US 20120223811A1

(19) United States
(12) Patent Application Publication
Wild et al.

(10) Pub. No.: US 2012/0223811 A1
(43) Pub. Date: Sep. 6, 2012

(54) MULTIPLE ANTENNA LOCALIZING

(75) Inventors: **Ben J. Wild**, San Francisco, CA (US); **Artem Tkachenko**, San Francisco, CA (US); **Steve Wang**, Mickelton, NJ (US); **Robert Barton**, San Jose, CA (US)

(73) Assignee: **CHECKPOINT SYSTEMS, INC.**, Philadelphia, PA (US)

(21) Appl. No.: **13/039,405**

(22) Filed: **Mar. 3, 2011**

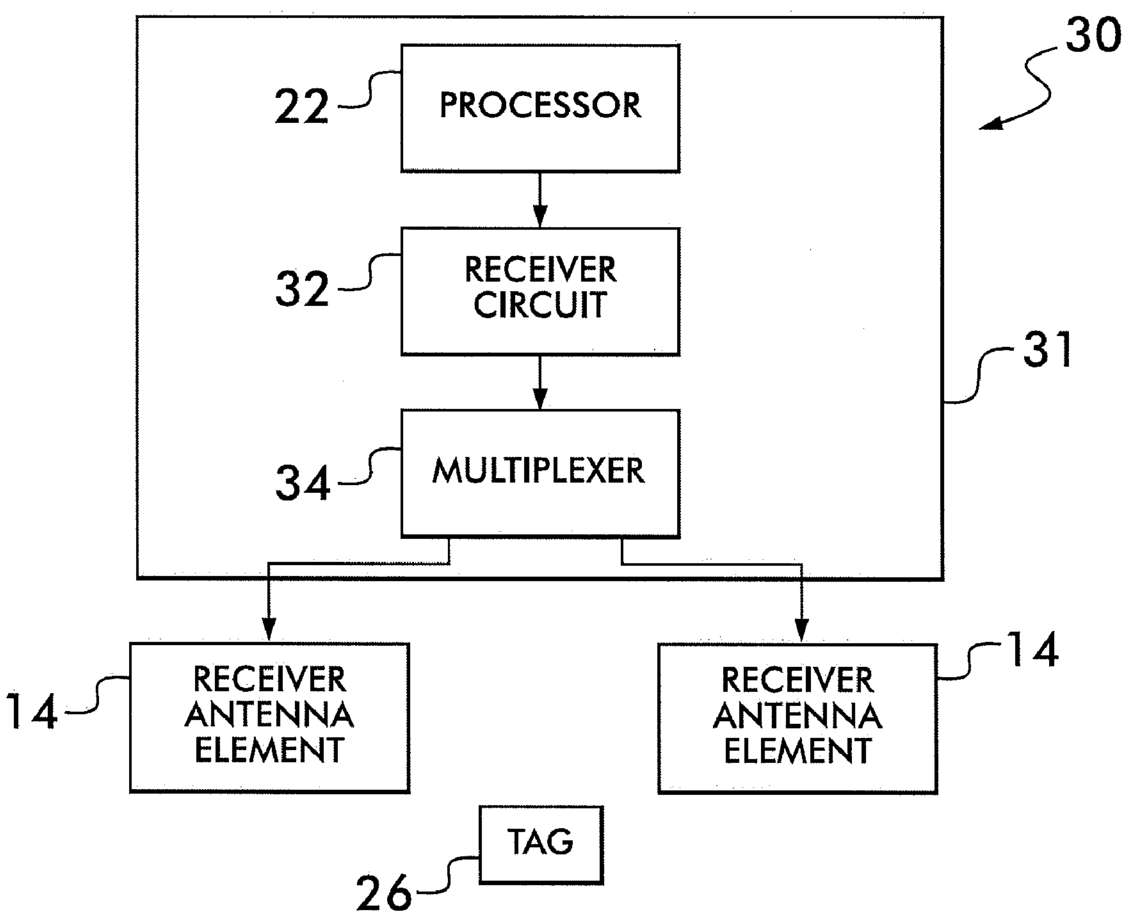
Publication Classification

(51) **Int. Cl.**
H04Q 5/22 (2006.01)

(52) **U.S. Cl.** **340/10.1**

(57) **ABSTRACT**

A reader includes a single receiver circuit and a switching circuit coupled to the single receiver circuit. A first antenna connection is coupled to the switching circuit, wherein the first antenna connection is configured to receive a first signal from a source of radio frequency waves. A second antenna connection is coupled to the switching circuit and configured to receive a second signal from the source of radio frequency waves. A processor is configured to determine angle of arrival information in accordance with the first and second signals. The processor is further configured to determine relative phase information in accordance with the first and second signals. Additionally, the processor is configured to localize the source of radio frequency waves in accordance with the angle of arrival information. The switching circuit includes a multiplexer selectively coupling the first and second antenna connections to the single receiver circuit.



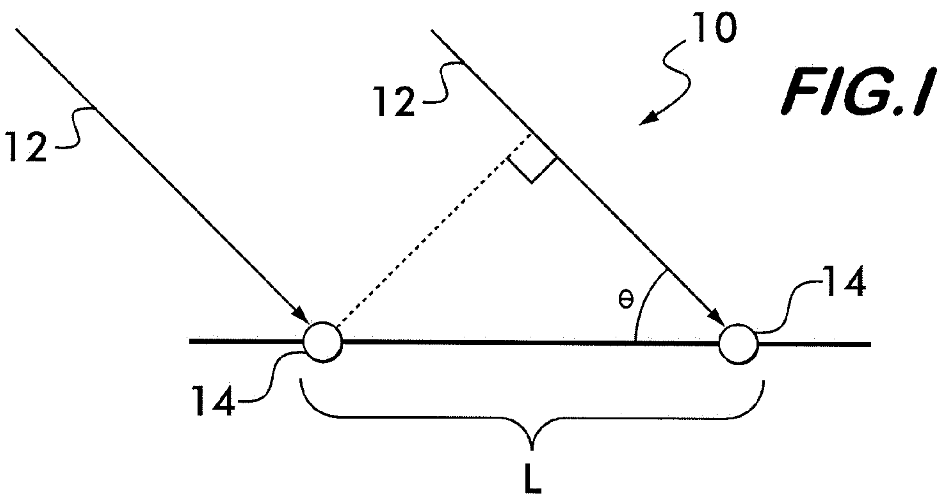


FIG.1

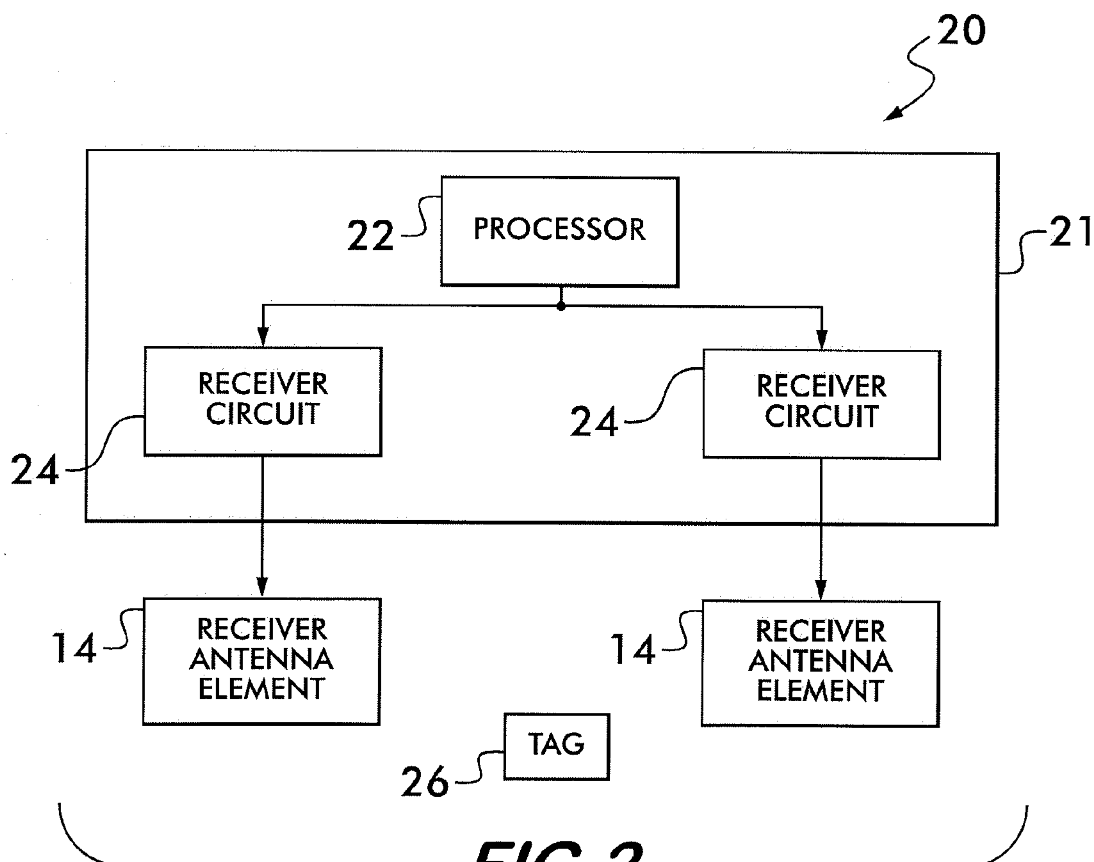
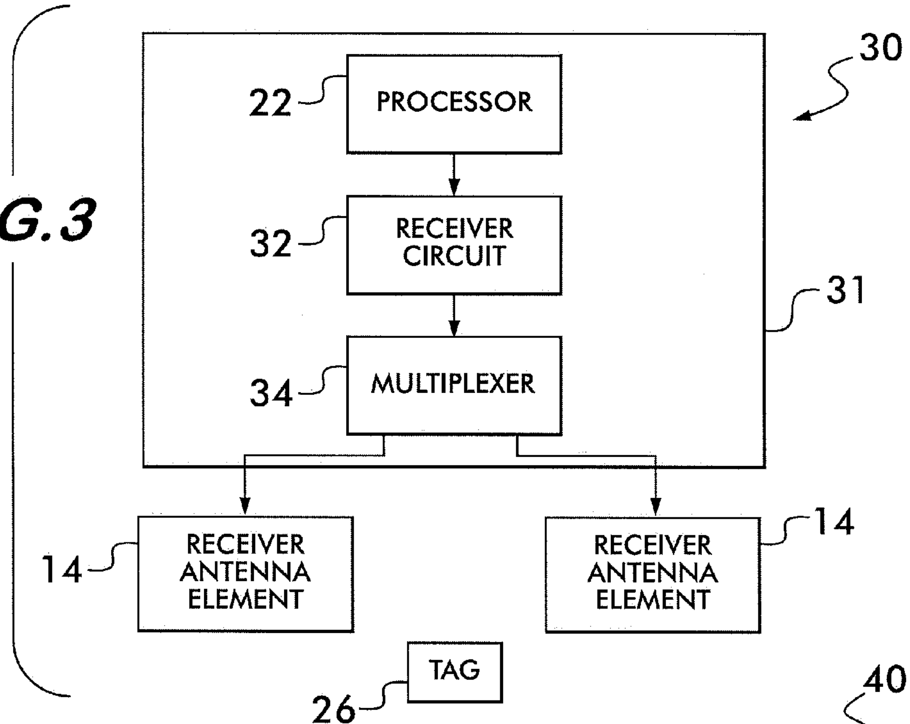


FIG.2
(PRIOR ART)

FIG. 3


30
22
PROCESSOR
32
RECEIVER CIRCUIT
31
34
MULTIPLEXER
14
RECEIVER ANTENNA ELEMENT
14
RECEIVER ANTENNA ELEMENT
TAG
26

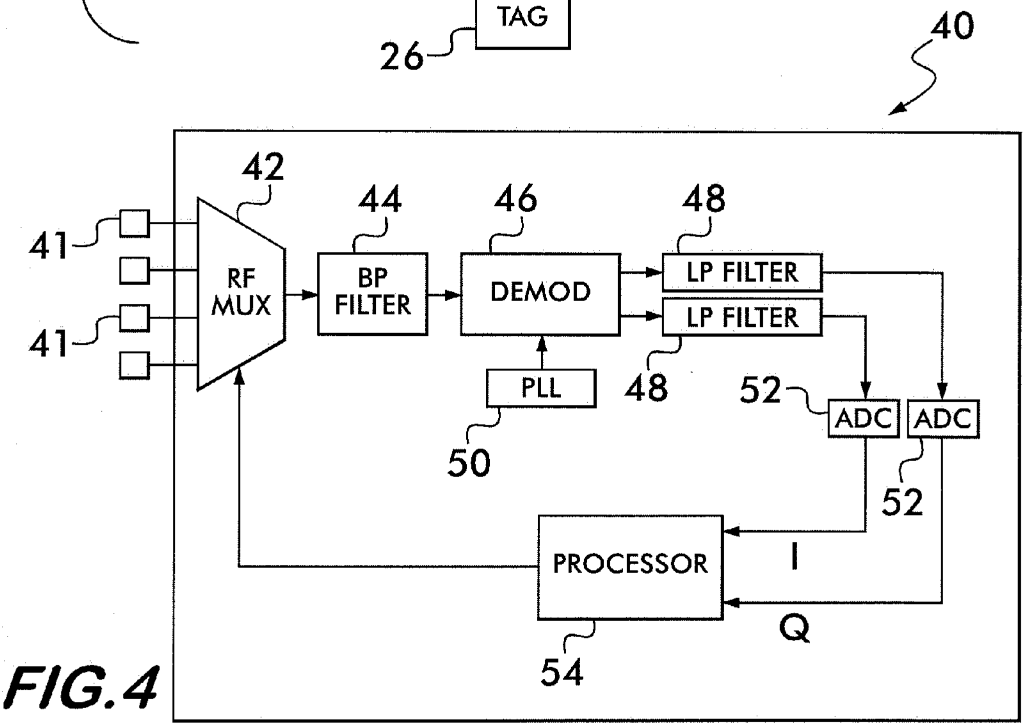

40
42
41
41
RF MUX
44
BP FILTER
46
DEMOD
48
LP FILTER
LP FILTER
48
PLL
50
52
ADC
ADC
52
PROCESSOR
54
I
Q

FIG. 4

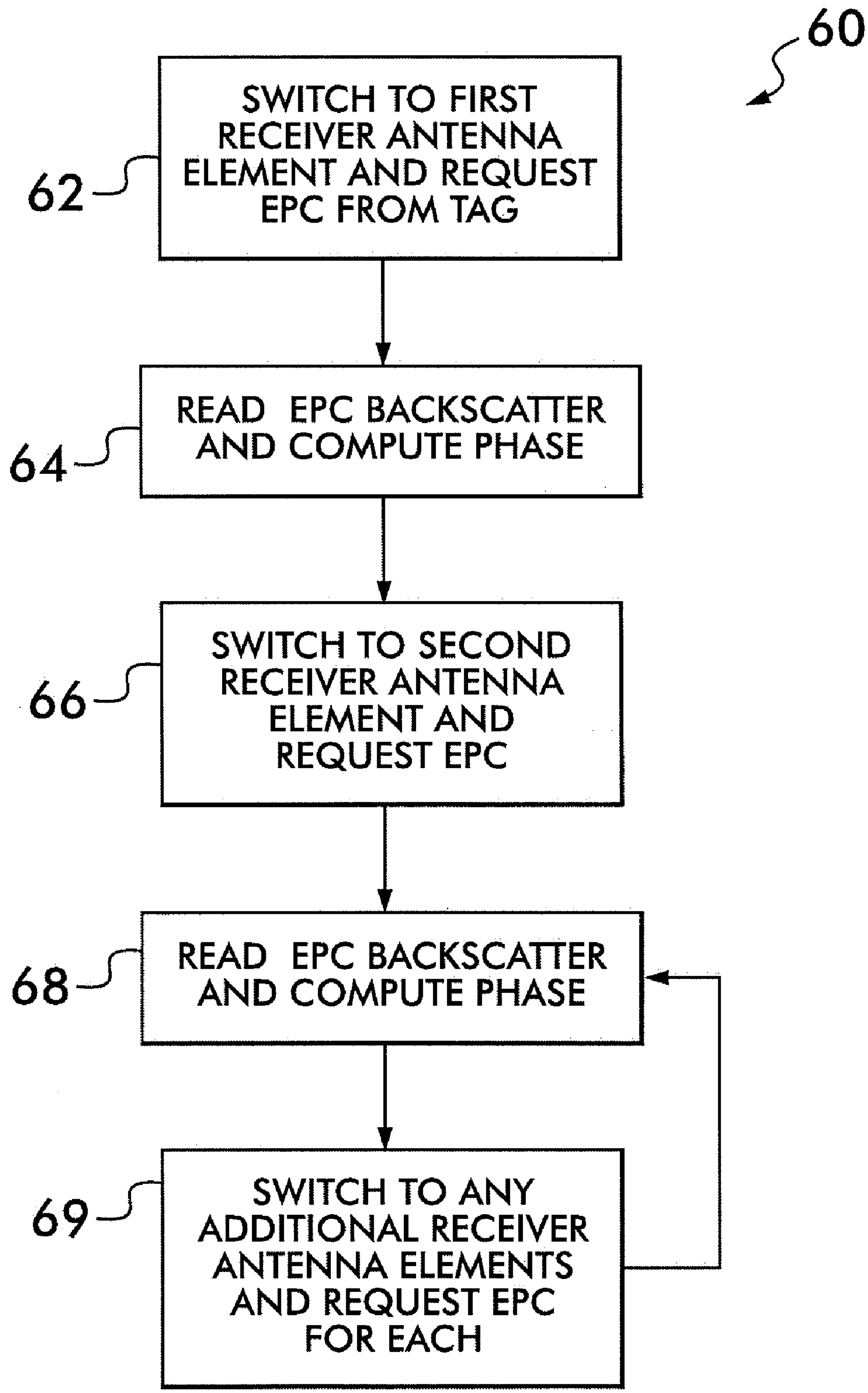

60
62
SWITCH TO FIRST RECEIVER ANTENNA ELEMENT AND REQUEST EPC FROM TAG
64
READ EPC BACKSCATTER AND COMPUTE PHASE
66
SWITCH TO SECOND RECEIVER ANTENNA ELEMENT AND REQUEST EPC
68
READ EPC BACKSCATTER AND COMPUTE PHASE
69
SWITCH TO ANY ADDITIONAL RECEIVER ANTENNA ELEMENTS AND REQUEST EPC FOR EACH

FIG. 5

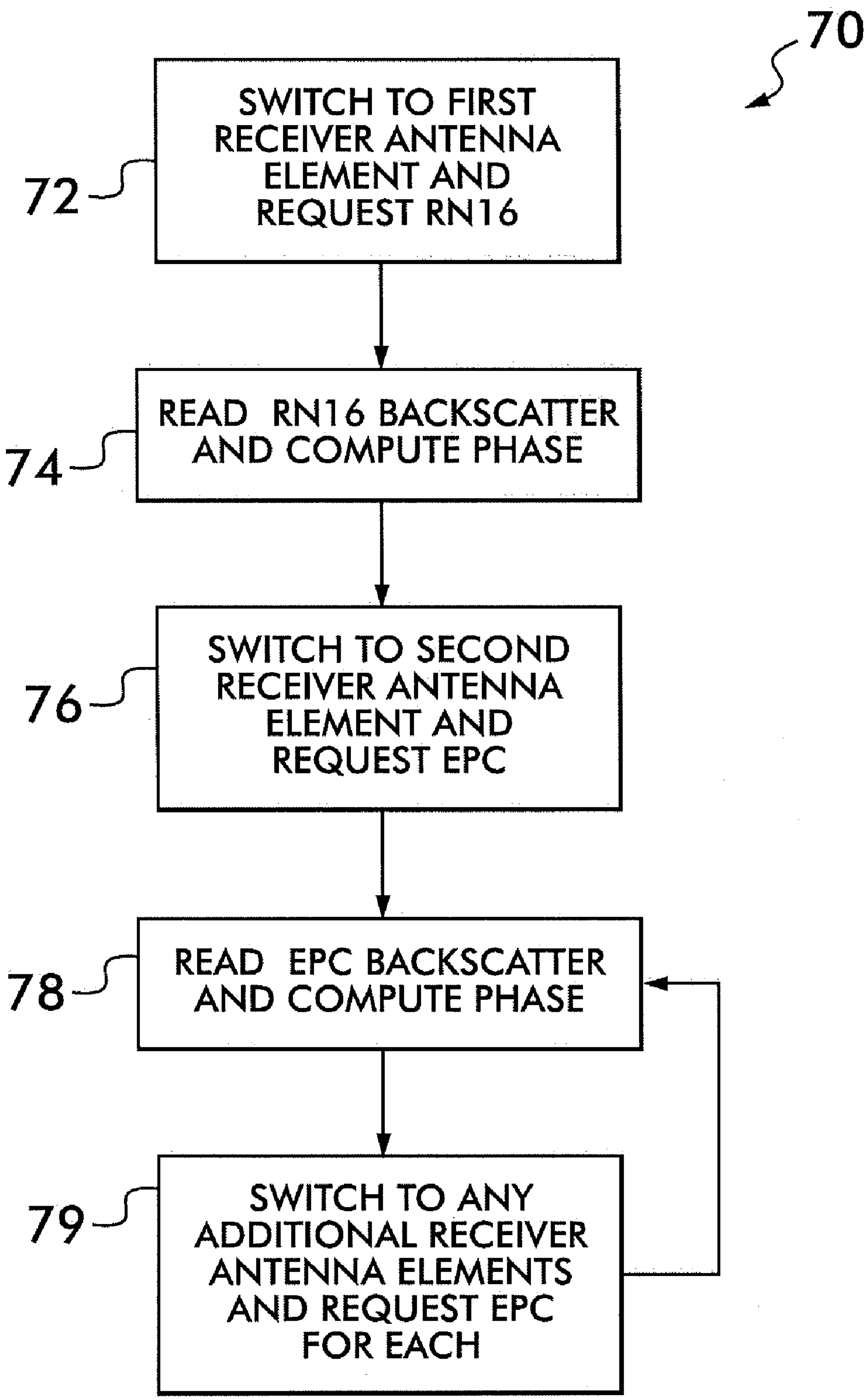

70
72
SWITCH TO FIRST RECEIVER ANTENNA ELEMENT AND REQUEST RN16
74
READ RN16 BACKSCATTER AND COMPUTE PHASE
76
SWITCH TO SECOND RECEIVER ANTENNA ELEMENT AND REQUEST EPC
78
READ EPC BACKSCATTER AND COMPUTE PHASE
79
SWITCH TO ANY ADDITIONAL RECEIVER ANTENNA ELEMENTS AND REQUEST EPC FOR EACH

FIG. 6

MULTIPLE ANTENNA LOCALIZING

BACKGROUND OF THE INVENTION

[0001] 1. Field of Invention

[0002] The present invention generally relates to the field of RFID communication systems, and more particularly, to a system and method for localizing sources of radio frequency waves within RFID communication systems.

[0003] 2. Description of Related Art

[0004] RFID technology has been applied in many different applications to improve business efficiencies. RFID tags are typically associated with assets, and the asset tags are read by RFID readers as they move through a supply chain. As RFID technology has improved over the years, the read range of RFID tags has increased significantly. Furthermore, it is expected that the read range of RFID tags will continue to increase in the future as the technology continues to improve. This has driven the development of new technologies that can determine the position of RFID tags with a higher degree of accuracy.

[0005] Several technologies for positioning tags are currently known in the art. For example, phased array antennas have been used to obtain the angle of arrival of tag backscatter signals from RFID tags. The angle of arrival information of the backscatter signals can be used to estimate the positioning information of the RFID tags. When phased arrays are used to obtain the angle of arrival of the tag backscatter signals in this manner the positioning information of the tags can be obtained more accurately.

[0006] However, a major disadvantage of using a phased array for obtaining the angle of arrival information in this manner in the known art is that it requires an RFID reader with multiple receiver chains, where each receiver in the RFID reader is connected to a separate antenna element in the antenna array. While this can significantly improve the accuracy of the positioning information obtained, it also significantly increases the costs of the readers since the RFID receivers can be very expensive. Furthermore, most of the RFID communication systems on the market include single receiver readers. Therefore, it would be useful to allow users of new and existing RFD) systems to obtain angle of arrival information, and thus RFID tag positions, using the lower cost single receiver RFID readers.

[0007] US. Pat. Pub. No. US2002/0190845 A1 published Dec. 19, 2002 by Moore discloses an RFID communications system for locating objects with tags in which remote sensing antennas are placed at locations to be monitored for the presence of tags. In the system taught by Moore scanning interrogators with multiplexed antenna inputs are connected to the remote sensing antennas. One antenna at a time is activated by a multiplexer, and a common detection circuit is used for detecting the proximity of RFID tags. Each RFID antenna has a known location, and when an RFID tag is read by an antenna the known location of the antenna is used to indicate a region in which the tag is located. However, the RFID communications system disclosed by Moore does not permit a determination of the tag position based on the angle of arrival information using a reader with a single receiver.

[0008] U.S. Pat. Pub. No. US2005/0273218 A1 by Breed published Dec. 8, 2005 discloses a system for obtaining information about components in a car. In the Breed system multiple antennas and multiple sensors and switches are provided for reading RFID tags located in different areas of the car. Multiplexing can be used with the antennas in the Breed system, and correlation of the signals received by the antennas can be used to isolate signals based on the direction of the signals. Additionally, the phase shifts of a SAW accelerometer are measured with a single antenna, and signals from multiple transmitting devices are spatially multiplexed to allow more than one device to communicate at the same time and frequency.

[0009] Additionally, U.S. Pat. Pub. No. US2010/0039228 A1 published Feb. 18, 2010 by Sadr discloses an RFID communication system using multiple receiver antennas to estimate RFID tag location. U.S. Pat. Pub. No. US2007/0106897 A1 published May 10, 2007 by Kulakowski discloses a system using a multiplexer to couple RFID reader circuitry to one of two antennas. WO2010/129833 A1 by Johnson discloses a system having a plurality of RFID antennas disposed in mating connectors multiplexed to an RFID transceiver.

[0010] However, none of the foregoing RFID communications systems permit users to determine angle of arrival information or positioning information using a relatively inexpensive single receiver RFID reader.

[0011] All references cited herein are incorporated herein by reference in their entireties.

BRIEF SUMMARY OF THE INVENTION

[0012] Summary information will be provided when claims are finalized.

BRIEF DESCRIPTION OF SEVERAL VIEWS OF THE DRAWINGS

[0013] The invention will be described in conjunction with the following drawings in which like reference numerals designate like elements and wherein:

[0014] FIG. **1** shows a schematic representation of radio frequency waves incident upon receiver antenna elements of an antenna array.

[0015] FIG. **2** shows a block diagram representation of a prior art angle of arrival measurement system for localizing a source of radio frequency waves in an RFID communication system.

[0016] FIG. **3** shows a block diagram representation of an angle of arrival measurement system for localizing a source of radio frequency waves suitable for use with the system and method of the present invention.

[0017] FIG. **4** shows a more detailed schematic representation of an angle of arrival measurement reader for localizing a source of radio frequency waves suitable for use with the system and method of the present invention.

[0018] FIG. **5** shows a flow chart representation of a preferred embodiment of the system and method of the present invention.

[0019] FIG. **6** shows a flow chart representation of an alternate preferred embodiment of the system and method of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

[0020] Referring now to FIG. **1**, there is shown a schematic representation **10** of radio frequency waves **12** from an RFID source incident upon receiver antenna elements **14** of a receiver antenna array. The receiver antenna elements **14** are spaced a distance L apart from each other. The schematic representation **10** is useful for illustrating a system and method for determining angle of arrival (AOA) information in RFID communications systems. Angle of arrival measurement is a method for determining the direction of propagation of radio frequency waves, such as the radio frequency waves **12**, incident upon the receiver antenna elements **14** of an RFID antenna array.

[0021] Furthermore, angle of arrival measurements obtained using the schematic representation **10** can be used to determine the direction of propagation of the radio frequency waves **12** by measuring the time difference of arrival (TDOA) at the individual receiver elements **14** of the antenna array. Based upon the delays indicated by the TDOA measured at the individual receiver antenna elements **14**, the direction of propagation of the radio frequency waves **12** can be calculated. For narrowband systems, the TDOA measurement can be made by measuring the difference in the received phases at each of the receiver antenna elements **14** in a multiantenna array. With an antenna array consisting of the two receiver antenna elements **14** mounted along a line as shown in the schematic representation **10**, it is possible to measure a single angle of arrival of the radio frequency waves **12**.

[0022] Referring now to FIG. **2**, there is shown a block diagram representation of a prior art angle of arrival measurement system **20**. The angle of arrival measurement system **20** has an RFID reader **21** and two receiver antenna elements **14** for receiving the radio frequency waves **12** from an RFID source such as the RFID tag **26**, as shown in the schematic representation **10**. Therefore, the angle of arrival measurement system **20** can be used to estimate the angle of arrival of backscattered radio frequency signals **12** from a source of radio frequency signals, such as an RFID tag **26**. Additionally, the angle of arrival measurement system **20** can approximately position the RFID tag **26** using the estimated angle of arrival information.

[0023] The RFID reader **21** of the angle of arrival system **20** includes two receiver circuits **24** and a processor **22**. Each of the receiver circuits **24** is coupled to one of the receiver antenna elements **14**, so that each receiver circuit **24** can process the signals received by one of the receiver antenna elements **14**. The two receiver circuits **24** are also coupled to the processor **22**. The processor **22** can perform the operations on the signals received from the RFD source by way of the receiver antenna elements **14** and the receiver circuits **24**, as required for estimating the angle of arrival information and the position information of the RFID tag **26**.

[0024] If the RFID tag **26** providing the backscatter signals to the angle of arrival measurement system **20** is far enough away from the receiver antenna elements **14**, it can be assumed that the radio frequency waves **12** arrive at the antenna array as a plane wave. Under these circumstances the radio frequency signals **12** arrive substantially parallel to the receiver antenna array. This assumption is valid if the distance from the RFID tag **26** to the receiver antenna elements **14** is on the order of ten times larger than the distance L between the individual receiver antenna elements **14**.

[0025] It is well known to those skilled in the art that the relationship between the angle of arrival, θ, of the radio frequency waves **12** at an antenna array, and the phase difference, ϕ, between the signals received by the receiver antenna elements **14** of the antenna array can be expressed by the following equations:

$$\phi = \frac{\cos(\theta)L}{\lambda}2\pi \tag{1}$$

-continued

$$\theta = \cos^{-1}\left(\frac{\phi\cdot\lambda}{2\pi L}\right) \tag{2}$$

where λ is the wavelength of the radio frequency waves **12**.

[0026] Furthermore, there is a unique one to one relationship between the angle of arrival θ and the phase difference ϕ as long as the antenna spacing L is less than half the wavelength λ of the incident radio frequency waves **12**. That is, there is a one to one relationship between the angle of arrival θ and the phase difference ϕ if $L \leqq \lambda/2$. Typically, if there is noise present in the system the angle of arrival estimate is more accurate when the antenna spacing is larger. Thus, a spacing of λ/2 between the receiver antenna elements **14** is typically chosen as the antenna spacing. With an antenna spacing of $L=\lambda/2$, the relationship between the angle of arrival θ of the radio frequency waves **12** and the phase difference ϕ at the receiver antenna elements **14** can be expressed by the following equations:

$$\phi=\cos(\theta)\cdot\pi \tag{3}$$

$$\theta = \cos^{-1}\left(\frac{\phi}{\pi}\right). \tag{4}$$

Thus, an estime of the angle of arrival and the location of the source of radio frequency waves **12** can be performed using this method. However, in this method a separate receiver circuit **24** is required for each receiver antenna element **14**. Therefore, obtaining angle of arrival information in this manner is very expensive.

[0027] Referring now to FIG. **3**, there is shown a block diagram representation of an embodiment of an angle of arrival measurement system **30** of the present invention. The angle of arrival measurement system **30** can be used to determine the angle of arrival of radio frequency signals, for example the radio frequency waves **12** from the RFID tag **26**. Additionally, the angle of arrival measured by the measurement system **30** can be used for positioning the RFID tag **26**. It will be understood that the angle of arrival measurement system **30** can be used for determining angle of arrival information and positioning information for any other type of device transmitting RF signals, for example other RFID readers.

[0028] The angle of arrival measurement system **30** includes an RFID reader **31** and two receiver antenna elements **14**. Any type of reader circuitry known to those skilled in the art can be used in the RFID reader **31** of the angle of arrival measurement system **30**. For example, the RFID reader **31** can be a conventional RFID reader for performing inventory rounds in a retail store having a large number of RFID tags fixed to assets in order to deter theft of the assets. In such inventory rounds tag populations can be queried for the contents of the memories of the tags. For example, the tags in the tag population can be queried for their Electronic Product Codes (EPC).

[0029] However, the RFID reader **31** within the angle of arrival system **30** can also include a single receiver circuit **32**. Additionally, the RFID reader **31** can include a multiplexer **34** or other switching circuitry, which is coupled to the single receiver circuit **32**. The multiplexer **34** is also coupled to the two receiver antenna elements **14**. Therefore, the multiplexer **34** can alternately couple the signals received by each of the receiver antenna elements **14** to the single receiver circuit **32**. Therefore, the signals received by the receiver antenna elements **14** can be alternately processed by the single receiver circuit **32**, and applied to the processor **22** within the RFID reader **31**, for positioning the RFID tag **26** or other source of radio frequency waves.

[0030] In alternate embodiments of the angle of arrival measurement system **30**, any number of receiver antenna elements **14** can be multiplexed onto the single receiver circuit **32** by the multiplexer **34**, for localizing the source of RFID signals using angle of arrival information obtained from the receiver antenna elements **14**. Additionally, in other alternate embodiments (not shown) any number of multiplexers **32** or other switching circuits can be used to multiplex the receiver antenna elements **14** onto the single receiver circuit **32**. Furthermore, in another alternate embodiment of the invention (not shown), a plurality of receiver antenna elements **14** can be multiplexed onto a receiver circuit **32** of a multi receiver circuit RFID reader.

[0031] Referring now to FIG. **4**, there is shown a more detailed schematic representation of a possible embodiment of an RFID reader **40** of the present invention. The RFID reader **40** is suitable for use in the angle of arrival measurement system **30**. The RFID reader **40** can have direct downconversion circuitry suitable for determining the angle of arrival information of radio frequency signals such as the radio frequency waves **12**, from a source such as another RFID reader or the RFID tag **26**. Additionally, the angle of arrival information measured by the angle of arrival measurement system **40** can be used by the RFID reader **40** for determining the position of the source of the radio frequency waves **12**.

[0032] The RFD reader **40** can include a multiplexer **42** or other switching circuitry, which can be coupled to the reader input ports **41**. The reader input ports **41** can be any type of antenna connections that can to be coupled to receiver antenna elements of an antenna array, such as the receiver antenna elements **14**. In the embodiment of the RFID reader **40** four input ports **41** are shown for the purpose of illustration. However, it will be understood that the RFID reader **40** according to the invention can have any number of reader input ports **41** greater than two. The multiplexer **24** can multiplex the incoming backscatter signals received from the RFID tag **26**, by way of the receiver antenna elements **14** and the reader input ports **41**, onto the downconversion circuitry of the RFID reader **40** for processing.

[0033] The bandpass filter **44** within the RFID reader **40** receives the multiplexed antenna signal from the multiplexer **42**. The filtering by the bandpass filter **44** can prevent unwanted out of band signals from jamming the circuitry of the RFID reader **40**. After bandpass filtering, the signal is downconverted to baseband using a quadrature demodulator **46**. The quadrature demodulator **46** mixes the incoming backscatter signal received from the bandpass filter **44** with an RF signal generated by a phase locked loop **50**. The downconverted signal from the quadrature demodulator **46** can be centered at 0 Hz. Furthermore, the downconverted signal can be split into two component signals: an in phase component I and a quadrature component Q. The I and Q component signals are 90 degrees out of phase with each other.

[0034] By measuring the amplitude of the I and Q components, an absolute phase of the incoming backscatter signals received by the multiplexed receiver antenna elements **14** can be calculated. In a preferred embodiment the measurement can be made in the digital domain. Therefore, the I and Q components can be low pass filtered separately by the respective low pass filters **48**. The low pass filtered I and Q signals can then be digitized by respective analog to digital converters **52**. The resulting digitized I and Q signals from the analog to digital converters **52** can then be applied to a processor **54**. The processor **54** can then compute the absolute phase of the input radio frequency waves **12**. The absolute phase of a single input radio frequency wave **12** can be calculated as:

$$\text{phase} = \tan^{-1}\left(\frac{Q}{I}\right) \tag{5}$$

where I is the amplitude of the in phase component and Q is the amplitude of the quadrature component. However, as previously described, the angle of arrival measurements necessary for localizing a source of radio frequency waves require the determination of the relative phases between the signals received at the receiver antenna elements **14**. The absolute phase of the signals does not provide enough information by itself.

[0035] Referring now to FIG. **5**, there is shown a flowchart representation of an RF source localizing method **60** for localizing sources of radio frequency signals in RFID communications systems using a single receive channel according to the invention. For example, the RF source localizing method **60** can be used by the processor **54** of the RFID reader **40** to localize a source of radio frequency waves **12** such as the RFID tag **26**.

[0036] It is well known to those skilled in the art that RFID readers such as the RFID reader **40** can obtain a signal such as an EPC from an RFID tag **26** by transmitting a request signal to the RFID tag **26**. The request signal from the RFID reader **40** causes the RFID tag **26** to transmit a backscatter response signal containing the EPC or other information associated with the RFID tag **26**. Therefore, in this embodiment of the invention, a switching circuit such as the multiplexer **42** of the RFID reader **40** can switch to a first receiver antenna element **14**, and request a backscatter signal such as an EPC signal from the RFID tag **26** as shown in block **62**. The backscattered EPC response signal from the RFID tag **26** can be read by the RFID reader **40** using the first receiver antenna element **14** as shown in block **64**. The processor **54** within the RFID reader **40** can compute the phase or delay information of the EPC backscatter signal received by the first receiver antenna element **14**.

[0037] The multiplexer **42** in the RFID reader **40** can then switch a second receiver antenna element **14** onto the circuitry of the single receiver channel of the RFID reader **40**, and again request the EPC or other information from the RFID tag **26**, as shown in block **66**. The multiplexer **42** can be any switching circuitry known to those in the art to selectively couple and uncouple whatever number of receiver antenna elements with the circuitry of the receiver channel of the RFID reader **40**. The backscatter EPC signal transmitted in response to the request of block **66** is received by way of the second receiver antenna element **14** as shown in block **68**. The processor **54** can then compute the phase or delay information of the received backscatter signal.

[0038] Using the phase information, or the delay information, calculated for the two receiver antenna elements **14** in blocks **64**, **68**, the processor **54** in the RFID reader **40** can calculate the angle of arrival information of the radio frequency signals **12** incident on the first and second receiver antenna elements **14**. If there are any additional receiver antenna elements **14** coupled to the input ports **41** of the RFID reader **40**, the RFID reader **40** can request the EPC from the RFID tag **26** again for each additional antenna element **14**, as shown in block **69**. The phase can also be computed for each additional EPC backscatter signal.

[0039] Thus, a backscatter signal such as an EPC response signal can be requested from the RFID tag **26** for each receiver antenna element **14** coupled to the RFID reader **40**. Each time the RFID tag **26** receives a request signal, and backscatters in response to the request, the RFID reader **40** can read the backscatter response signal by way of one of the multiplexed receiver antenna elements **14** and its single receive channel. Each time a backscattered EPC response signal is received in this manner the processor **54** can compute the phase of the received signal. In this embodiment of the invention the number of EPC reads that are made by the RFID reader **40** for each RFID tag **26** can determine the tag throughput.

[0040] In one embodiment of the invention the multiplexer **42** can multiplex the receiver antenna elements **14**, receiving the backscatter response signals from the RFID tag **26** over multiple backscatter packets, occurring over multiple inventory rounds. The received packets can contain a random number backscatter signal, such as a typical 16 bit random number (RN16) backscatter signal, an EPC backscatter signal, or backscatter signals including any other contents of the memory of the RFID tag **26**. In one embodiment, the angle of arrival and localization computations can be performed by the RFID reader **40** over the multiple inventory rounds. For example, one read can be performed for each round. In another embodiment, the multiplexer **42** can multiplex several or all of the receiver antenna elements **14** receiving the backscatter signals from the RFID tag **26** during a single backscatter packet of a single inventory round. Accordingly, the angle of arrival can be computed over a few inventory rounds or during a single inventory round.

[0041] Referring now to FIG. **6**, there is shown a flowchart representation of an RF source localizing method **70**. The RF source localizing method **70** is an alternate embodiment of the invention for localizing sources of RF signals such as RFID readers or RFID tags in RFID communications systems. In the RF source localizing method **70** the multiplexer **42** in the RFID reader **40** can select a first receiver antenna element **14** as shown in block **72**. However, in this embodiment of the invention, the RFID reader **40** can request a value other than an EPC from the RFID tag **26**. For example, the reader can request an RN16 signal, as also shown in block **72**. The RFID reader **40** can then receive the backscattered RN16 response signal from the RFID tag **26** by way of the first receiver antenna element **14**, and compute the phase for the received signal as shown in block **74**.

[0042] It will be understood by those skilled in the art that the RN16 signal which can be requested in block **72** represents a value commonly used in conventional RFID communications protocols, and is therefore commonly available to the RFID reader **40** as part of performing the conventional protocols. Thus, the RF source localizing method **70** can use a read of the RN16 signal that is performed as part of the protocols, to compute the phase information of the RFID tag **26** without performing any extra request or read operations. This can increase the throughput of the RF source localizing method **70**.

[0043] The multiplexer **42** in the RFID reader **40** can then select a second receiver antenna element **14** as shown in block **76**. The RFID reader **40** can then request another value from the tag **26**. For example, the RFID reader **40** can request the EPC signal from the RFID tag **26**, and the backscattered EPC response signal can be received from an RFID tag **26** by way of the second receiver antenna element **14**. The phase can then be computed for the backscatter signal received by way of the second receiver antenna element **14**, as shown in block **78**. Since the EPC is required for many RFID communications protocols, the use of the EPC by the RF source localizing method **70** to compute the phase information can avoid overhead and increase throughput.

[0044] If there are any additional receiver antenna elements **14** coupled to the input ports **41** of the RFID reader **40**, an additional EPC or other value can be requested, and the phase information can be computed for each response as shown in block **79**. Based on the phase information, the angle of arrival information can be computed by the RF source localizing method **70** as described above.

[0045] As previously described, an RN16 backscatter signal and an EPC backscatter signal may already be required by conventional tag communication protocols when interrogating an RFID tag **26**. For example both of these signals are required in the Gen 2 protocol. Thus, the angle of arrival information may be obtained using values that are available as part of performing the protocols. For example, in the case where the RFID reader **40** has only two receiver antenna elements **14**, the RFID tag **26** can be interrogated once, and the necessary angle of arrival information can be computed for both receiver antenna elements **14**. One angle of arrival can be computed for the RN16 backscatter and one for the EPC backscatter. However, in embodiments of the invention including more than two receiver antenna elements **14**, the EPC or any other values transmitted by the source of radio frequency waves can be read additional times for the additional receiver antenna elements **14**. The other values that are read can include, for example, hashed values, such as hashed EPC values, and access control values, such as access control values dependent on access privileges. The additional reads required for the additional antenna elements can add to the overhead required for performing the single receiver angle of arrival method, and may reduce the effective tag throughput.

[0046] While the invention has been described in detail and with reference to specific examples thereof, it will be apparent to one skilled in the art that various changes and modifications can be made therein without departing from the spirit and scope thereof.

1. A reader, comprising:

a single receiver circuit;

a switching circuit coupled to the single receiver circuit;

a first antenna connection coupled to the switching circuit, the first antenna connection configured to receive a first signal from a source of radio frequency waves;

a second antenna connection coupled to the switching circuit, the second antenna connection configured to receive a second signal from the source of radio frequency waves; and

a processor configured to determine angle of arrival information in accordance with the first and second signals.

2. The reader of claim **1**, wherein the processor is further configured to determine relative phase information in accordance with the first and second signals.

3. The reader of claim **1**, wherein the processor is further configured to localize the source of radio frequency waves in accordance with the angle of arrival information.

4. The reader of claim **1**, wherein the switching circuit further comprises a multiplexer selectively coupling the first and second antenna connections to the single receiver circuit.

5. The reader of claim **1**, wherein the first antenna connection is further configured to receive an electronic product code signal from a tag.

6. The reader of claim **5**, wherein the second antenna connection is further configured to receive a further electronic product code signal.

7. The reader of claim **1**, wherein the first antenna connection is further configured to receive a random number signal from a tag.

8. The reader of claim **7**, wherein the second antenna connection is further configured to receive an electronic product code signal.

9. The reader of claim **1**, wherein the reader comprises a further receiver circuit.

10. The reader of claim **1**, wherein the first and second signals are received by the reader during a single packet transmission by the source of radio frequency waves.

11. The reader of claim **1**, wherein the first and second signals are received by the reader during differing packet transmissions by the source of radio frequency waves.

12. The reader of claim **1**, wherein the first signal is received in accordance with a tag communication protocol.

13. The reader of claim **12**, wherein the second signal is received in accordance with a tag communication protocol.

14. A tag communication method in a reader having at least two antenna connections, comprising:

(a) coupling a first antenna connection to a single receiver circuit;

(b) receiving a first signal from a source of radio frequency waves by way of the first antenna connection and the single receiver circuit,

(c) coupling a second antenna connection to the single receiver circuit;

(d) receiving a second signal from the source of radio frequency waves by way of the second antenna connection and the single receiver circuit; and

(e) determining angle of arrival information in accordance with the first and second signals.

15. The tag communication method of claim **14**, further comprising localizing the source of radio frequency waves in accordance with the angle of arrival information.

16. The tag communication method of claim **14**, wherein the first signal further comprises an electronic product code signal from a tag.

17. The tag communication method of claim **14**, further comprising selectively coupling the first and second antenna connections to the single receiver circuit using a switching circuit.

18. The tag communication method of claim **14**, further comprising receiving the first and second signals during a single packet transmission by the source of radio frequency.

19. The tag communication method of claim **14**, further comprising receiving the first and second signals during differing packet transmissions by the source of radio frequency.

20. The tag communication method of claim **14**, further comprising receiving at least one of the first and second signals in accordance with a tag communication protocol.

* * * * *