warfighter support.

D. Unmanned Aircraft Systems / Intelligence, Surveillance, Reconnaissance

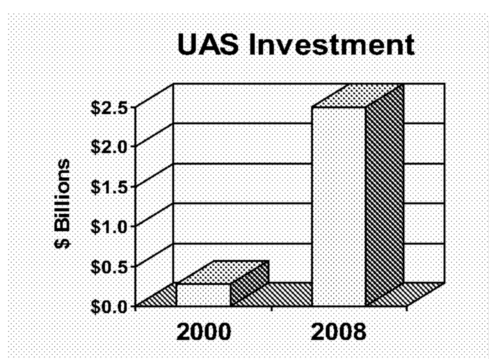
Executive Summary. Persistent reconnaissance and surveillance capabilities provided by Unmanned Aircraft Systems (UAS) have proven invaluable force multipliers in Iraq and Afghanistan. Consequently, the Department has experienced a dramatic increase in operational demand for UAS assets. In response, the Department has significantly increased investment in new Unmanned Aircraft Systems / Intelligence, Surveillance, and Reconnaissance (ISR) platforms, sensors, payloads and architectures. Concurrent with growing demand for UAS/ISR systems, the rapidly evolving operational battlespace has led to new and emerging mission sets which present challenges and opportunities for developing, acquiring, and employing UAS/ISR capabilities.

The Department's vision is to integrate UAS/ISR capabilities seamlessly into the Intelligence Enterprise in support of warfighters and the nation.

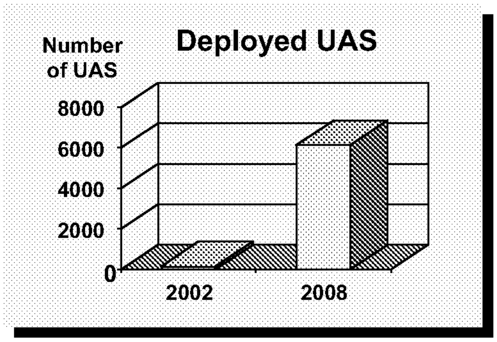
The Department has determined it is appropriate for each Service to develop, acquire, and operate unmanned aircraft systems, while developing and implementing improvements to increase jointness and interoperability of UAS/ISR capabilities. During the QRM, a UAS/ISR issue team, co-led by the Under Secretary of Defense for Intelligence and U.S. Strategic Command, developed steps to address challenges associated with UAS/ISR planning and direction; Tasking, Processing, Exploitation, and Dissemination (TPED); data standards and interoperability; communications architecture; and airspace access. These initiatives, which address improvements in oversight, integration, and interoperability of UAS/ISR capabilities, will collectively achieve significant increases in the Department's warfighting effectiveness.

An Army infantryman with 82nd Airborne Division at Fort Bragg NC prepares to launch a RQ-11 Raven UAS into the air. The Raven is a Group 1 UAS (see Glossary for UAS category description). UAS are employed at all echelons of command to meet reconnaissance, surveillance, and target acquisition needs.

UAS/ISR Challenges. Warfighter demand for UAS/ISR capabilities has increased exponentially over the past several years, due in large part to the unique operational needs of ongoing irregular warfare operations in Iraq and Afghanistan. These operations often require General Purpose Forces and Special Operations Forces operating in tandem to find and track mobile, elusive and fleeting targets, rather than traditional imaging of fixed, structural targets. Given their ability to provide a persistent aerial reconnaissance and surveillance capability against these highly perishable targets, UAS are increasingly tasked to support irregular warfare missions. UAS have surpassed 500,000 flight hours supporting operations in Iraq and Afghanistan alone. The



Growth in UAS Investment



Growth in UAS Deployments

significant increase in demand for UAS/ISR capabilities is also driven by our military's ability and need to engage targets with high precision around the globe. The Department continues to progress toward meeting increased demand for UAS/ISR capabilities. For example, the number of deployed UAS has increased from approximately 167 aircraft in 2002 to over 6,000 in 2008, while defense investment in UAS capabilities has dramatically grown from $284 million in Fiscal Year 2000 to $2.5 billion in Fiscal Year 2008. While it is clear warfighters understand the essential capabilities UAS deliver to the fight, it is also clear that new missions and future applications present long-term challenges and opportunities for the development, acquisition and employment of these critical systems.

UAS/ISR Vision. The future vision for UAS/ISR capabilities is in concert with the 2008 *Defense Intelligence Strategy*, which calls for a fully and seamlessly integrated Intelligence Enterprise. To achieve this vision, UAS/ISR capabilities must be developed, acquired, and operated in a manner which allows full integration of collected intelligence from the tactical to national levels. The Department will continue to provide direction and advocacy to coordinate UAS/ISR development and acquisition across the Services, Combat Support Agencies, Combatant Commands, and our interagency partners. Future UAS/ISR capability enhancements will focus on increasing aircraft performance and improving communications, data links, and weapon and sensor payloads.

Decisions and Initiatives. The Department has determined the following initiatives hold the most potential for significantly enhancing warfighting effectiveness and avoiding unnecessary duplication of effort.

Planning and Direction for ISR Support to Warfighters. The Defense Department has well-established processes for determining joint force priorities. However, the highly dynamic environment of current operations in Afghanistan and Iraq, along with other new and emerging requirements, have stressed our ability to plan for and provide sufficient UAS/ISR capabilities. Recognizing this, the Department has developed new, more responsive oversight, guidance development, and planning structures and processes. These changes will help the Department better define joint UAS/ISR priorities and integrate multi-mission capable UAS/ISR collection, processing, exploitation, analyses and dissemination activities.

An RQ-8A Fire Scout (Group 4 UAS) Vertical Takeoff and Landing Tactical Unmanned Aerial Vehicle (VTUAV) System prepares to land aboard the amphibious transport dock ship USS Nashville (LPD 13).

- In concert with the Department's Joint Capability Integration and Development System, the Battlespace Awareness Capability Portfolio Management process identifies and mitigates ISR capability gaps. Leveraging these processes, the Under Secretary of Defense for Intelligence and U.S. Strategic Command, as the warfighters' ISR proponents, work together to champion resources needed to meet Combatant Commanders' UAS/ISR priorities.

- The Deputy Secretary of Defense has directed the Undersecretary of Defense for Acquisition, Technology and Logistics to lead a UAS Task Force to develop initiatives that will enhance operations, enable interdependencies across the Department's Components, and streamline UAS acquisition. Additionally, the Department chartered the U.S. Joint Forces Command Joint UAS Center of Excellence to support Combatant Commanders and Military Departments by facilitating development and integration of common UAS operating standards, capabilities, doctrine and training.

A fully armed MQ-9 Reaper (Group 5 UAS) taxis before a mission in Afghanistan. The MQ-9 Reaper provides persistent surveillance and target engagement capabilities to warfighters in Iraq and Afghanistan.

U.S. Air Force photo by Staff Sergeant Brian Ferguson

- A Department of Defense ISR Task Force is focused on leveraging all elements of the Intelligence Community to rapidly acquire and deploy ISR assets in support of U.S. Special Operations Command and U.S. Central Command operations in Iraq and Afghanistan. The ISR Task Force is integrating ISR and strike capabilities while working toward mainstreaming and institutionalizing UAS/ISR related processes in the Department's Planning, Programming, Budgeting, and Execution cycle.

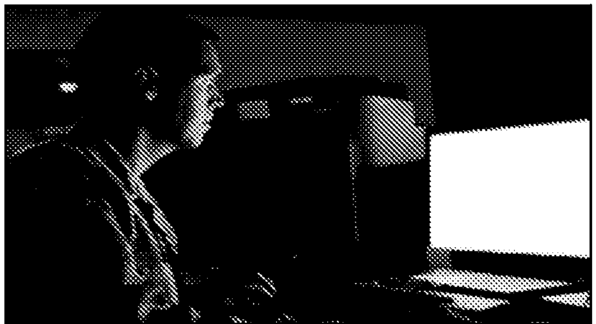
- U.S. Strategic Command is leading efforts to develop an ISR Force Sizing Construct for the Department. This initiative will develop a sound analytical foundation for future ISR allocation and procurement decisions.

- The Department has completed a Persistent ISR Joint Capabilities Document which identifies needed improvements to provide joint force commanders with more effective capabilities. The two highest priority capability gaps identified are attaining broad visibility and traceability throughout the intelligence collection, analysis, and distribution process, and improving multi-intelligence collection strategies in support of joint force commanders.

- In October 2007, the Department took a major step toward improving the Defense ISR Operations Enterprise by integrating functions performed by U.S. Strategic Command's Joint Functional Component Command for ISR and the Defense Joint Intelligence Operations Center to form the Defense Intelligence Operations Coordination Center (DIOCC). The DIOCC is responsible for validating, recommending priorities, and registering defense intelligence collection requirements, including UAS/ISR requirements, with the Intelligence Community. As the DIOCC continues to mature, its alignment with the National Intelligence Coordination Center will improve their rapid synchronization and timely operational support to Combatant Commanders.

Tasking, Processing, Exploitation, and Dissemination (TPED). TPED comprises the people, processes, and systems that transform collected data into operationally executable intelligence.

TPED enables warfighters to request collection and intelligence products tailored to meet their operational needs. TPED is vital to the effectiveness of any ISR system, and TPED implications must be considered when planning UAS acquisition and employment. Currently, requirements for UAS-derived actionable intelligence outpace TPED capacity, and future projections suggest this mismatch will continue temporarily. Over time, multiple TPED processes have been created to support UAS operations. Furthermore, the breadth of current and emerging UAS/ISR missions have caused TPED processes and systems associated with each intelligence discipline (signals, imaging, etc.) to differ across the Services, Combat Support Agencies, and from national to tactical assets and applications. As a result, the Department's ability to accurately define TPED mission needs has not kept pace with the rapid development and employment of UAS/ISR capabilities. Accordingly:



An imagery analyst at Langley Air Force Base, Virginia reviews previous damage assessments from Hurricane Katrina between contingency taskings from U.S. Central Command. Reach-back exploitation analysts provide tailored intelligence products to customers including SOF and domestic disaster relief agencies.

U.S. Air Force photo by Master Sergeant Steve [illegible]

- The Department is leading a comprehensive effort to redefine TPED in order to enable Services and Combat Support Agencies to develop and operate the various TPED systems using common standards and rule sets. The Joint Staff, as part of the ISR Task Force, is addressing TPED issues and concerns across the Services, including capacity, manpower, storage requirements, technology, and exploitation/dissemination timeliness. The U.S. Joint Forces Command Joint UAS Center of Excellence will work with the Joint Staff and the Office of the Under Secretary of Defense for Intelligence to review UAS TPED-related tasks to establish basic training qualifications, standards, and objectives. Ultimately, the Department will establish a community-wide definition of TPED to support development of concept of operations, joint doctrine, and capability requirements documentation.

- The Under Secretary of Defense for Intelligence, in coordination with the Services, is sponsoring an annual Empire Challenge capability demonstration that provides a venue for UAS, ground station and TPED interoperability assessment. Empire Challenge provides a key opportunity to identify and correct interoperability issues uncovered during this month long series of test events.

<u>Data Standards and Platform Interoperability</u>. As Services and Defense Agencies develop UAS/ISR capabilities, collected data formats and transmission protocols must be standardized to ensure UAS/ISR platforms become truly interoperable with joint and service TPED architectures. Effective sensor data and metadata formats and standards will promote interoperability between the databases and ground stations—such as the Distributed Common Ground System—used by Combat Support Agencies, Services, Intelligence Community, and interagency partners. These systems are crucial to sharing data from national to tactical levels of operation.

- The Under Secretary of Defense for Acquisition, Technology, and Logistics, in concert with the Joint Chiefs of Staff, is developing a joint acquisition approach to satisfy warfighter requirements. This approach will capture the benefits of standardized platforms, communications and logistics.

- The Under Secretary of Defense for Intelligence, in conjunction with the Joint Chiefs of Staff and UAS Task Force, is addressing the need for a Joint Capabilities Document for UAS Interoperability to resolve UAS/ISR interoperability issues. This document will create the foundation that will lead to identification of information and communications architectures, sensor data and interoperability standards and provide a link to a Joint UAS Concept of Operations.

Airmen prepare to land an MQ-1 Predator (Group 4 UAS) at Ali AB Iraq. UAS/ISR operations rely upon robust communications architectures for command, control, and data dissemination.

U.S. Air Force photo by Airman 1st Class Christopher Griffin

Communications Architecture. UAS/ISR relies heavily on communications to command and control aircraft and sensors for disseminating collected data. As the number of deployed UAS increase, more communication links, bandwidth and spectrum, and protected communications paths are required. Meeting the resultant frequency spectrum demand is a significant challenge. Furthermore, to meet increased warfighter demands for ISR support, the Services have developed methods for employing UAS tailored to their individual operating environments. However, one Service's methods may not be consistent with other Service or joint communications architectures. While Service-specific methods have delivered capability to warfighters, a more comprehensive approach will ensure communication demands are better managed to improve interoperability and cross-Service support, especially when satellite support is constrained or not possible. Accordingly:

- The UAS Task Force has identified the need to: (1) ensure effective spectrum planning and guidelines are incorporated into all UAS development efforts; and (2) Service and joint oversight verify compliance with these guidelines.

- The Department is expanding its Airborne Intelligence Surveillance and Reconnaissance Model to include all those entities requiring connection to the communications architecture. This change will better enable the Department to model and plan for dynamic communications architecture requirements.

Airspace Access for Operational and Training Missions. Combat effectiveness of our joint warfighters requires UAS to operate safely, efficiently, and have readily-available access to the National Airspace System. By 2013, the Services estimate they will require over one million flight hours for UAS operational and training missions. Due to high mission demands and limited restricted airspace availability, the majority of UAS flight hours will be accomplished outside of restricted airspace. Accordingly, the Department is seeking to better define technological, procedural, and standardized training qualifications to ensure UAS have access to appropriate classes of airspace to fulfill Service and national needs. This effort will require a concerted approach by the Department working alongside federal, state and civilian organizations. In support of this objective:

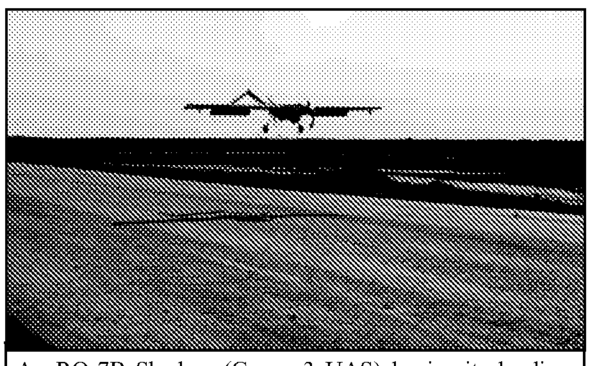
- The UAS Task Force is developing an 18 month plan that focuses on alleviating flight restrictions for all classes of UAS and supports near-term Service operational and training requirements in the National Airspace System.

An RQ-4 Global Hawk (Group 5 UAS) unmanned aerial vehicle is towed back to its hangar following a mission at a deployed location in Southwest Asia. The Global Hawk requires access to all classes of airspace for the conduct of operational and training missions.

- U.S. Joint Forces Command Joint UAS Center of Excellence is leading a coordinated review of current and future Department UAS airspace access requirements for all classes of UAS, and leading a Service review to develop a minimum set of UAS pilot/operator qualification requirements and/or standards to operate in the National Airspace System.

- U.S. Joint Forces Command Joint UAS Center of Excellence has identified three areas necessary to ensure access to applicable classes of the National Airspace System: (1) Airworthiness Certification; (2) establishment of standardized basic UAS qualifications consistent with Federal Aviation Administration guidelines for each class of airspace; and (3) development of sense and avoid technology. Working with the Services, the U.S. Joint Forces Command Joint UAS Center of Excellence will ensure these areas are addressed during UAS development.

Looking Forward. Capabilities provided by UAS are essential to today's warfighters. With newly emerging UAS missions and still-maturing ISR applications, the Department is aggressively pursuing opportunities to improve development, acquisition and employment of UAS. The Department's vision of seamlessly integrating UAS/ISR capabilities into the Intelligence Enterprise requires developing interagency and Congressional partnerships to increase airspace access and improve communications connectivity around the globe. Additionally, the Defense Department must better integrate its capabilities with growing UAS efforts of other federal agencies and partner nations. With the support of the Congress, the Department will continue to appropriately resource UAS platforms and associated TPED support to meet growing warfighter demand for ISR capabilities.



An RQ-7B Shadow (Group 3 UAS) begins its landing sequence following a flight to provide troops operating in Iraq with another set of eyes. Shadows are employed by the Marine Corps and Army.

V. The Road Ahead: Interagency Opportunities

Today's complex security environment places increased demands on the capabilities and resources of departments and agencies across the U.S. Government. Individually, departments and agencies are not as effective as when we unify our actions toward achieving a common vision. The Department strongly supports initiatives to increase unity of effort across the government for addressing our common national security problems. While significant progress toward this end has been made over the past five years, continued improvement requires a sustained focus on developing whole-of-government strategies and plans, as well as addressing operational seams between military and civilian agencies. During the QRM, the Department explored interagency issues and problems associated with key national security challenges, including cooperative security, stability operations, irregular warfare, and homeland defense and civil support. While these activities are core mission areas for the Department, they require substantial military and civilian interaction. QRM results affirm our need to continue to strongly support initiatives to build a cohesive, whole-of-government approach to our Nation's enduring security challenges.

The Department's vision is to support maturation of whole-of-government approaches to national security problems. Solutions to address strategic and operational security challenges will be based on employing integrated flexible, mutually-supporting interagency capabilities.

Vision. The Department supports institutionalizing whole-of-government approaches to addressing national security challenges. The desired end state is for U.S. Government national security partners to develop plans and conduct operations from a shared perspective. Toward this end, the Department will continue to work with its interagency partners to plan, organize, train, and employ integrated, mutually-supporting capabilities to achieve unified action at home and abroad.

An Afghan engineer talks with a member of the Nangarhar Provincial Reconstruction Team at a metal working shop in the Nangarhar province of Afghanistan. The team assesses community needs and builds schools, government centers, roads, medical facilities and basic infrastructure throughout the area.

Photo by: Staff Sergeant Joshua T. Jasper, U.S. Air Force

- An essential element of this vision is establishing a coherent framework for developing whole-of-government approaches for addressing national security challenges. A framework that includes commonly understood strategic concepts, operational principles, relationships between agencies, and roles and responsibilities would help delineate how to best coordinate and synchronize efforts as well as transition between military-led and civilian-led activities during operations.

- As proposed by the 2006 QDR, whole-of-government national security planning would be facilitated by publishing an authoritative national-level strategic guidance document that addresses interagency roles and responsibilities, resolves seam issues between agencies, and establishes priorities for planning and development of each organization's capabilities.

- Perhaps the most important critical element of this vision is the human dimension – developing a federal workforce trained and educated in a manner that fosters mutual understanding across agencies, expands knowledge of other agencies' roles and missions, and increases opportunities for building relationships across the Federal Government as well as with state and local governments.

Initiatives. As summarized throughout this report, the Department is pursuing initiatives to address our internal roles and missions issues. However, QRM results also reinforce the need for the Department to continue to work with our national security partners on complex roles and missions seam issues. To advance whole-of-government solutions, the Department strongly supports the following initiatives.

<u>Strategic and Operational Planning</u>. Several ongoing initiatives will improve how the interagency conducts national level planning.

- The Department of Defense and Department of State, in coordination with other agencies, are building an interagency planning framework to provide a prevention, response, and contingency capability to address foreign states at risk or in the process of instability, collapse, or post-conflict recovery.
    - This initiative to develop a whole-of-government planning approach and supporting tools are the result of National Security Presidential Directive 44 (and is now authorized under Title XVI of the 2009 National Defense Authorization Act). Led by the Department of State's Coordinator for Reconstruction and Stabilization, this planning framework is supported by the Interagency Management System (IMS), which provides a structure for civilian planning and implementation of reconstruction and stabilization activities at the strategic, operational, and tactical level. The IMS structure is also built to interface and integrate with existing military organizations when necessary. The capacity for the IMS is provided by the Department of State's as yet fully implemented or funded Civilian Stabilization Initiative, of which the Civilian Response Corps was recently partially funded via supplemental appropriation.

U.S. Army photo by Spc. Thomas Day

A Civil Affair unit member with the Parwan Provincial Reconstruction Team (PRT) hands out toys at a school opening in Kabul, Afghanistan.

- The Department is working with the U.S. Agency for International Development to improve collaboration, coordination, and synchronization of existing foreign-based strategic guidance and operational plans to take advantage of lessons learned from recent operations. The newly published U.S. Agency for International Development "Civil-Military Cooperation Policy," which calls for improved coordination with the military, demonstrates significant potential. The Department of Defense will continue to support this positive step towards creation of mutually supportive development-based and military-based plans.

- For homeland security, the Departments of Defense and Homeland Security are establishing a pilot Task Force for Emergency Readiness consisting of a small group of interagency planners to develop plans that ensure a whole-of-government response to disasters. The task force will integrate local, state, and federal organizations, as well as the private sector. The pilot task force will begin in five states within the next calendar year.

- At the national level, the Department supports development of a whole-of-government strategic planning document that outlines national objectives, priorities and specific actions for improving interagency coordination and operational planning.

Concept Development. Over the last several years, the Department has developed Joint Operating Concepts that propose future interagency activities, including concepts for cooperative security, irregular warfare, stability operations and homeland defense and civil support. These JOCs were developed in informal collaboration with the Department of State and other agencies. Although they incorporate a broader interagency perspective than previous Department-centric documents, there are opportunities for continued improvement, to include conducting comprehensive whole-of-government capability and capacity gap analyses across all lines of operation.

- The Department of Defense advocates establishing a formal forum for collaborating with other elements of the U.S. Government on Joint Operating Concepts. The objective is to continue to evolve JOCs into truly whole-of-government concepts that would better define responsibilities across the whole-of-government, such as border security, disaster relief operations abroad, and domestic counterterrorism security programs, among other shared security challenges.

A member of the U.S. Navy amphibious assault ship USS Kearsarge (LHD 3) provides medical care during hurricane relief operations in Haiti. The Department of Defense advocates expanding whole-of-government collaboration on concepts such as disaster relief operations abroad.

Authorities and Resources. Fiscal Year 2006 National Defense Authorization Act Section 1206 "Global Train and Equip" and Section 1207 "Security and Stabilization Assistance" authorities have proven highly effective at combining assets to address urgent national security problems. These programs recognize the need to augment, not supplant, what other agencies can bring to the table – particularly the Department of State and U.S. Agency for International Development – with Defense Department capabilities that address mutual needs in the field.

- Internally, the Department will continue developing capabilities for stabilization, reconstruction, foreign internal defense, and counterinsurgency operations supported by force growth initiatives, new doctrine, operational concepts, adjusting roles of the civilian work force, and enhancing training and education.

- Externally, the Department will continue to collaborate with the Congress and Department of State to explore new authorities that would better integrate capabilities and funding priorities for these shared missions.

- The Department of Defense strongly supports the State Department's Civilian Stabilization Initiative budget request to continue development of expeditionary civilian capabilities in eight U.S. Government departments and agencies.

Interagency Secure Communications Challenges. While all agencies can communicate on unclassified networks, not all agencies and departments required to plan and conduct operations together are able to communicate with each other on classified networks. For example, information sharing between Federal Government departments and local/state entities involved with homeland security is predominately over unclassified networks. Similarly, information sharing concerning other threats, emergency and disaster management, planning, and other domestic security and response is underdeveloped.

- In cooperation with its interagency partners, the Department will continue to aggressively pursue solutions that ensure it can communicate over classified networks with critical domestic partners.

National Security Professional Development. Many lingering challenges between interagency staffs may be partially attributable to a lack of understanding and appreciation of each others' organizational cultures, priorities, requirements, and practices. Traditionally, civil servants and military members have few formal opportunities for interagency training, education, and professional development. Beyond rudimentary familiarization at staff courses, personnel systems have not typically encouraged professional development that fosters a deep understanding of other agencies. In 2007, the President directed the creation of a "National Security Professional Development" system to address these cross-agency challenges.

- In support of national security professional development, the Department is working proactively with its partners to provide more students from other agencies access to courses at Defense Department educational institutions, notably the National Defense University.

Future Opportunities.

Conducting Stabilization and Reconstruction Operations. Today, military forces are conducting a wide range of civil-military operations and activities, including security and policing assistance, humanitarian relief, reconstruction, governance, civil capacity building, medical and security cooperation. Hardly new to the Department, military forces have performed these missions for more than a century and likely will continue to do so in the future. However, recent operations have exposed gaps between civilian and military capabilities, and highlighted a need to develop a better understanding of how civilian-military efforts must be mutually supportive and when operations should transition between military-led and civilian-led activities. National Security Presidential Directive (NSPD) 44 *"Management of Interagency Efforts Concerning Reconstruction and Stabilization"* and Title XVI of the 2009 National Defense Authorization

Act have made a substantial first step in building interagency capabilities and conducting strategic and operational planning.

- While NSPD-44 and Title 16 of the 2009 National Defense Authorization Act broadly define responsibilities of various departments during foreign stabilization and reconstruction operations, full realization of the ongoing capabilities development for these types of operations will not be realized without full funding of the Civilian Stabilization Initiative.

Resources to Increase Civilian Expertise. Lessons learned in recent operations stress the critical need to further develop deployable civilian expertise for conducting stabilization, reconstruction, and counterinsurgency operations. Today, civil agencies and departments have insufficient resources for carrying out missions associated with transition from violence to lasting stability.

- Accordingly, the Department supports establishing a better balance between the civil and military instruments of national power by significantly increasing resources needed for governance, strategic communication, security assistance, civic action, and economic reconstruction and development.

Strategic Communication. The Department of Defense recognizes strategic communication as a process through which information activities (including public affairs, psychological operations, information operations, public diplomacy, and policy) are harmonized and synchronized with other operations. The Department will continue to improve the alignment of actions and information with policy objectives to integrate strategic communication into defense missions and to support larger U.S. policies as well as the State Department's public diplomacy priorities.

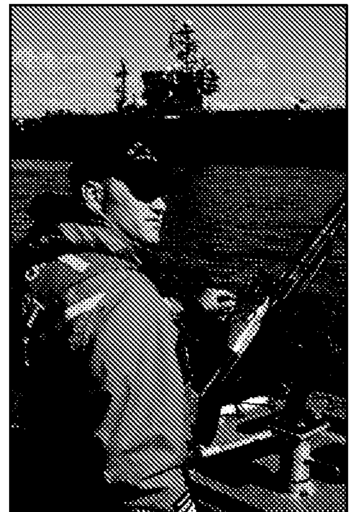
- The Department has significant capabilities and resources to support strategic communication priorities, particularly to counter ideological support to terrorism in Iraq and Afghanistan. We are committed to using our operational and informational activities and strategic communication processes in support of the Department of State's broader public diplomacy efforts. This cooperation will better enable the U.S. Government to engage foreign audiences holistically and with unity of effort.

- The Department of Defense and Department of State will expand our partnership to conduct strategic communication planning in support of the Global War on Terror, building partnership capacity, and regional issues. This partnership encompasses the full range of information and Theater Security Cooperation activities to synchronize efforts; improve regional and cultural expertise; develop and deliver information products; and train international partners to build their information networks.

Authorities and Oversight. Funding and authorities dedicated solely to individual agencies may not be sufficient to ensure that the activities of multiple agencies are fully integrated and that all seam issues between organizations are addressed. "Stovepiped" funding and authorities could have the unintended effect of encouraging the development of uncoordinated approaches to national security challenges as well as unneeded competition between departments and agencies.

- The Department recognizes the need for authorities and approaches to funding for whole-of-government operations.

Looking Forward. In summary, the Department of Defense places a high priority on integrating whole-of-government capabilities to deal with shared challenges to our Nation's security. Future conflict will require integrated planning and implementation efforts as well as smooth transitions between our military forces and civilian counterparts, not just to win wars, but to prevent them and mitigate the underlying causes of conflicts and instability. In order to plan and execute essential national security tasks at home and abroad, we seek to increase defense and civil support and building partnership capacity in addition to fielding fully-ready joint forces. Since our Nation's future security depends equally on interagency cooperation, coordination, and integration efforts, building unity of effort requires us to expand the concept of jointness beyond the Department of Defense. To help establish the right balance between our Nation's capabilities, we strongly support increasing resources and capacities in other departments and agencies, notably the Department of State and the U.S. Agency for International Development.



A Coast Guard Petty Officer from Winthrop, MA mans a M-240 machine gun aboard a rigid hull inflatable boat as the conventionally-powered aircraft carrier USS John F. Kennedy (CV 67) moves into port.

U.S. Coast Guard photo by Public Affairs Specialist 3rd Class Lisa Hennings

GLOSSARY

The following information on specific concepts, processes, and definitions supplement text in the Quadrennial Roles and Missions Review Issue Team sections.

A. Irregular Warfare Key Terms and Concepts

- **Counterinsurgency (COIN):** Those military, paramilitary, political, economic, psychological, and civic actions taken by a government to defeat insurgency.

- **Counter-terrorism (CT):** Operations that include the offensive measures taken to prevent, deter, preempt, and respond to terrorism.

- **Foreign Internal Defense (FID):** Participation by civilian and military agencies of a government in any of the action programs taken by another government or other designated organization to free and protect its society from subversion, lawlessness, and insurgency.

- **General Purpose Forces (GPF):** All forces except Special Operations and Strategic Forces. General Purpose Forces are not limited to any one domain (i.e., General Purpose Forces are not only ground forces).

- **Irregular Warfare:** A violent struggle among state and non-state actors for legitimacy and influence over the relevant populations. Irregular warfare favors indirect and asymmetric approaches, though it may employ the full range of military and other capabilities, in order to erode an adversary's power, influence, and will.

- **Special Operations Forces (SOF):** Those Active and Reserve Component forces of the Military Services designated by the Secretary of Defense and specifically organized, trained, and equipped to conduct and support special operations.

- **Stability Operations:** An overarching term encompassing various military missions, tasks, and activities conducted outside the United States in coordination with other instruments of national power to maintain or reestablish a safe and secure environment, provide essential governmental services, emergency infrastructure reconstruction, and humanitarian relief.

- **Unconventional Warfare (UW):** A broad spectrum of military and paramilitary operations, normally of long duration, predominantly conducted through, with, or by indigenous or surrogate forces who are organized, trained, equipped, supported, and directed in varying degrees by an external source. It includes, but is not limited to, guerrilla warfare, subversion, sabotage, intelligence activities, and unconventional assisted recovery.

B. Cyber Key Terms and Concepts

- **Cyberspace:** A global domain within the information environment consisting of the interdependent network of information technology, infrastructures, including the Internet, telecommunications networks, computer systems, and embedded processors and controllers.

- **Global Information Grid (GIG):** The globally interconnected, end-to-end set of information capabilities, associated processes and personnel for collecting, processing, storing, disseminating, and managing information on demand to warfighters, policy makers, and support personnel. The Global Information Grid includes owned and leased communications and computing systems and services, software (including applications), data, security services, other associated services and National Security Systems.

C. Intratheater Airlift Key Terms and Concepts

- **Time Sensitive / Mission Critical (TS/MC) Movement Requirements:** Justification for organic transportation assets to conduct direct support mission are based on need to satisfy TS/MC requirements. TS/MC requirements create a demand for delivery of equipment, supplies, and personnel that are generally non-routine in nature and must be delivered to the point of need or point of effect in an accelerated time period. These demands require the lift capacity to be supremely responsive to the supported commander's immediate operational or tactical priorities. TS/MC demands cannot routinely be accommodated via planned resupply and movement processes where efficiency is the primary consideration. (Note: Although no specific response time is specified, depending on the operational scenario and unit mission, TS/MC movement requirements are usually conducted with less than 24 hours notice.)

- **Point of Need:** A physical location designated by the JFC as a receiving point for forces or commodities, for subsequent employment, emplacement, or consumption.

- **Point of Effect:** A physical location designated by the functional component commander, Service component commander or a subordinate commander to support operations normally within the combat zone.

- **Port of Debarkation (POD):** The geographical point at which cargo or personnel are discharged. This may be a seaport or aerial port of debarkation; for unit requirements; it may or may not coincide with the destination.

- **Port of Embarkation (POE):** The geographic point in a routing scheme from which cargo or personnel depart. This may be a seaport or aerial port from which personnel and equipment flow to a port of debarkation; for unit and non-unit requirements, it may or may not coincide with the origin.

D. Unmanned Aircraft Systems / Intelligence, Surveillance, Reconnaissance Key Terms and Concepts

- **Command and Control:** The exercise of authority and direction by a properly designated commander over assigned and attached forces in the accomplishment of the mission. Command and control functions are performed through an arrangement of personnel, equipment, communications, facilities, and procedures employed by a commander in planning, directing, coordinating, and controlling forces and operations in the accomplishment of the mission. Also called C2.

- **Unmanned Aircraft System (UAS):** The system, whose components include the necessary equipment, data communication links, and personnel to control and employ an unmanned aircraft. The unmanned aircraft system is composed of six components: the aircraft, payloads, data communication links, ground control stations, ground support equipment, and ground operators.

- **JUAS Categories:** A classification system for current UAS based primarily on a categorization schema that groups UAS according to three enduring attributes: UA weight, normal operating altitude, and speed.

  - **Group 1 UAS.** UAS typically less than 20 pounds in weight and normally operate below 1,200 feet Above Ground Level at speeds less than 250 knots

  - **Group 2 UAS.** UAS in the 21 – 55 pound weight class and normally operate less than 3,500 feet Above Ground Level at speed less than 250 knots.

  - **Group 3 UAS.** UAS weigh more than 55 pounds, but less than 1320 pounds. They normally operate below 18,000 feet Mean Sea Level at speeds less than 250 knots.

  - **Group 4 UAS.** UAS weigh more than 1,320 pounds and normally operate below 18,000 feet Mean Sea Level at any speed.

  - **Group 5 UAS.** UAS weight more than 1,320 pounds and normally operate higher than 18,000 feet Mean Sea Level at any speed.

E. Interagency Opportunities Key Terms and Concepts

- **Strategic Communication:** Focused U.S. Government processes and efforts to understand and engage key audiences to create, strengthen or preserve conditions favorable to advance national interests and objectives through the use of coordinated information, themes, plans, programs, and actions synchronized with other elements of national power.

QRM

![ANALOG DEVICES]

8-Bit, 250 MSPS 3.3 V A/D Converter

AD9481

FEATURES

DNL = ±0.35 LSB
INL = ±0.26 LSB
Single 3.3 V supply operation (3.0 V to 3.6 V)
Power dissipation of 439 mW at 250 MSPS
1 V p-p analog input range
Internal 1.0 V reference
Single-ended or differential analog inputs
De-multiplexed CMOS outputs
Power-down mode
Clock duty cycle stabilizer

APPLICATIONS

Digital oscilloscopes
Instrumentation and measurement
Communications
- **Point-to-point radios**
- **Digital predistortion loops**

FUNCTIONAL BLOCK DIAGRAM

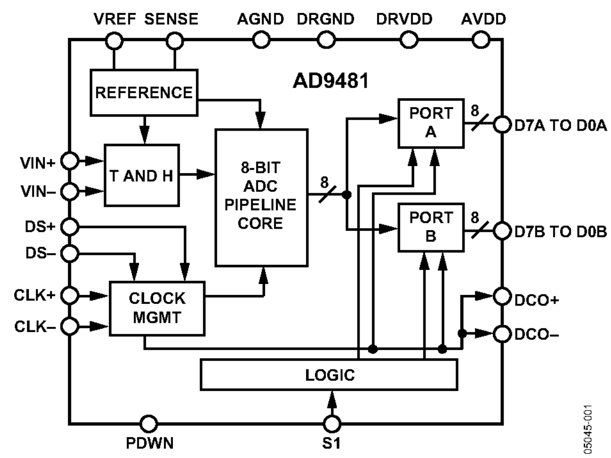


Figure 1.

GENERAL DESCRIPTION

The AD9481 is an 8-bit, monolithic analog-to-digital converter (ADC) optimized for high speed and low power consumption. Small in size and easy to use, the product operates at a 250 MSPS conversion rate, with excellent linearity and dynamic performance over its full operating range.

To minimize system cost and power dissipation, the AD9481 includes an internal reference and track-and-hold circuit. The user only provides a 3.3 V power supply and a differential encode clock. No external reference or driver components are required for many applications.

The digital outputs are TTL/CMOS-compatible with an option of twos complement or binary output format. The output data bits are provided in an interleaved fashion along with output clocks that simplifies data capture.

The AD9481 is available in a Pb-free, 44-lead, surface-mount package (TQFP-44) specified over the industrial temperature range (−40°C to +85°C).

PRODUCT HIGHLIGHTS

1. Superior linearity. A DNL of ±0.35 makes the AD9481 suitable for many instrumentation and measurement applications
2. Power-down mode. A power-down function may be exercised to bring total consumption down to 15 mW.
3. De-multiplexed CMOS outputs allow for easy interfacing with low cost FPGAs and standard logic.

One Technology Way, P.O. Box 9106, Norwood, MA 02062-9106, U.S.A.
Tel: 781.329.4700 www.analog.com
Fax: 781.326.8703

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REVISION HISTORY

10/04—Revision 0: Initial Version

DC SPECIFICATIONS

AVDD = 3.3 V, DRVDD = 3.3 V; T_{MIN} = −40°C, T_{MAX} = +85°C, A_{IN} = −1 dBFS, full scale = 1.0 V, internal reference, differential analog and clock inputs, unless otherwise noted.

Table 1.

Parameter	Temp	Test Level	AD9481-250 Min	Typ	Max	Unit
RESOLUTION				8		Bits
ACCURACY						
No Missing Codes	Full	VI		Guaranteed		
Offset Error	25°C	I	−40		40	mV
Gain Error[1]	25°C	I	−6.0		6.0	% FS
Differential Nonlinearity (DNL)	Full	VI	−0.85	±0.35	0.85	LSB
Integral Nonlinearity (INL)	Full	VI	−0.9	±0.26	0.9	LSB
TEMPERATURE DRIFT						
Offset Error	Full	V		30		µV/°C
Gain Error	Full	V		0.03		% FS/°C
Reference	Full	V		±0.025		mV/°C
REFERENCE						
Internal Reference Voltage	Full	VI	0.97	1.0	1.03	V
Output Current[2]	25°C	IV			1.5	mA
I_{VREF} Input Current[3]	25°C	I			100	µA
I_{SENSE} Input Current[2]	25°C	I			10	µA
ANALOG INPUTS (VIN+, VIN−)						
Differential Input Voltage Range[4]	Full	V		1		V p-p
Common-Mode Voltage	Full	VI	1.6	1.9	2.1	V
Input Resistance	Full	VI	8.4	10	11.2	kΩ
Input Capacitance	25°C	V		4		pF
Analog Bandwidth, Full Power	25°C	V		750		MHz
POWER SUPPLY						
AVDD	Full	IV	3.0	3.3	3.6	V
DRVDD	Full	IV	3.0	3.3	3.6	V
Supply Currents						
IAVDD[5]	Full	VI		133	145	mA
IDRVDD[5]	Full	VI		39	42.5	mA
Power Dissipation[5]	25°C	V		439		mW
Power-Down Dissipation	25°C	V		15	37	mW
Power Supply Rejection Ratio (PSRR)	25°C	V		−4.2		mV/V

[1] Gain error and gain temperature coefficients are based on the ADC only (with a fixed 1 V external reference and 1 V p-p input range).
[2] Internal reference mode; SENSE = AGND.
[3] External reference mode; VREF driven by external 1.0 V reference; SENSE = AVDD.
[4] In FS = 1 V, both analog inputs are 500 mV p-p and out of phase with each other.
[5] Supply current measured with rated encode and a 20 MHz analog input. Power dissipation measured with dc input, see the Terminology section for power vs. clock rate.

DIGITAL SPECIFICATIONS

AVDD = 3.3 V, DRVDD = 3.3 V; T_{MIN} = −40°C, T_{MAX} = +85°C, A_{IN} = −1 dBFS, full scale = 1.0 V, internal reference, differential analog and clock inputs, unless otherwise noted.

Table 2.

Parameter	Temp	Test Level	AD9481-250 Min	Typ	Max	Unit
CLOCK AND DS INPUTS (CLK+, CLK−, DS+, DS−)						
Differential Input	Full	IV	200			mV p-p
Common-Mode Voltage[1]	Full	VI	1.38	1.5	1.68	V
Input Resistance	Full	VI	4.2	5.5	6.0	kΩ
Input Capacitance	25°C	V		4		pF
LOGIC INPUTS (PDWN, S1)						
Logic 1 Voltage	Full	IV	2.0			V
Logic 0 Voltage	Full	IV			0.8	V
Logic 1 Input Current	Full	VI			±160	µA
Logic 0 input Current	Full	VI			10	µA
Input Resistance	25°C	V		30		kΩ
Input Capacitance	25°C	V		4		pF
DIGITAL OUTPUTS						
Logic 1 Voltage[2]	Full	VI	DRVDD − 0.05			mV
Logic 0 Voltage	Full	VI			0.05	V
Output Coding	Full	IV	Twos complement or binary			

[1] The common mode for CLOCK inputs can be externally set, such that 0.9 V < CLK ± < 2.6 V.
[2] Capacitive loading only.

AC SPECIFICATIONS

AVDD = 3.3 V, DRVDD = 3.3 V; T_{MIN} = −40°C, T_{MAX} = +85°C, A_{IN} = −1 dBFS, full scale = 1.0 V, internal reference, differential analog and clock inputs, unless otherwise noted.

Table 3.

Parameter	Temp	Test Level	AD9481-250 Min	Typ	Max	Unit
SIGNAL-TO-NOISE RATIO (SNR)						
f_{IN} = 19.7 MHz	25°C	V		46		dB
f_{IN} = 70.1 MHz	25°C	I	44.5	45.7		dB
SIGNAL-TO-NOISE AND DISTORTION (SINAD)						
f_{IN} = 19.7 MHz	25°C	V		45.9		dB
f_{IN} = 70.1 MHz	25°C	I	44.4	45.7		dB
EFFECTIVE NUMBER OF BITS (ENOB)						
f_{IN} = 19.7 MHz	25°C	V		7.5		Bits
f_{IN} = 70.1 MHz	25°C	I	7.2	7.5		Bits
WORST SECOND OR THIRD HARMONIC DISTORTION						
f_{IN} = 19.7 MHz	25°C	V		−64.8		dBc
f_{IN} = 70.1 MHz	25°C	I		−64.8	−54	dBc
WORST OTHER						
f_{IN} = 19.7 MHz	25°C	V		−68		dBc
f_{IN} = 70.1 MHz	25°C	I		−65.8	−56	dBc
SPURIOUS-FREE DYNAMIC RANGE (SFDR)[1]						
f_{IN} = 19.7 MHz	25°C	V		−64.8		dBc
f_{IN} = 70.1 MHz	25°C	I		−64.8	−54	dBc
TWO-TONE INTERMODULATION DISTORTION (IMD)						
f_{IN1} = 69.3 MHz, f_{IN2} = 70.3 MHz	25°C	V		−64.9		dBc

[1] DC and Nyquist bin energy ignored.

SWITCHING SPECIFICATIONS

AVDD = 3.3 V, DRVDD = 3.3 V; differential encode input, duty cycle stabilizer enabled, unless otherwise noted.

Table 4.

Parameter	Temp	Test Level	AD9481-250 Min	Typ	Max	Unit
CLOCK						
Maximum Conversion Rate	Full	VI	250			MSPS
Minimum Conversion Rate	Full	IV			20	MSPS
Clock Pulse-Width High (t_{EH})	Full	IV	1.2	2		ns
Clock Pulse-Width Low (t_{EL})	Full	IV	1.2	2		ns
DS Input Setup Time (t_{SDS})	Full	IV	0.5			ns
DS Input Hold Time (t_{HDS})	Full	IV	0.5			ns
OUTPUT PARAMETERS[1]						
Valid Time (t_V)[2]	Full	VI	2.5			ns
Propagation Delay (t_{PD})	Full	VI		4	5.4	ns
Rise Time (t_R) 10% to 90%	Full	V		670		ps
Fall Time (t_F) 10% to 90%	Full	V		360		ps
DCO Propagation Delay (t_{CPD})[3]	Full	VI	2.5	3.9	5.3	ns
Data-to-DCO Skew (t_{PD} − t_{CPD})[4]	Full	VI	−0.5		+0.5	ns
A Port Data to DCO− Rising (t_{SKA})[5]	Full	IV		4		ns
B Port Data to DCO+ Rising (t_{SKB})	Full	IV		4		ns
Pipeline Latency (A, B)	Full	IV		8		Cycles
APERTURE						
Aperture Delay (t_A)	25°C	V		1.5		ns
Aperture Uncertainty (Jitter)	25°C	V		0.25		ps rms
OUT-OF-RANGE RECOVERY TIME	25°C	V		1		Cycle

[1] C_{LOAD} equals 5 pF maximum for all output switching specifications.
[2] Valid time is approximately equal to minimum t_{PD}.
[3] T_{CPD} equals clock rising edge to DCO (+ or −) rising edge delay.
[4] Data changing to (DCO+ or DCO−) rising edge delay.
[5] T_{SKA}, T_{SKB} are both clock rate dependent delays equal to T_{CYCLE} − (Data to DCO skew).

TIMING DIAGRAM

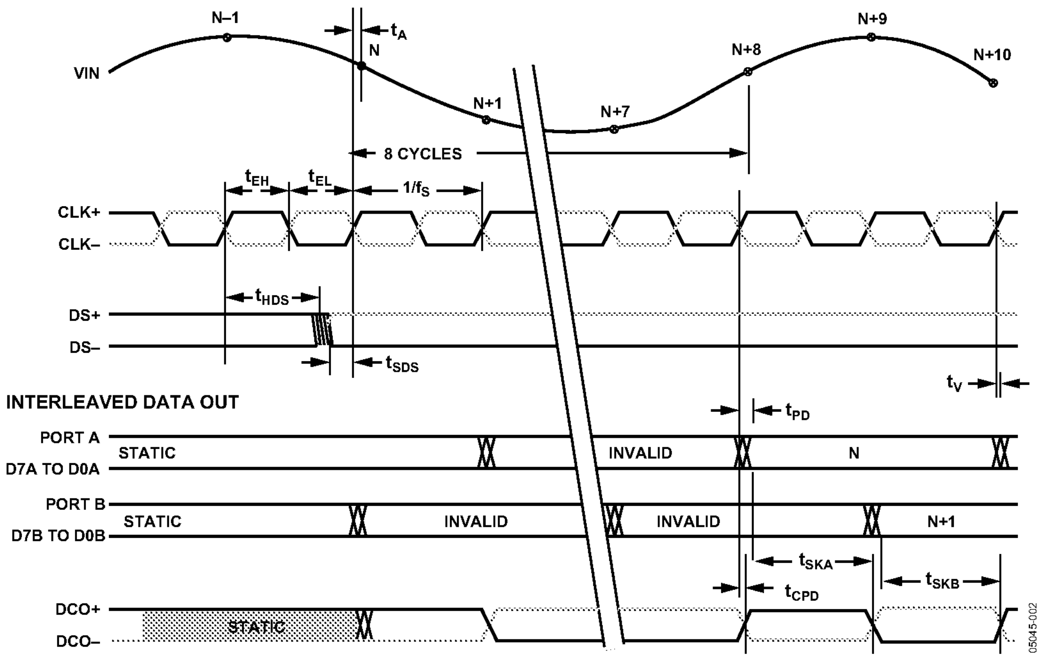

Figure 2. Timing Diagram

ABSOLUTE MAXIMUM RATINGS

Thermal impedance (θ_{JA}) = 46.4°C/W (4-layer PCB).

Table 5.

Parameter	Min. Rating	Max. Rating
ELECTRICAL		
AVDD (With respect to AGND)	−0.5 V	+4.0 V
DRVDD (With respect to DRGND)	−0.5 V	+4.0 V
AGND (With respect to DRGND)	−0.5 V	+0.5 V
Digital I/0 (With respect to DRGND)	−0.5 V	DRVDD + 0.5 V
Analog Inputs (With respect to AGND)	−0.5 V	AVDD + 0.5 V
ENVIRONMENTAL		
Operating Temperature	−40°C	+85°C
Junction Temperature		150°C
Storage Temperature		150°C

Stresses above those listed under Absolute Maximum Ratings may cause permanent damage to the device. This is a stress rating only; functional operation of the device at these or any other conditions above those indicated in the operational section of this specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

EXPLANATION OF TEST LEVELS

Table 6.

Level	Description
I	100% production tested.
II	100% production tested at 25°C and guaranteed by design and characterization at specified temperatures.
III	Sample tested only.
IV	Parameter is guaranteed by design and characterization testing.
V	Parameter is a typical value only.
VI	100% production tested at 25°C and guaranteed by design and characterization for industrial temperature range.

ESD CAUTION

ESD (electrostatic discharge) sensitive device. Electrostatic charges as high as 4000 V readily accumulate on the human body and test equipment and can discharge without detection. Although this product features proprietary ESD protection circuitry, permanent damage may occur on devices subjected to high energy electrostatic discharges. Therefore, proper ESD precautions are recommended to avoid performance degradation or loss of functionality.

PIN CONFIGURATION AND FUNCTION DESCRIPTIONS

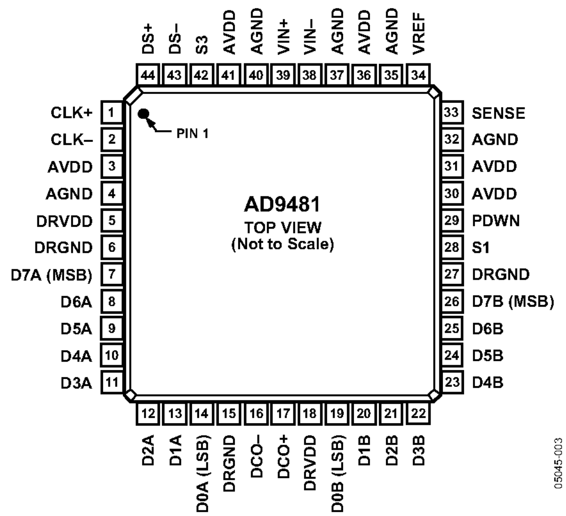

Figure 3. Pin Configuration

Table 7. Pin Function Descriptions

Pin No.	Name	Description
1	CLK+	Input Clock—True
2	CLK–	Input Clock—Complement
3	AVDD	3.3 V Analog Supply
4	AGND	Analog Ground
5	DRVDD	3.3 V Digital Output Supply
6	DRGND	Digital Ground
7	D7A	Data Output Bit 7—Channel A (MSB)
8	D6A	Data Output Bit 6—Channel A
9	D5A	Data Output Bit 5—Channel A
10	D4A	Data Output Bit 4—Channel A
11	D3A	Data Output Bit 3—Channel A
12	D2A	Data Output Bit 2—Channel A
13	D1A	Data Output Bit 1—Channel A
14	D0A	Data Output Bit 0—Channel A (LSB)
15	DRGND	Digital Ground
16	DCO–	Data Clock Output—Complement
17	DCO+	Data Clock Output—True
18	DRVDD	3.3 V Digital Output Supply
19	D0B	Data Output Bit 0—Channel B (LSB)
20	D1B	Data Output Bit 1—Channel B
21	D2B	Data Output Bit 2—Channel B
22	D3B	Data Output Bit 3—Channel B
23	D4B	Data Output Bit 4—Channel B
24	D5B	Data Output Bit 5—Channel B
25	D6B	Data Output Bit 6—Channel B
26	D7B	Data Output Bit 7—Channel B (MSB)
27	DRGND	Digital Ground
28	S1	Data Format Select and Duty Cycle Stabilizer Select
29	PDWN	Power-Down Selection
30	AVDD	3.3 V Analog Supply
31	AVDD	3.3 V Analog Supply
32	AGND	Analog Ground
33	SENSE	Reference Mode Selection
34	VREF	Voltage Reference Input/Output
35	AGND	Analog Ground
36	AVDD	3.3 V Analog Supply
37	AGND	Analog Ground
38	VIN–	Analog Input—Complement
39	VIN+	Analog Input—True
40	AGND	Analog Ground
41	AVDD	3.3 V Analog Supply
42	S3	DCO Enable Select (Tie to AVDD for DCO Active)
43	DS–	Data Sync Complement (If Unused, Tie to DRVDD)
44	DS+	Data Sync True (If Unused, Tie to DGND)

TERMINOLOGY

Analog Bandwidth
The analog input frequency at which the spectral power of the fundamental frequency (as determined by the FFT analysis) is reduced by 3 dB.

Aperture Delay
The delay between the 50% point of the rising edge of the encode command and the instant the analog input is sampled.

Aperture Uncertainty (Jitter)
The sample-to-sample variation in aperture delay.

Clock Pulse-Width/Duty Cycle
Pulse-width high is the minimum amount of time that the clock pulse should be left in a Logic 1 state to achieve rated performance; pulse-width low is the minimum time clock pulse should be left in a low state. See timing implications of changing t_{EH} in the Clocking the AD9481 section. At a given clock rate, these specifications define an acceptable clock duty cycle.

Crosstalk
Coupling onto one channel being driven by a low level (−40 dBFS) signal when the adjacent interfering channel is driven by a full-scale signal.

Differential Analog Input Resistance, Differential Analog Input Capacitance, and Differential Analog Input Impedance
The real and complex impedances measured at each analog input port. The resistance is measured statically and the capacitance and differential input impedances are measured with a network analyzer.

Differential Analog Input Voltage Range
The peak-to-peak differential voltage that must be applied to the converter to generate a full-scale response. Peak differential voltage is computed by observing the voltage on a single pin and subtracting the voltage from the other pin, which is 180° out of phase. Peak-to-peak differential is computed by rotating the inputs phase 180° and taking the peak measurement again. The difference is then computed between both peak measurements.

Differential Nonlinearity
The deviation of any code width from an ideal 1 LSB step.

Effective Number of Bits (ENOB)
ENOB is calculated from the measured SINAD based on the equation (assuming full-scale input)

$$ENOB = \frac{SINAD_{MEASURED} - 1.76\ \text{dB}}{6.02}$$

Full-Scale Input Power
Expressed in dBm. Computed using the following equation

$$Power_{FULLSCALE} = 10\log\left(\frac{\dfrac{V^2_{FULLSCALE}\,rms}{Z_{INPUT}}}{0.001}\right)$$

Gain Error
Gain error is the difference between the measured and ideal full-scale input voltage range of the ADC.

Harmonic Distortion, Second
The ratio of the rms signal amplitude to the rms value of the second harmonic component, reported in dBc.

Harmonic Distortion, Third
The ratio of the rms signal amplitude to the rms value of the third harmonic component, reported in dBc.

Integral Nonlinearity
The deviation of the transfer function from a reference line measured in fractions of 1 LSB using a best straight line determined by a least square curve fit.

Minimum Conversion Rate
The encode rate at which the SNR of the lowest analog signal frequency drops by no more than 3 dB below the guaranteed limit.

Maximum Conversion Rate
The encode rate at which parametric testing is performed.

Output Propagation Delay
The delay between a differential crossing of CLK+ and CLK− and the time when all output data bits are within valid logic levels.

Noise (for Any Range within the ADC)
This value includes both thermal and quantization noise.

$$V_{noise} = \sqrt{Z \times 0.001 \times 10^{\left(\frac{FS_{dBm} - SNR_{dBc} - Signal_{dBFS}}{10}\right)}}$$

where:

Z is the input impedance.

FS is the full scale of the device for the frequency in question.

SNR is the value for the particular input level.

Signal is the signal level within the ADC reported in dB below full scale.

Power Supply Rejection Ratio
The ratio of a change in input offset voltage to a change in power supply voltage.

Signal-to-Noise and Distortion (SINAD)
The ratio of the rms signal amplitude (set 1 dB below full scale) to the rms value of the sum of all other spectral components, including harmonics, but excluding dc.

Signal-to-Noise Ratio (without Harmonics)
The ratio of the rms signal amplitude (set at 1 dB below full scale) to the rms value of the sum of all other spectral components, excluding the first five harmonics and dc.

Spurious-Free Dynamic Range (SFDR)
The ratio of the rms signal amplitude to the rms value of the peak spurious spectral component. The peak spurious component may or may not be a harmonic. It also may be reported in dBc (degrades as signal level is lowered) or dBFS (always related back to converter full scale).

Two-Tone Intermodulation Distortion Rejection
The ratio of the rms value of either input tone to the rms value of the worst third-order intermodulation product, in dBc.

Two-Tone SFDR
The ratio of the rms value of either input tone to the rms value of the peak spurious component. The peak spurious component may or may not be an IMD product. It also may be reported in dBc (degrades as signal level is lowered) or in dBFS (always relates back to converter full scale).

Worst Other Spur
The ratio of the rms signal amplitude to the rms value of the worst spurious component (excluding the second and third harmonic), reported in dBc.

Transient Response Time
The time it takes for the ADC to reacquire the analog input after a transient from 10% above negative full scale to 10% below positive full scale.

Out-of-Range Recovery Time
This is the time it takes for the ADC to reacquire the analog input after a transient from 10% above positive full scale to 10% above negative full scale, or from 10% below negative full scale to 10% below positive full scale.

TYPICAL PERFORMANCE CHARACTERISTICS

AVDD, DRVDD = 3.3 V, T = 25°C, A_{IN} differential drive, FS = 1, internal reference mode, unless otherwise noted.

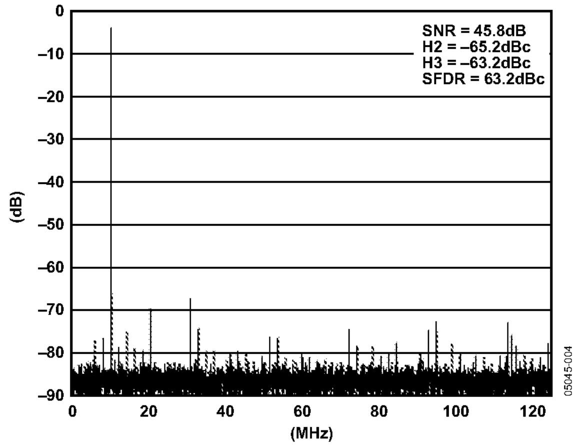

Figure 4. FFT: f_S = 250 MSPS, A_{IN} = 10.3 MHz @ −1 dBFS

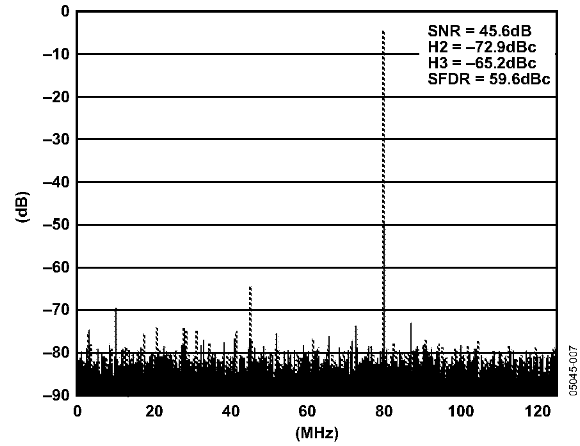

Figure 7. FFT: f_S = 250 MSPS, A_{IN} = 170 MHz @ −1 dBFS

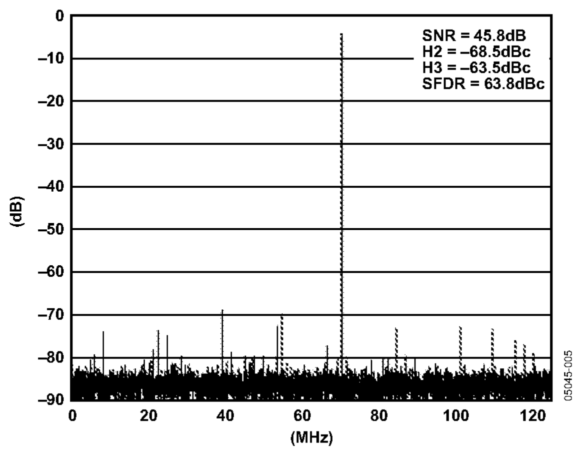

Figure 5. FFT: f_S = 250 MSPS, A_{IN} = 70 MHz @ −1 dBFS

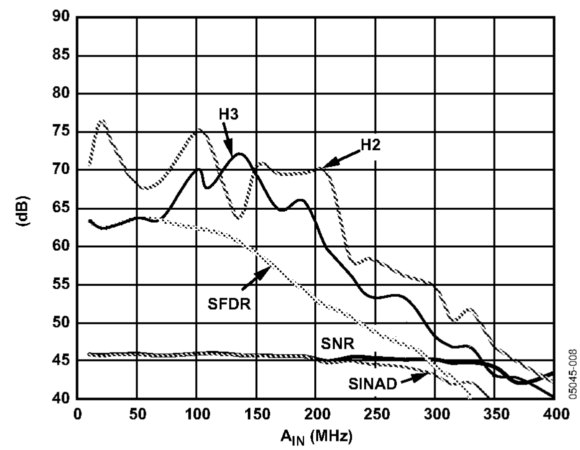

Figure 8. Analog Input Frequency Sweep,
A_{IN} = −1 dBFS, FS = 1 V, f_S = 250 MSPS

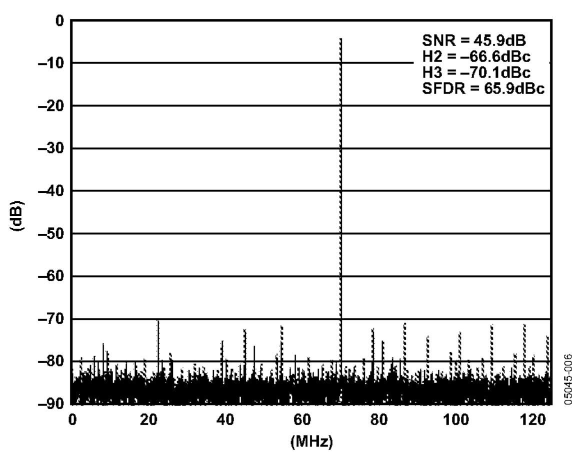

Figure 6. FFT: f_S = 250 MSPS, A_{IN} = 70 MHz @ −1 dBFS, Single-Ended Input

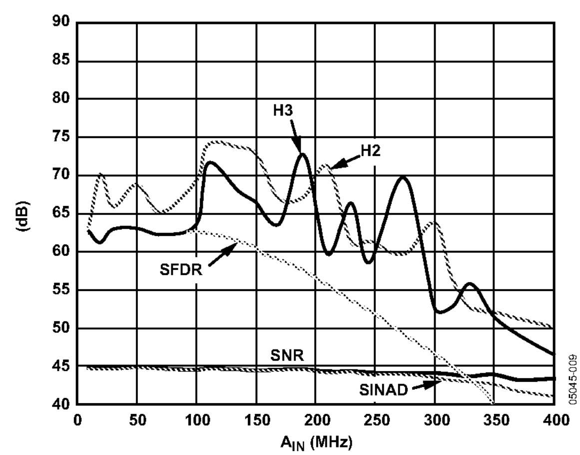

Figure 9. Analog Input Frequency Sweep,
A_{IN} =−1 dBFS, FS = 0.75 V, f_S = 250 MSPS, External VREF Mode

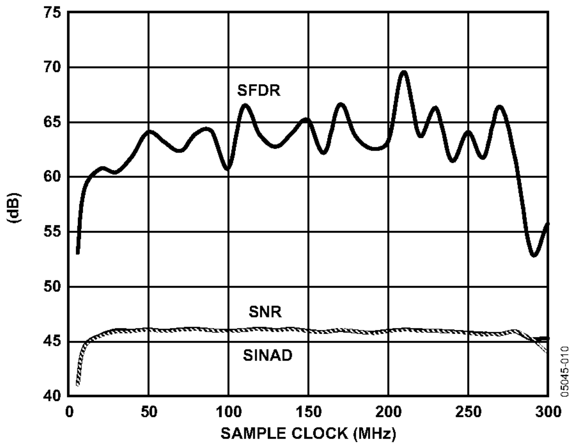

Figure 10. SNR, SINAD, SFDR vs. Sample Clock Frequency, A_{IN} = 70 MHz @ −1 dB

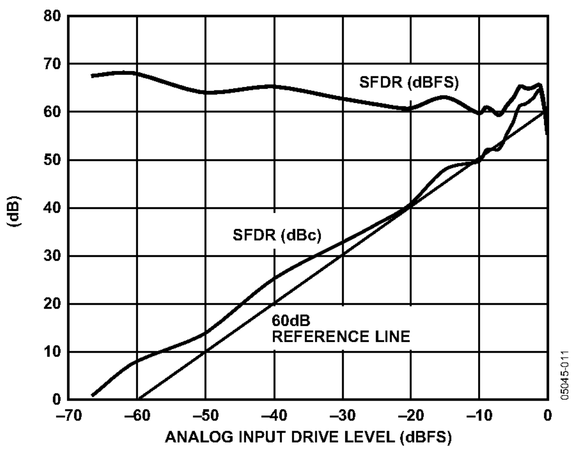

Figure 11. SFDR vs. A_{IN} Input Level; A_{IN} = 70 MHz @ 250 MSPS

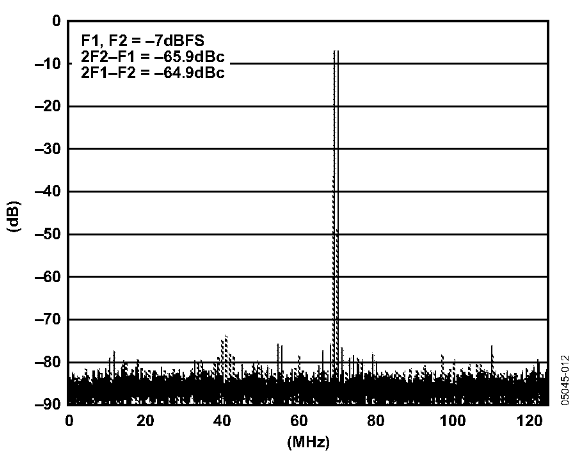

Figure 12. Two-Tone Intermodulation Distortion (69.3 MHz and 70.3 MHz; f_S = 250 MSPS)

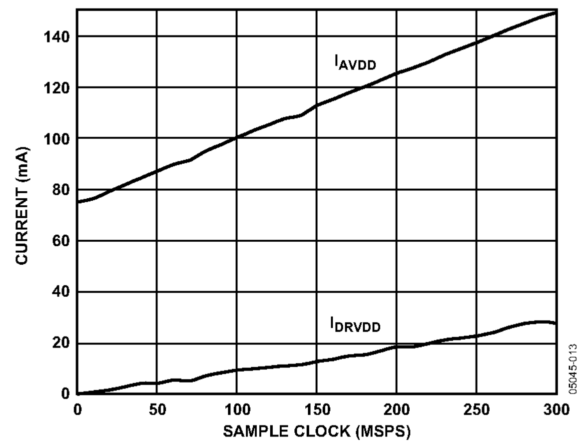

Figure 13. I_{AVDD} and I_{DRVDD} vs. Clock Rate, C_{LOAD} = 5 pF A_{IN} = 70 MHz @ −1 dBFS

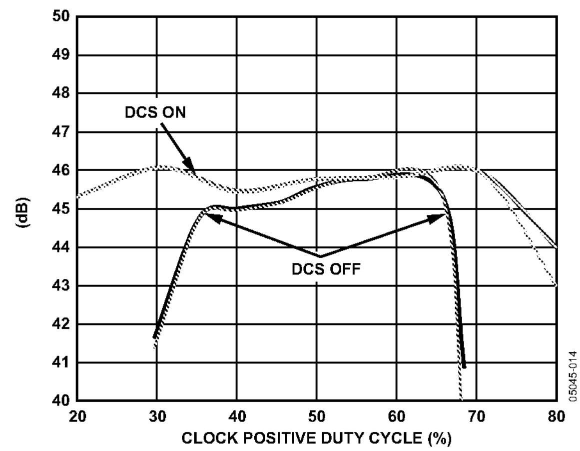

Figure 14. SNR, SINAD vs. Clock Pulse-Width High, A_{IN} = 70 MHz @ −1 dBFS, 250 MSPS, DCS On/Off

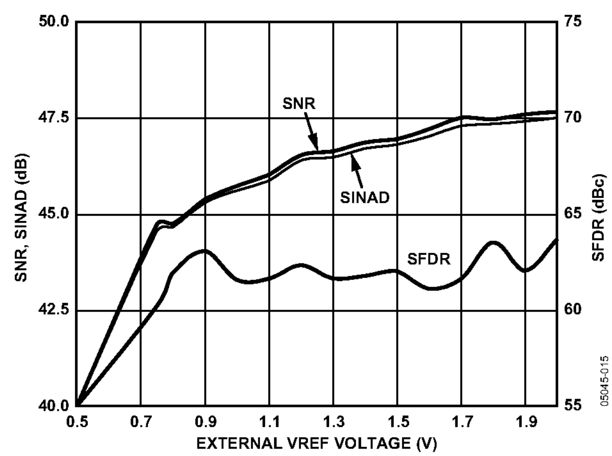

Figure 15. SNR, SINAD, and SFDR vs. VREF in External Reference Mode, A_{IN} = 70 MHz @ −1 dBFS, 250 MSPS

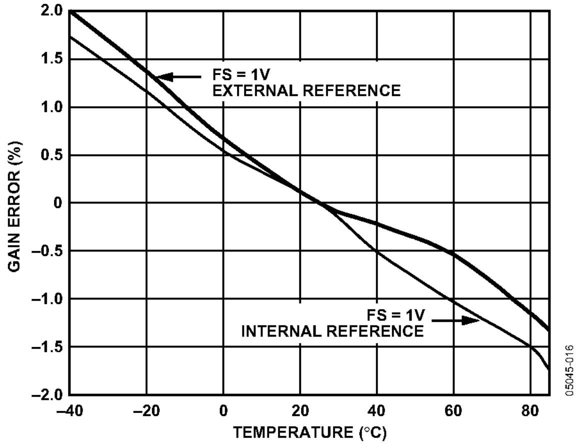

Figure 16. Full-Scale Gain Error vs. Temperature, A_{IN} = 70.3 MHz @ −0.5 dBFS, 250 MSPS

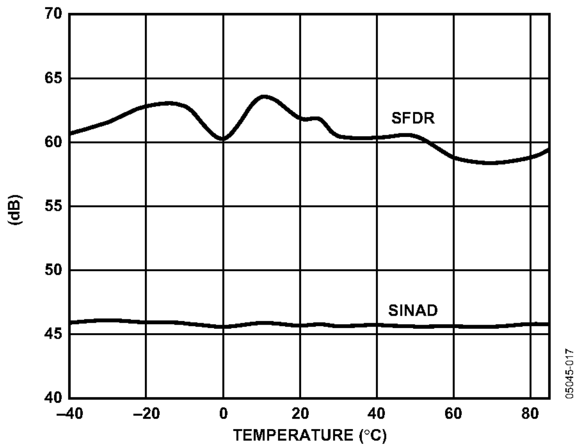

Figure 17. SINAD, SFDR vs. Temperature, A_{IN} = 70 MHz @ −1 dBFS, 250 MSPS

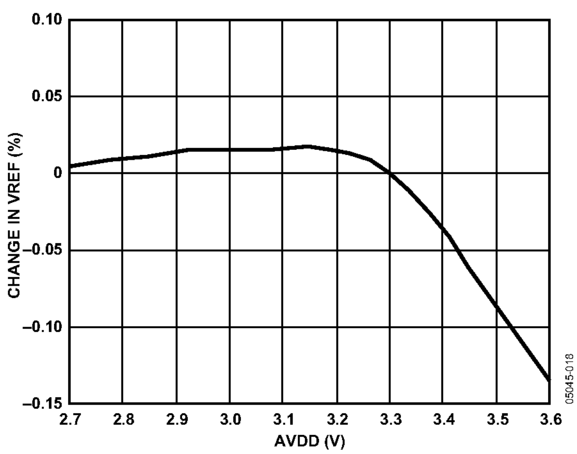

Figure 18. VREF Sensitivity to AVDD

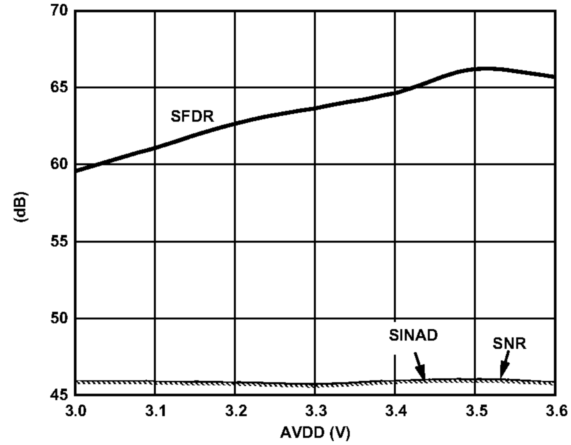

Figure 19. SNR, SINAD, and SFDR vs. Supply Voltage, A_{IN} = 70.3 MHz @ −1 dBFS, 250 MSPS

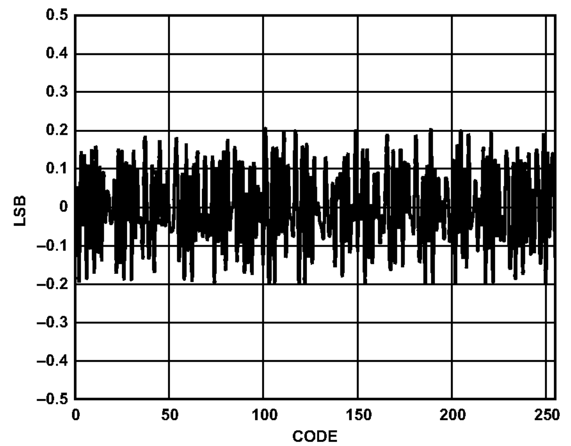

Figure 20. Typical DNL Plot, A_{IN} = 10.3 MHz @ −0.5 dBFS, 250 MSPS

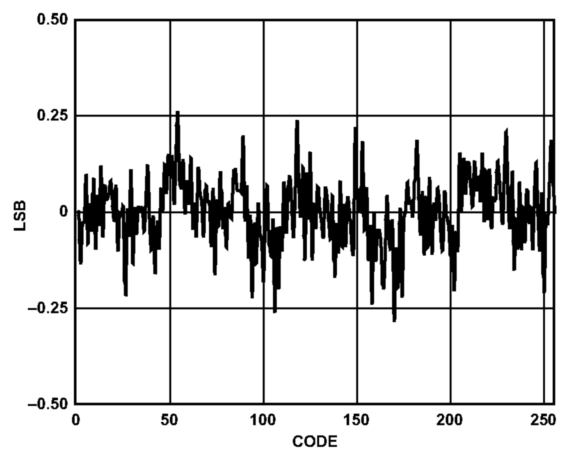

Figure 21. Typical INL Plot, A_{IN} = 10.3 MHz @ −0.5 dBFS, 250 MSPS

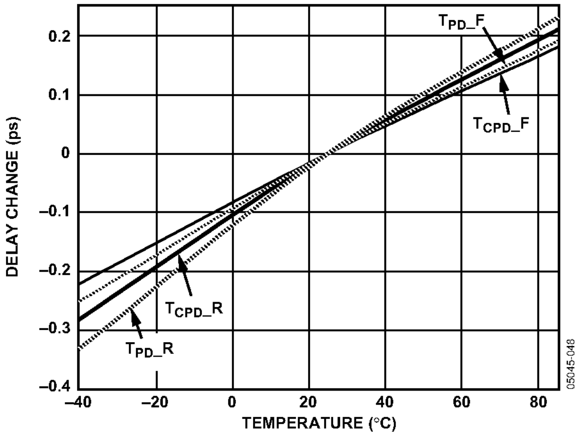

Figure 22. Propagation Delay Sensitivity vs. Temperature

EQUIVALENT CIRCUITS

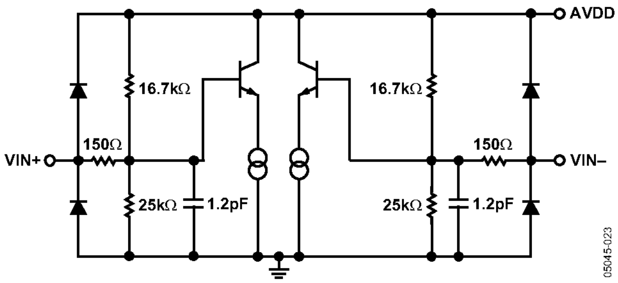

Figure 23. Analog Inputs

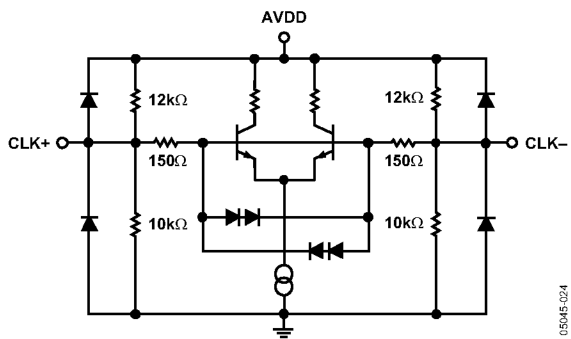

Figure 24. Clock Inputs

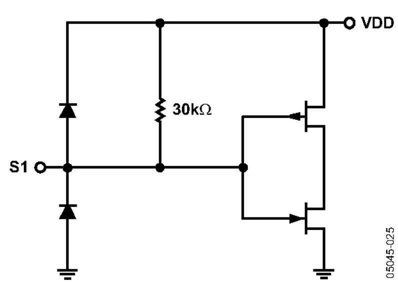

Figure 25. S1 Input

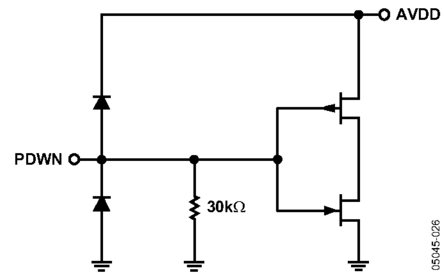

Figure 26. Power-Down Input

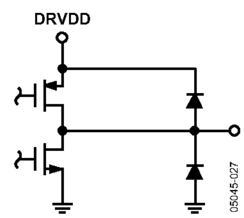

Figure 27. Data, DCO Outputs

APPLICATIONS

The AD9481 uses a 1.5 bit per stage architecture. The analog inputs drive an integrated high bandwidth track-and-hold circuit that samples the signal prior to quantization by the 8-bit core. For ease of use, the part includes an on-board reference and input logic that accepts TTL, CMOS, or LVPECL levels. The digital output logic levels are CMOS-compatible.

ANALOG INPUTS

The analog input to the AD9481 is a differential buffer. For best dynamic performance, impedances at VIN+ and VIN− should match. Optimal performance is obtained when the analog inputs are driven differentially. SNR and SINAD performance can degrade if the analog input is driven with a single-ended signal. The analog inputs self-bias to approximately 1.9 V; this common-mode voltage can be externally overdriven by approximately ±300 mV if required.

A wideband transformer, such as the Mini-Circuits ADT1-1WT, can provide the differential analog inputs for applications that require a single-ended-to-differential conversion. Note that the filter and center-tap capacitor on the secondary side is optional and dependent on application requirements. An RC filter at the secondary side helps reduce any wideband noise getting aliased by the ADC.

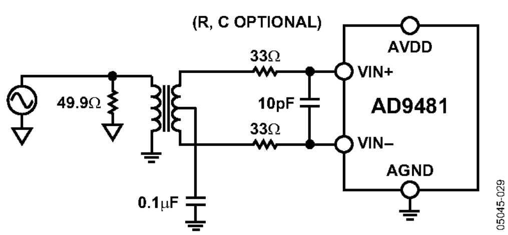

Figure 28. Driving the ADC with an RF Transformer

For dc-coupled applications, the AD8138/AD8139 or AD8351 can serve as a convenient ADC driver, depending on requirements. Figure 29 shows an example with the AD8138. The AD9481 PCB has an optional AD8351 on board, as shown in Figure 39 and Figure 40. The AD8351 typically yields better performance for frequencies greater than 30 MHz to 40 MHz. The AD9481's linearity and SFDR start to degrade at higher analog frequencies (see the Typical Performance Characteristics section). For higher frequency applications, the AD9480 with LVDS outputs and superior AC performance should be considered.

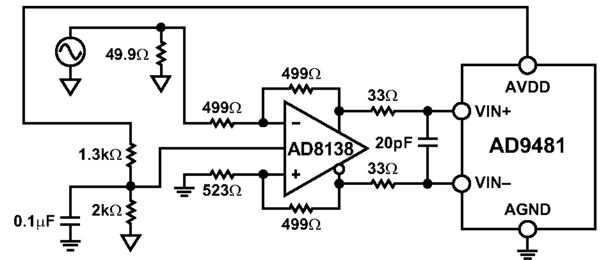

Figure 29. Driving the ADC with the AD8138

The AD9481 can be easily configured for different full-scale ranges. See the Voltage Reference section for more information. Optimal performance is achieved with a 1 V p-p analog input.

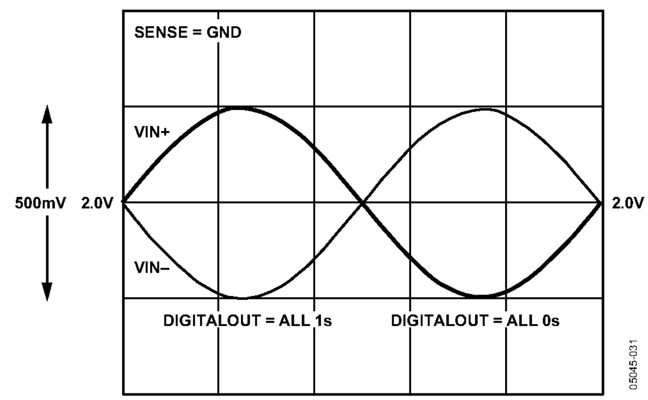

Figure 30. Analog Input Full Scale

VOLTAGE REFERENCE

A stable and accurate 1.0 V reference is built into the AD9481. Users can choose this internal reference or provide an external reference for greater accuracy and flexibility. Figure 32 shows the typical reference variation with temperature. Table 8 summarizes the available reference configurations.

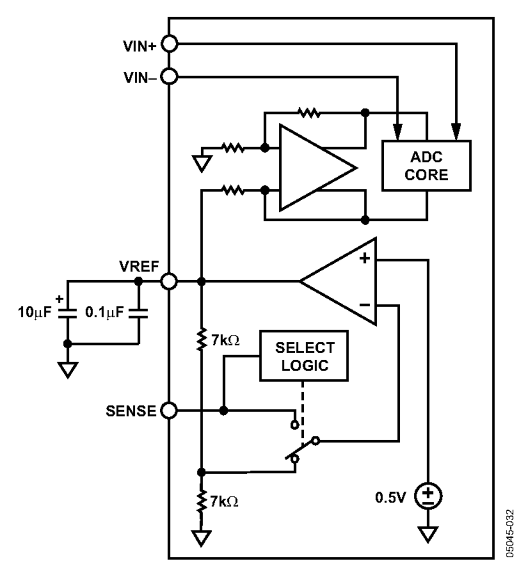

Figure 31. Internal Reference Equivalent Circuit

Fixed Reference

The internal reference can be configured for a differential span of 1 V p-p (see Figure 34). It is recommended to place a 0.1 μF capacitor as close as possible to the VREF pin; a 10 μF capacitor is also required (see the PCB layout for guidance). If the internal reference of the AD9481 is used to drive multiple converters to improve gain matching, the loading of the reference by the other converters must be considered. Figure 34 depicts how the internal reference voltage is affected by loading.

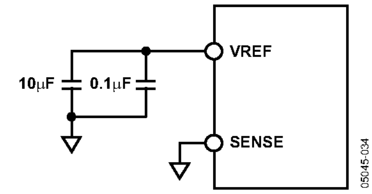

Figure 33. Internal Fixed Reference (1 V p-p)

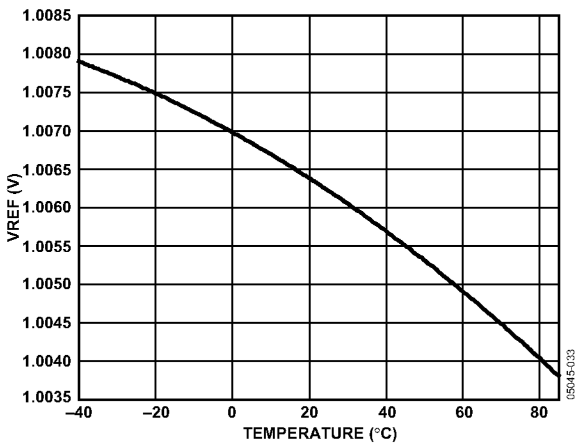

Figure 32. Typical Reference Variation with Temperature

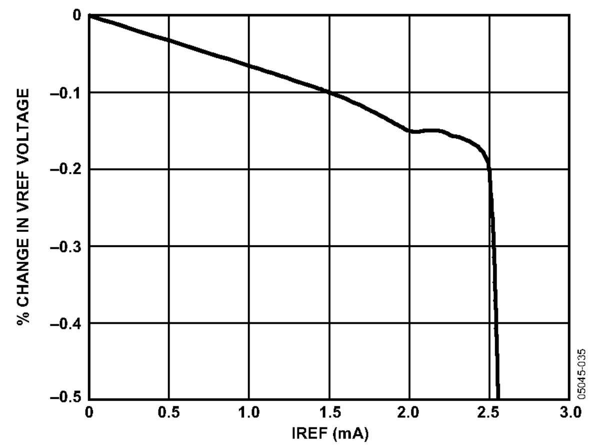

Figure 34. Internal VREF vs. Load Current

Table 8. Reference Configurations

SENSE Voltage	Resulting VREF	Reference	Differential Span
AVDD	N/A (external reference input)	External	1 × external reference voltage
0.5 V (Self-Biased)	0.5 × (1 + R1/R2) V	Programmable	1 × VREF (0.75 V p-p to 1.5 V p-p)
AGND to 0.2 V	1.0 V	Internal fixed	1 V p-p

External Reference

An external reference can be used for greater accuracy and temperature stability when required. The gain of the AD9481 can also be varied using this configuration. A voltage output DAC can be used to set VREF, providing for a means to digitally adjust the full-scale voltage. VREF can be externally set to voltages from 0.75 V to 1.5 V; optimum performance is typically obtained at VREF = 1 V. (See the Typical Performance Characteristics section.)

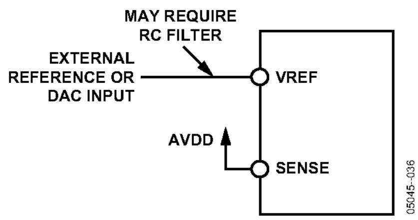

Figure 35. External Reference

Programmable Reference

The programmable reference can be used to set a differential input span anywhere between 0.75 V p-p and 1.5 V p-p by using an external resistor divider. The SENSE pin self-biases to 0.5 V, and the resulting VREF is equal to 0.5 × (1 + R1/R2). It is recommended to keep the sum of R1 + R2 ≥ 10 kΩ to limit VREF loading (for VREF = 1.5 V, set R1 equal to 7 kΩ and R2 equal to 3.5 kΩ).

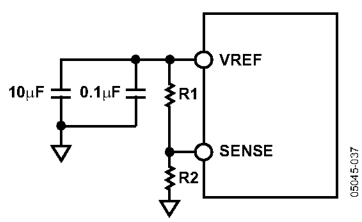

Figure 36. Programmable Reference

CLOCKING THE AD9481

Any high speed ADC is extremely sensitive to the quality of the sampling clock provided by the user. A track-and-hold circuit is essentially a mixer, and any noise, distortion, or timing jitter on the clock is combined with the desired signal at the A/D output. Considerable care has been taken in the design of the CLOCK input of the AD9481, and the user is advised to give commensurate thought to the clock source.

The AD9481 has an internal clock duty cycle stabilization circuit that locks to the rising edge of CLOCK and optimizes timing internally for sample rates between 100 MSPS and 250 MSPS. This allows for a wide range of input duty cycles at the input without degrading performance. Jitter on the rising edge of the input is still of paramount concern and is not reduced by the internal stabilization circuit. The duty cycle control loop does not function for clock rates less than 70 MHz nominally. The loop has a time constant associated with it that needs to be considered in applications where the clock rate can change dynamically, requiring a wait time of 5 µs after a dynamic clock frequency increase before valid data is available. The clock duty cycle stabilizer can be disabled at Pin 28 (S1).

The clock inputs are internally biased to 1.5 V (nominal) and support either differential or single-ended signals. For best dynamic performance, a differential signal is recommended. An MC100LVEL16 performs well in the circuit to drive the clock inputs (ac coupling is optional). If the clock buffer is greater than two inches from the ADC, a standard LVPECL termination may be required instead of the simple pull-down termination shown in Figure 37.

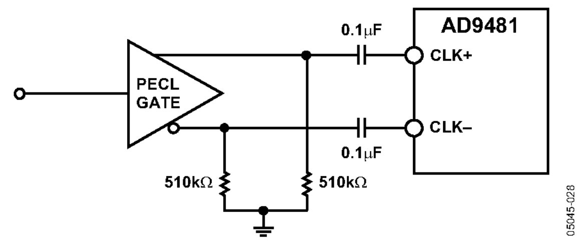

Figure 37. Clocking the AD9481

DS INPUTS

The data sync inputs (DS+, DS−) can be used in applications which require that a given sample appear at a specific output port (A or B) relative to a given external timing signal.

The DS inputs can also be used to synchronize two or more ADCs in a system to maintain phasing between Ports A and B on separate ADCs (in effect, synchronizing multiple DCO outputs).

The DS inputs are internally biased to 1.5 V (nominal) and support either differential or single-ended signals. When DS+ is held high (DS− low), the ADC data outputs and DCO outputs do not switch and are held static. Synchronization is accomplished by the assertion (falling edge) of DS+ within the timing constraints t_{SDS} and t_{HDS}, relative to a clock rising edge. (On initial synchronization, t_{HDS} is not relevant.) If DS+ falls within the required setup time (t_{SDS}) before a given clock rising edge N, the analog value at that point in time is digitized and available at Port A, eight cycles later in interleaved mode. The next sample, N + 1, is sampled by the next rising clock edge and available at Port B, eight cycles after that clock edge.

Driving each ADC's DS inputs by the same sync signal accomplishes synchronization between multiple ADCs. In applications which require synchronization, one-shot synchronization is recommended. An easy way to accomplish synchronization is by a one-time sync at power-on reset.

Table 9. S1 Voltage Levels

S1 Voltage	Data Format	Duty Cycle Stabilizer
(0.9 × *AVDD*) → *AVDD*	Offset binary	Disabled
(2/3 × *AVDD*) ± (0.1 × *AVDD*)	Offset binary	Enabled
(1/3 × *AVDD*) ± (0.1 × *AVDD*)	Twos complement	Enabled
AGND → (0.1 × *AVDD*)	Twos complement	Disabled

DIGITAL OUTPUTS

The CMOS digital outputs are TTL-/CMOS-compatible for lower power consumption. The outputs are biased from a separate supply (DRVDD), allowing easy interface to external logic. The outputs are CMOS devices that swing from ground to DRVDD (with no dc load). It is recommended to minimize the capacitive load the ADC drives by keeping the output traces short (< 2 inch, for a total C_{LOAD} < 5 pF). When operating in CMOS mode, it is also recommended to place low value series damping resistors on the data lines close to the ADC to reduce switching transient effects on performance.

Table 10. Output Coding (FS = 1 V)

Code	(VIN+) − (VIN−)	Offset Binary	Twos Complement
255	> +0.512 V	1111 1111	0111 1111
255	+0.512 V	1111 1111	0111 1111
254	+0.508 V	1111 1110	0111 1110
•	•	•	•
•	•	•	•
129	+0.004 V	1000 0001	0000 0001
128	+0.0 V	1000 0000	0000 0000
127	−0.004 V	0111 1111	1111 1111
•	•	•	•
•	•	•	•
2	−0.504 V	0000 0010	1000 0010
1	−0.508 V	0000 0001	1000 0001
0	−0.512 V	0000 0000	1000 0000
0	< −0.512 V	0000 0000	1000 0000

INTERLEAVING TWO AD9481s

Instrumentation applications may prefer to interleave (or ping-pong) two AD9481s to achieve twice the sample rate, or 500 MSPS. In these applications, it is important to match the gain and offset of the two ADCs. Varying the reference voltage allows the gain of the ADCs to be adjusted; external dc offset compensation can be used to reduce offset mismatch between two ADCs. The sampling phase offset between the two ADCs is extremely important as well and requires very low skew between clock signals driving the ADCs (< 2 ps clock skew for a 100 MHz analog input frequency).

DATA CLOCK OUT

A data clock is available at DCO+ and DCO−. These clocks can facilitate latching off-chip, providing a low skew clocking solution. The on-chip delay of the DCO clocks tracks with the on-chip delay of the data bits, (under similar loading) such that the variation between t_{PD} and t_{CPD} is minimized. It is recommended to keep the trace lengths on the data and DCO pins matched and 2 inches maximum. A series damping resistor at the clock outputs is also recommended. The DCO outputs can be disabled and placed in a high impedance state by tying S3 to ground (tie to AVDD for DCO active). Switching both into and out of high impedance is accomplished in 4 ns from S3 switching.

POWER-DOWN INPUT

The ADC can be placed into a low power state by setting the PDWN pin to AVDD. Time to go into (or come out of) power down equals 30 ns typically from PDWN switching.

AD9481 EVALUATION BOARD

The AD9481 evaluation board offers an easy way to test the device. It requires a clock source, an analog input signal, and a 3.3 V power supply. The clock source is buffered on the board to provide the clocks for the ADC and a data-ready signal. The digital outputs and output clocks are available at an 80-pin output connector, P3, P23. (Note that P3, P23 are represented schematically as two 40-pin connectors, and this connector is implemented as one 80-pin connector on the PCB.) The board has several different modes of operation and is shipped in the following configuration:

- Offset binary
- Internal voltage reference

POWER CONNECTOR

Power is supplied to the board via two detachable 4-pin power strips.

Table 11. Power Connector

Terminal	Comments
VDL (3.3 V)	Output supply for external latches and data ready clock buffer ~ 30 mA
AVDD[1] 3.3 V	Analog supply for ADC ~ 140 mA
DRVDD[1] 3.3 V	Output supply for ADC ~ 30 mA
VCTRL[1] 3.3 V	Supply for support clock circuitry ~ 60 mA
Op amp, ext. ref	Optional supply for op amp and ADR510 reference

[1] AVDD, DRVDD, VDL, and VCTRL are the minimum required power connections.

ANALOG INPUTS

The evaluation board accepts a 700 mV p-p analog input signal centered at ground at SMB Connector J3. This signal is terminated to ground through 50 Ω by R22. The input can be alternatively terminated at the T1 transformer secondary by R21 and R28. T1 is a wideband RF transformer that provides the single-ended-to-differential conversion, allowing the ADC to be driven differentially, minimizing even-order harmonics. An optional transformer, T4, can be placed if desired (remove T1, as shown in Figure 39 and Figure 40).

The analog signal can be low-pass filtered by R21, C8 and R28, C9 at the ADC input.

GAIN

Full scale is set by the sense jumper. This jumper applies a bias to the SENSE pin to vary the full-scale range; the default position is SENSE = ground, setting the full scale to 1 V p-p.

OPTIONAL OPERATIONAL AMPLIFIER

The PCB has been designed to accommodate an optional AD8351 op amp that can serve as a convenient solution for dc-coupled applications. To use the AD8351 op amp, remove R29, R31, and C3. Populate R12, R17, and R36 with 25 Ω resistors, and populate C1, C21, C23, C31, C39, and C30 with 0.1 μF capacitors. Populate R54, R10, and R11 with 10 Ω resistors, and R34 and R32 with 1 kΩ resistors. Populate R15 with a 1.2 kΩ resistor and R14 with a 100 Ω resistor. Populate R37 with a 10 kΩ resistor.

CLOCK

The clock input is terminated to ground through 50 Ω at SMA Connector J1. The input is ac-coupled to a high speed differential receiver (LVEL16) that provides the required low jitter, fast edge rates needed for best performance. J1 input should be > 0.5 V p-p. Power to the LVEL16 is set to VCTRL (default) or AVDD by jumper placement at the device.

OPTIONAL CLOCK BUFFER

The PCB has been designed to accommodate the SNLVDS1 line driver. The SNLVDS1 is used as a high speed LVDS-level optional encode clock. To use this clock, please remove C2, C5, and C6. Place 0.1 μF capacitors on C34, C35, and C26. Place a 10 Ω resistor on R48, and place a 100 Ω resistor on R6. Place a 0 Ω resistor on both R49 and R53. For best results using the line driver, J1 input should be > 2.5 V p-p.

DS

The DS inputs are available on the PCB at J2 and J4. If driving DS+ externally, place a 0 Ω resistor at C48 and remove R53.

OPTIONAL XTAL

The PCB has been designed to accommodate an optional crystal oscillator that can serve as a convenient clock source. The footprint can accept both through-hole and surface-mount devices, including Vectron XO-400 and Vectron VCC6 family oscillators.

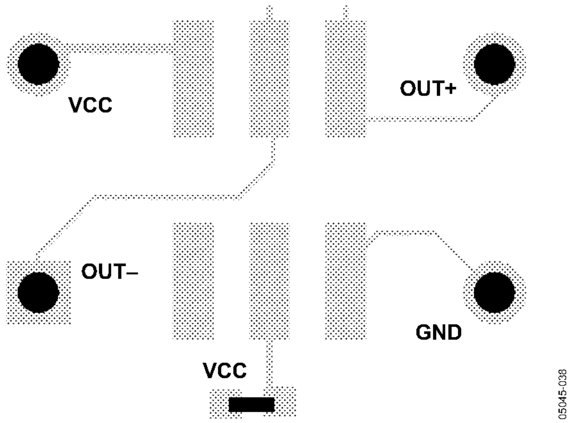

Figure 38. XTAL Footprint

To use either crystal, populate C38 and C40 with 0.1 μF capacitors. Populate R48 and R49 with 0 Ω resistors. Place R50, R51, R59, and R60 with 1 kΩ resistors. Remove C6 and C5. If the Vectron VCC6 family crystal is being used, populate R57 with a 10 Ω resistor. If using the XO-400 crystal, place jumper E21 or E22 to E23.

VOLTAGE REFERENCE

The AD9481 has an internal 1 V reference mode. The ADC uses the internal 1 V reference as the default when sense is set to ground. An optional on-board external 1.0 V reference (ADR510) can be used by setting the sense jumper to AVDD, by placing a jumper on E5 to E3, and by placing a 0 Ω resistor on R55. When using an external programmable reference, (R20, R30) remove the sense jumper.

DATA OUTPUTS

The ADC outputs are buffered on the PCB by LVT574 latches on the data outputs. The latch outputs have series terminating resistors at the output pins to minimize reflections.

EVALUATION BOARD BILL OF MATERIALS (BOM)

Table 12.

No.	Quantity	Reference Designator	Device	Package	Value
1	24	C1 to C6, C10 to C12, C14 to C15, C17 to C19, C22 to C29, C31, C48 to C49	Capacitors	0402	0.1 µF
2	1	C13	Capacitor	Tantalum (3528)	10 µF
3	5	C32 to C36	Capacitors	Tantalum (6032)	10 µF
4	4	J1 to J4	SMA	SMA	Degrees
5	3	P1, P12 to P13	4-pin power connectors	Post	Z5.531.3425.0
6	3	P1, P12 to P13	4-pin power connectors	Detachable connector	25.602.5453.0
7	2	P3, P23	80-pin connectors	Connector	TSW-140-08-L-D-RA
8	7	R1, R5, R19, R22, R27, R35, R53	Resistors	0603	50 Ω
9	8	R2 to R4, R6 to R9, R18, R14	Resistors	0603	100 Ω
10	7	R13, R42 to R45, R32, R34	Resistors	0603	1 kΩ
11	2	R16, R52	Resistors	0603	130 Ω
12	2	R23, R24	Resistors	0603	510 Ω
13	2	R25, R26	Resistors	0603	82 Ω
14	2	R29, R31	Resistors	0603	00 Ω
15	2	R33, R37	Resistors	0603	10 kΩ
16	1	R46	Resistor	0603	2 kΩ
17	3	R12, R17, R36	Resistors	0603	25 Ω
18	1	R15	Resistor	0603	1.2 kΩ
19	3	R54, R10 to R11	Resistors	0603	10 Ω
20	2	RP1 to RP2	Resistor Pack	100 Ω Res. Array	742C163100JTR
21	4	U3, U5 to U6, U8	Resistor Pack 100 Ω	100 Ω Res. Array	EXB-38V101JV
22	2	U4, U7	74LVT574	SO20	74LVT574WM
23	1	T1	Transformer	CD542	ADT1-1WT
24	1	U1	AD8351	MSOP-10	Op Amp
25	1	U2	74VCX86	SO-14	XOR
26	1	U10[1]	ADR510	SOT-23	Voltage Regulator
27	1	U9[1]	VCC6PECL6	VCC6-QAB-250M000	Vectron Crystal
28	1	U12	AD9481	TQFP-44	ADC
29	1	U11	MC100-LVEL16D	S08NB	Clock Buffer
30	1	T2[1]	ETC1-1-13	1-1 TX	M/A-COM/ETC 1-1-13
31	11	C1, C7 to C9, C16, C20, C30, C31, C38 to C40	Capacitors	0402	X[1]
32	18	R20 to R21, R28, R30, R38 to R41, R48 to R51, R55 to R60	Resistors	0603	X[1]
33	16	E98 to E102, E73 to E84	Jumpers		

[1] Not placed.

PCB SCHEMATICS

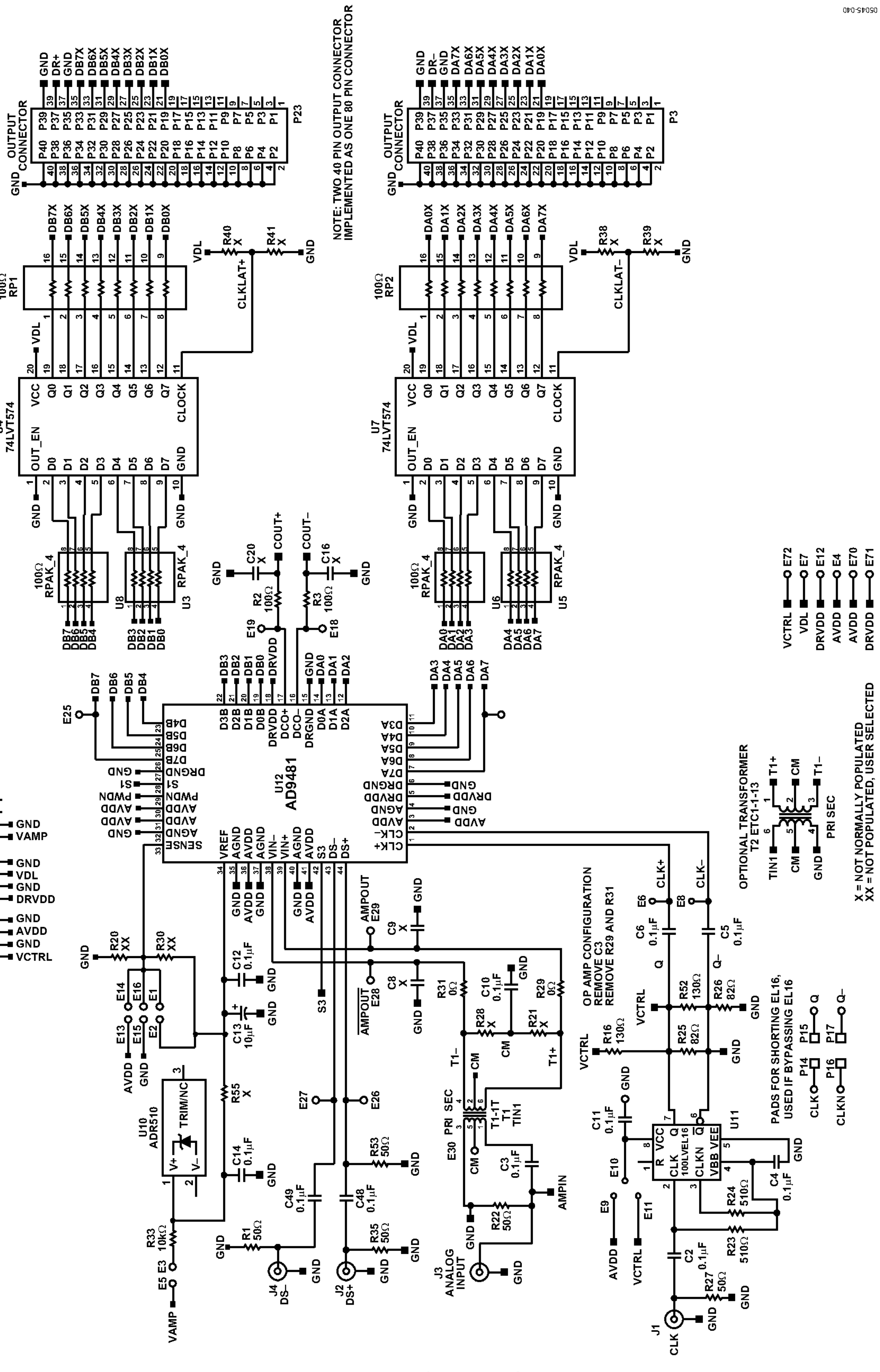

Figure 39. PCB Schematic (1 of 2)

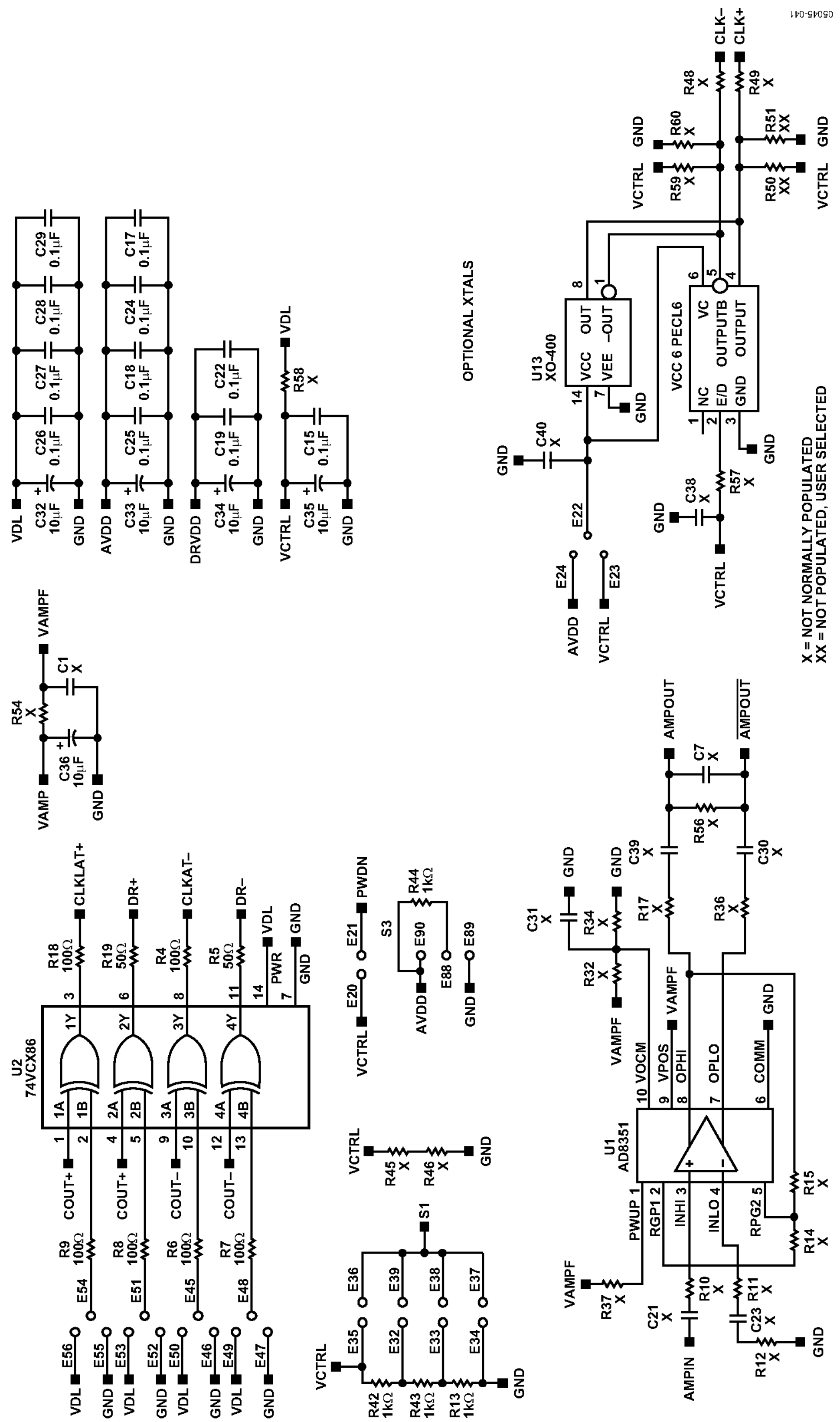

Figure 40. PCB Schematic (2 of 2)

PCB LAYERS

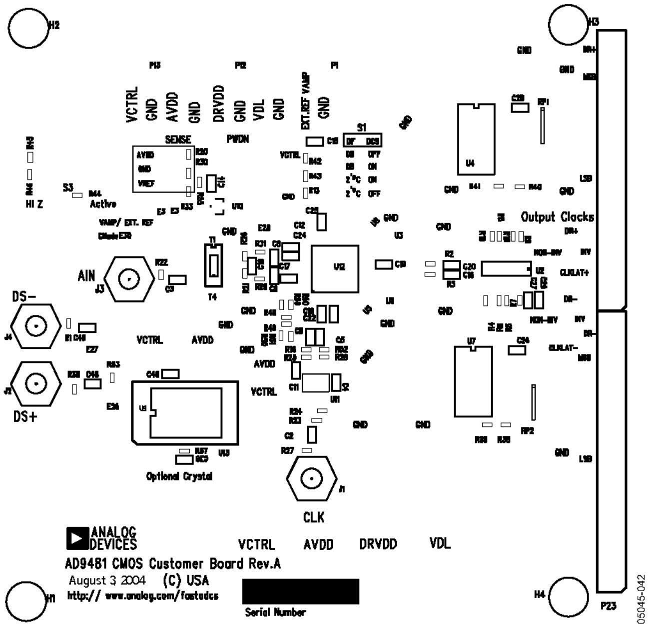

Figure 41. PCB Top-Side Silkscreen

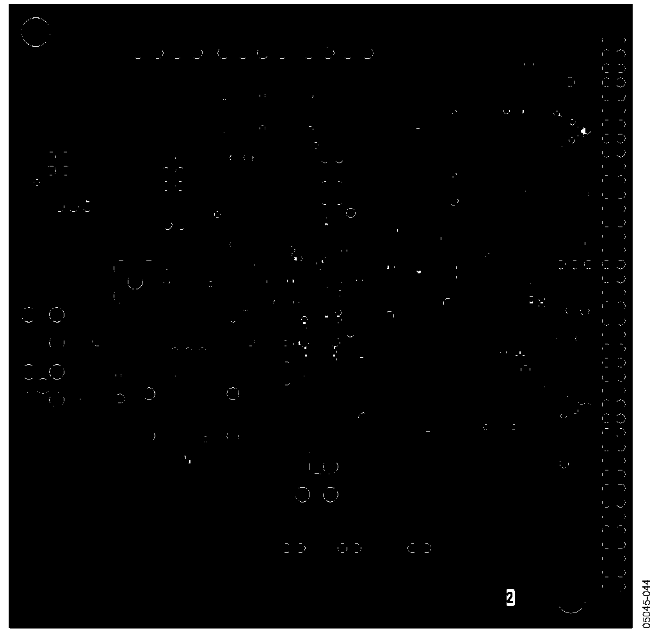

Figure 43. PCB Ground Layer

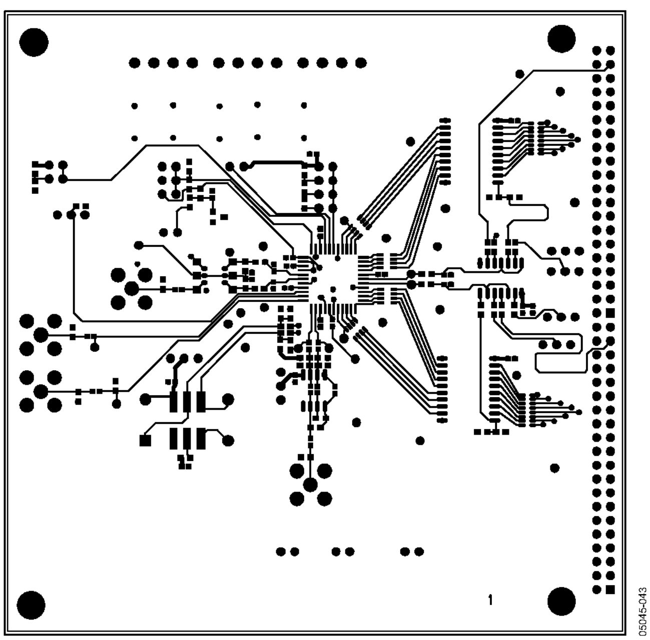

Figure 42. PCB Top-Side Copper Routing

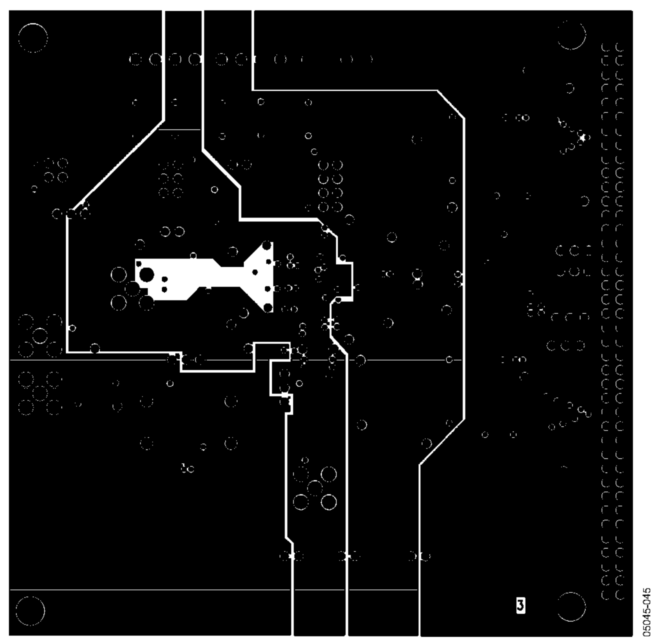

Figure 44. PCB Split Power Plane

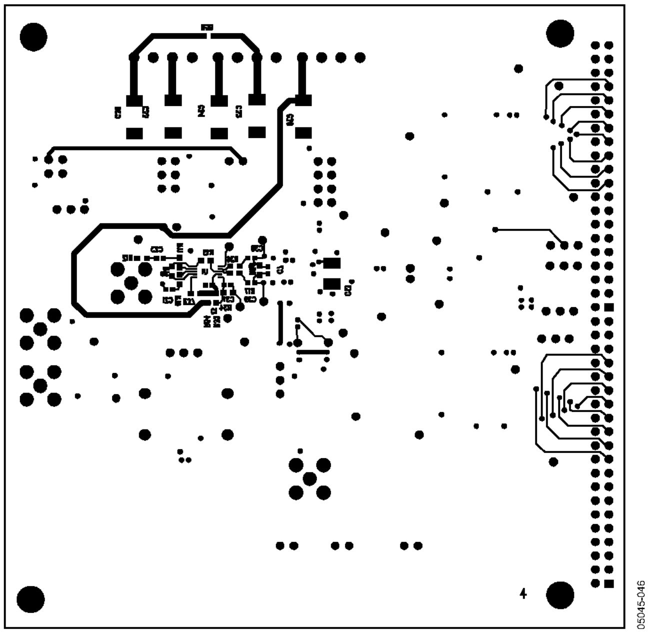

Figure 45. PCB Bottom-Side Copper Routing

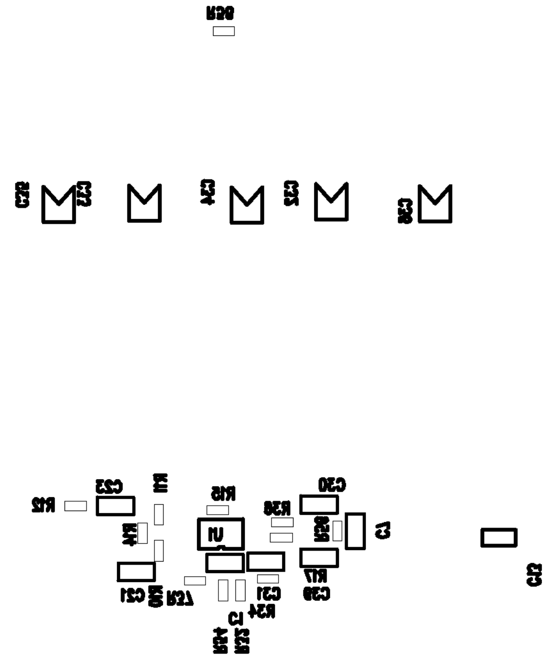

Figure 46. PCB Bottom-Side Silkscreen

OUTLINE DIMENSIONS

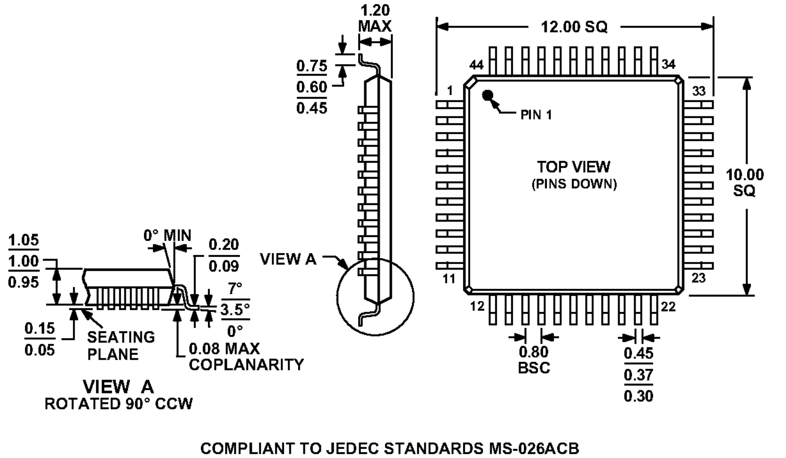

Figure 47. 44-Lead Thin Plastic Quad Flat Package [TQFP] (SU-44)—Dimensions shown in millimeters

ORDERING GUIDE

Model	Temperature Range	Package Description	Package Option
AD9481BSUZ-250[1]	−40°C to +85°C	44-Lead Thin Plastic Quad Flat Package (TQFP)	SU-44
AD9481-PCB[2]		Evaluation Board	

[1] Z = Pb-free part.
[2] Evaluation board shipped with AD9481BSUZ-250 installed.

D05045–0–10/04(0)

Electronic Patent Application Fee Transmittal

Application Number:	
Filing Date:	
Title of Invention:	System for sensing aircraft and other objects
First Named Inventor/Applicant Name:	Jed Margolin
Filer:	Jed Margolin
Attorney Docket Number:	

Filed as Small Entity

Utility under 35 USC 111(a) Filing Fees

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Basic Filing:				
Utility filing Fee (Electronic filing)	4011	1	82	82
Utility Search Fee	2111	1	270	270
Utility Examination Fee	2311	1	110	110
Pages:				
Claims:				
Independent claims in excess of 3	2201	4	110	440
Miscellaneous-Filing:				
Petition:				

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Patent-Appeals-and-Interference:				
Post-Allowance-and-Post-Issuance:				
Extension-of-Time:				
Miscellaneous:				
	Total in USD ($)			**902**

Electronic Acknowledgement Receipt

EFS ID:	8688736
Application Number:	12910779
International Application Number:	
Confirmation Number:	8875
Title of Invention:	System for sensing aircraft and other objects
First Named Inventor/Applicant Name:	Jed Margolin
Customer Number:	23497
Filer:	Jed Margolin
Filer Authorized By:	
Attorney Docket Number:	
Receipt Date:	22-OCT-2010
Filing Date:	
Time Stamp:	23:55:46
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	yes
Payment Type	Credit Card
Payment was successfully received in RAM	$902
RAM confirmation Number	5997
Deposit Account	
Authorized User	

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)

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3	Fee Worksheet (PTO-875)	jm_sense_fee.pdf	90402 32997defc361f4fbb68087deb398b6bc2074f244	no	1
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4	Specification	jm_sense_spec.pdf	199600 89e1fca68c9a5d1f8af12442bf1d4b0287dad496	no	42
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5	Claims	jm_sense_claims.pdf	42590 79f060f78b15da020311f4a813fdd91fb96b7ffa	no	14
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6	Abstract	jm_sense_abstract.pdf	10176 00660dbcece248fec5bcc24078228fd190321627	no	1
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7	Drawings-only black and white line drawings	jm_sense_figures.pdf	527114 4868251a3e3f1f4c4bcd96a06a06d290c5979b26	no	25
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New Applications Under 35 U.S.C. 111
If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

National Stage of an International Application under 35 U.S.C. 371
If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

New International Application Filed with the USPTO as a Receiving Office
If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

PTO/SB/06 (12-04)

Date: 10/22/10

Approved for use through 7/31/2006. OMB 0651-0032
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE

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PATENT APPLICATION FEE DETERMINATION RECORD

Substitute for Form PTO-875

Application or Docket Number: 12/910,779

APPLICATION AS FILED – PART I

FOR	NUMBER FILED (Column 1)	NUMBER EXTRA (Column 2)	SMALL ENTITY RATE ($)	SMALL ENTITY FEE ($)	OR	OTHER THAN SMALL ENTITY RATE ($)	OTHER THAN SMALL ENTITY FEE ($)
BASIC FEE (37 CFR 1.16(a), (b), or (c))	N/A	N/A	N/A	82		N/A	
SEARCH FEE (37 CFR 1.16(k), (i), or (m))	N/A	N/A	N/A	270		N/A	
EXAMINATION FEE (37 CFR 1.16(o), (p), or (q))	N/A	N/A	N/A	110		N/A	
TOTAL CLAIMS (37 CFR 1.16(i))	16 minus 20 =		x$26		OR	x$52	
INDEPENDENT CLAIMS (37 CFR 1.16(h))	7 minus 3 =	* 4	x$110	440		x$220	
APPLICATION SIZE FEE (37 CFR 1.16(s))	If the specification and drawings exceed 100 sheets of paper, the application size fee due is $260 ($130 for small entity) for each additional 50 sheets or fraction thereof. See 35 U.S.C. 41(a)(1)(G) and 37 CFR						
MULTIPLE DEPENDENT CLAIM PRESENT (37 CFR 1.16(j))			195			390	
			TOTAL	902		TOTAL	

* If the difference in column 1 is less than zero, enter "0" in column 2.

APPLICATION AS AMENDED – PART II

AMENDMENT A

	CLAIMS REMAINING AFTER AMENDMENT (Column 1)		HIGHEST NUMBER PREVIOUSLY PAID FOR (Column 2)	PRESENT EXTRA (Column 3)	SMALL ENTITY RATE ($)	SMALL ENTITY ADDITIONAL FEE ($)	OR	OTHER THAN SMALL ENTITY RATE ($)	OTHER THAN SMALL ENTITY ADDITIONAL FEE ($)
Total (37 CFR 1.16(i))	*	Minus	**	=	x =		OR	x =	
Independent (37 CFR 1.16(h))	*	Minus	***	=	x =		OR	x =	
Application Size Fee (37 CFR 1.16(s))									
FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))					N/A		OR	N/A	
					TOTAL ADD'T FEE		OR	TOTAL ADD'T FEE	

OR

AMENDMENT B

	CLAIMS REMAINING AFTER AMENDMENT (Column 1)		HIGHEST NUMBER PREVIOUSLY PAID FOR (Column 2)	PRESENT EXTRA (Column 3)	SMALL ENTITY RATE ($)	SMALL ENTITY ADDITIONAL FEE ($)	OR	OTHER THAN SMALL ENTITY RATE ($)	OTHER THAN SMALL ENTITY ADDITIONAL FEE ($)
Total (37 CFR 1.16(i))	*	Minus	**	=	x =		OR	x =	
Independent (37 CFR 1.16(h))	*	Minus	***	=	x =		OR	x =	
Application Size Fee (37 CFR 1.16(s))									
FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))					N/A		OR	N/A	
					TOTAL ADD'T FEE		OR	TOTAL ADD'T FEE	

* If the entry in column 1 is less than the entry in column 2, write "0" in column 3.
** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20".
*** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, enter "3".
The "Highest Number Previously Paid For" (Total or Independent) is the highest number found in the appropriate box in column 1.