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(54) **METHOD AND APPARATUS FOR
SELECTIVELY TRANSMITTING DATA
USING SPATIAL DIVERSITY**

(71) Applicant: **Google Technology Holdings LLC**,
Mountain View, CA (US)

(72) Inventors: **Armin W. Klomsdorf**, Chicago, IL
(US); **William P. Alberth, Jr.**, Prairie
Grove, IL (US)

(73) Assignee: **Google Technology Holdings LLC**,
Mountain View, CA (US)

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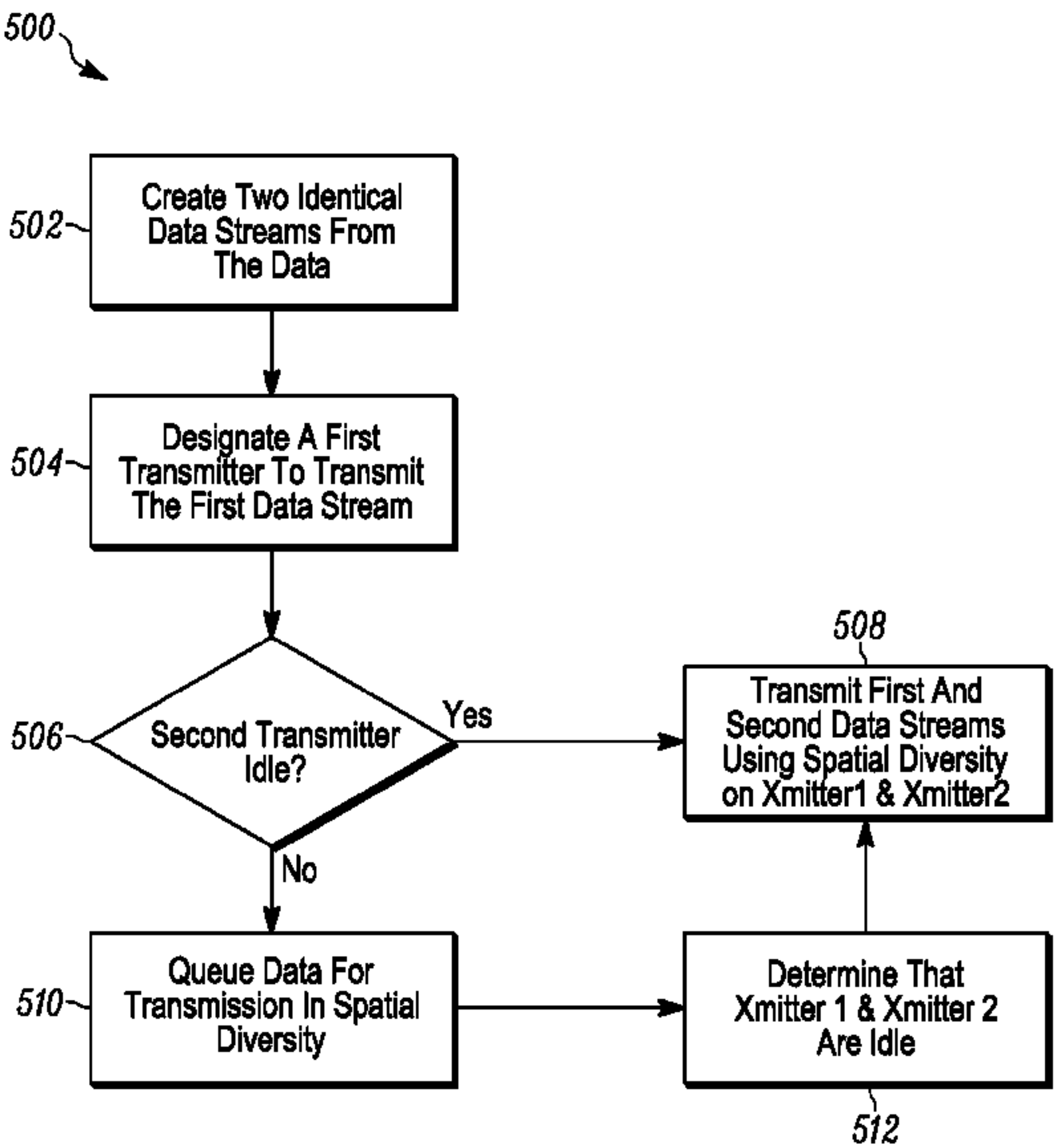
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Primary Examiner — Syed Haider
Assistant Examiner — Fabricio R Murillo Garcia
(74) *Attorney, Agent, or Firm* — Colby Nipper

(57) **ABSTRACT**

A method, performed in a communication device having
multiple transmitters, for selectively transmitting data using
spatial diversity, includes determining a type of data to be
transmitted, determining whether the type of data meets a
data type criteria, which comprises determining whether the
data includes priority data, and transmitting the data using
spatial diversity when the type of data meets the data type
criteria.

20 Claims, 5 Drawing Sheets



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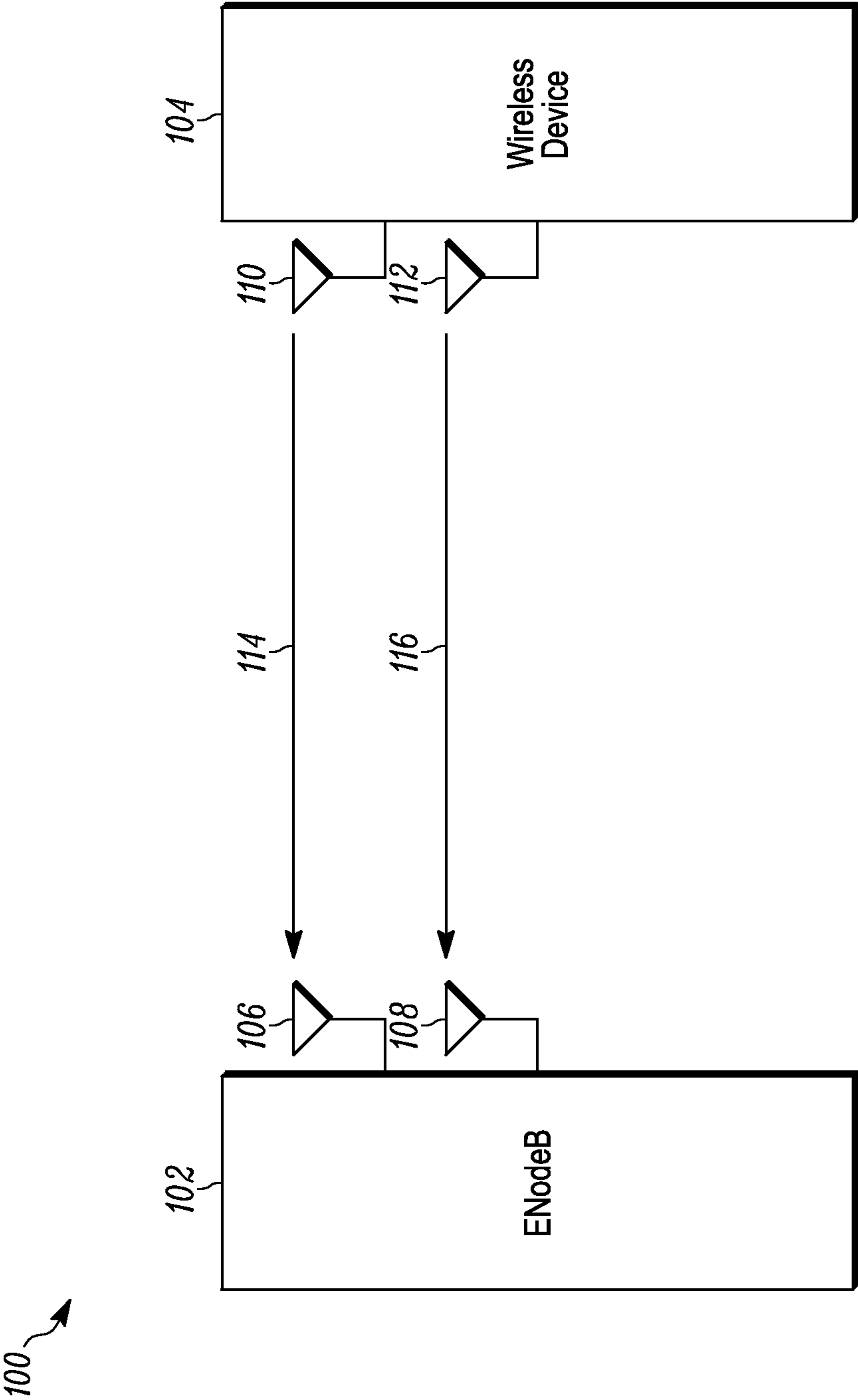


FIG. 1

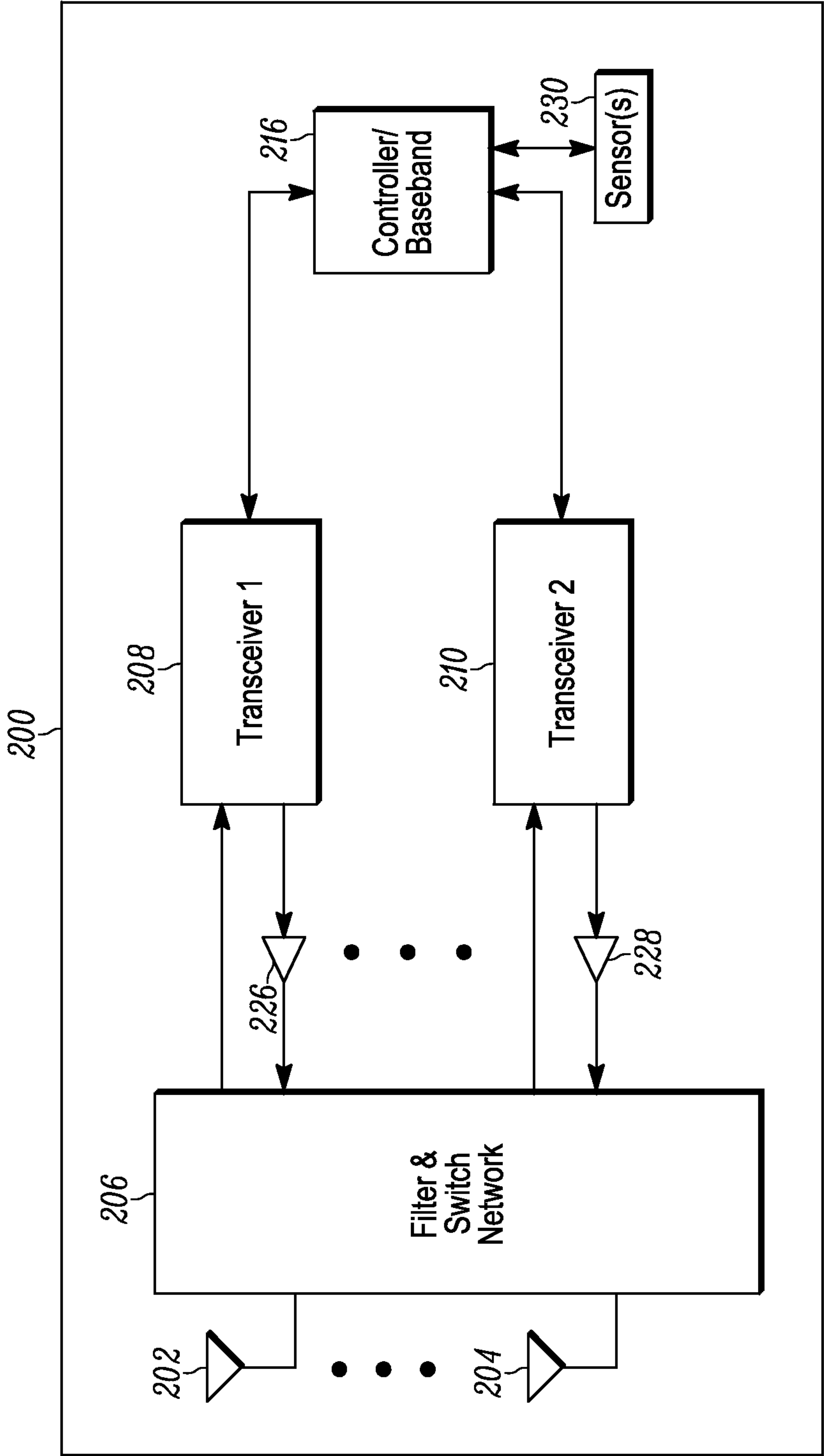


FIG. 2

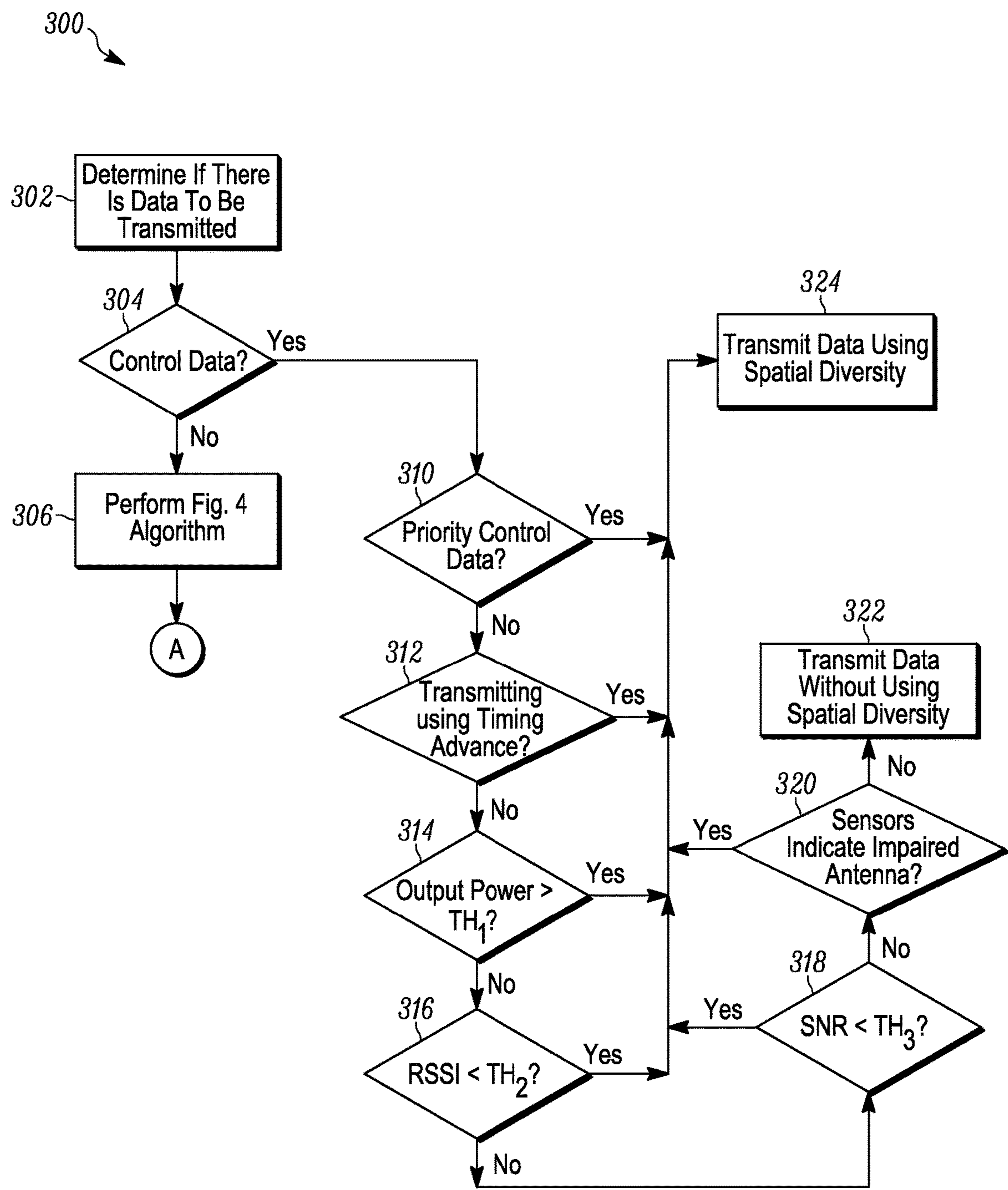


FIG. 3

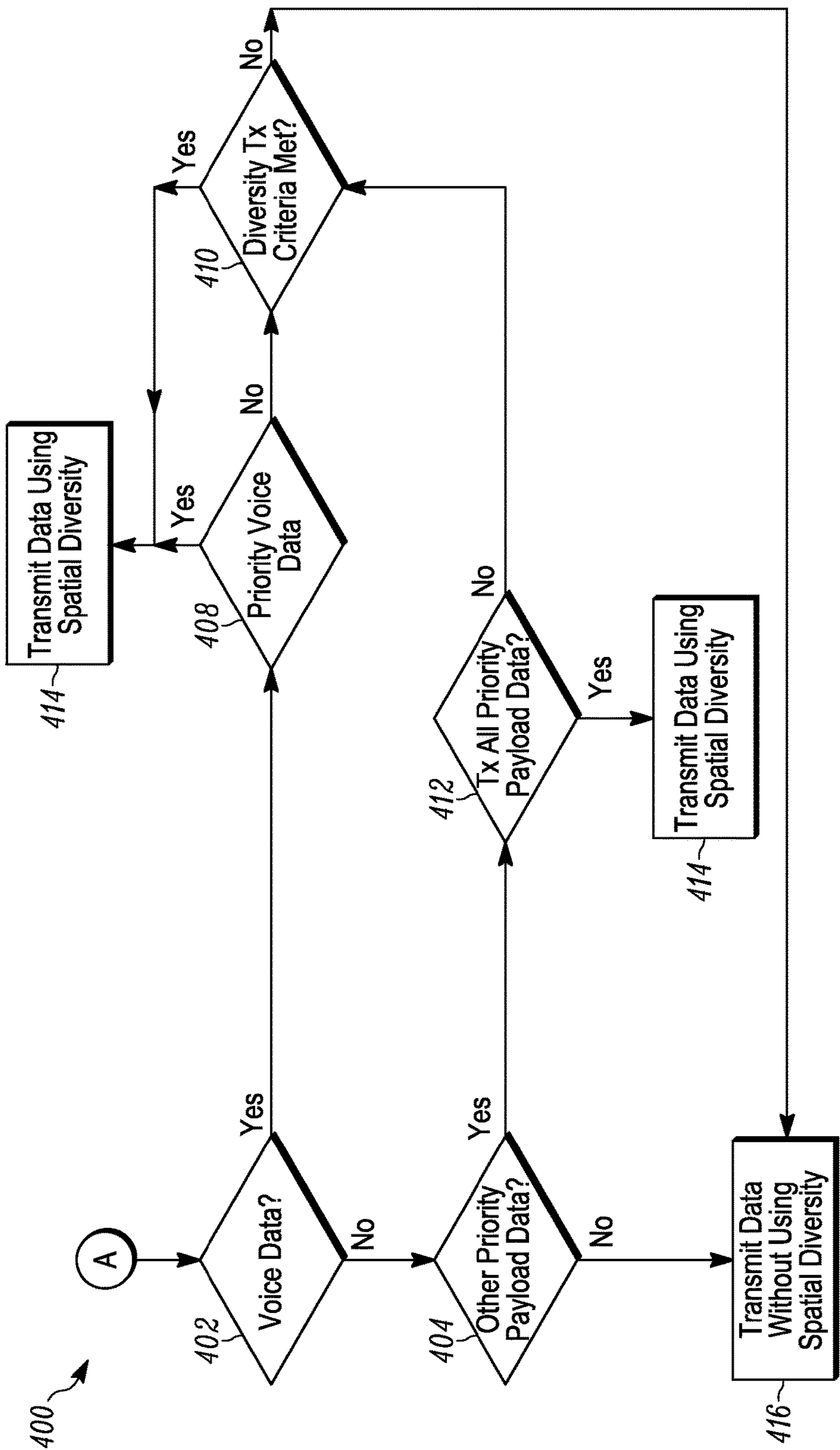


FIG. 4

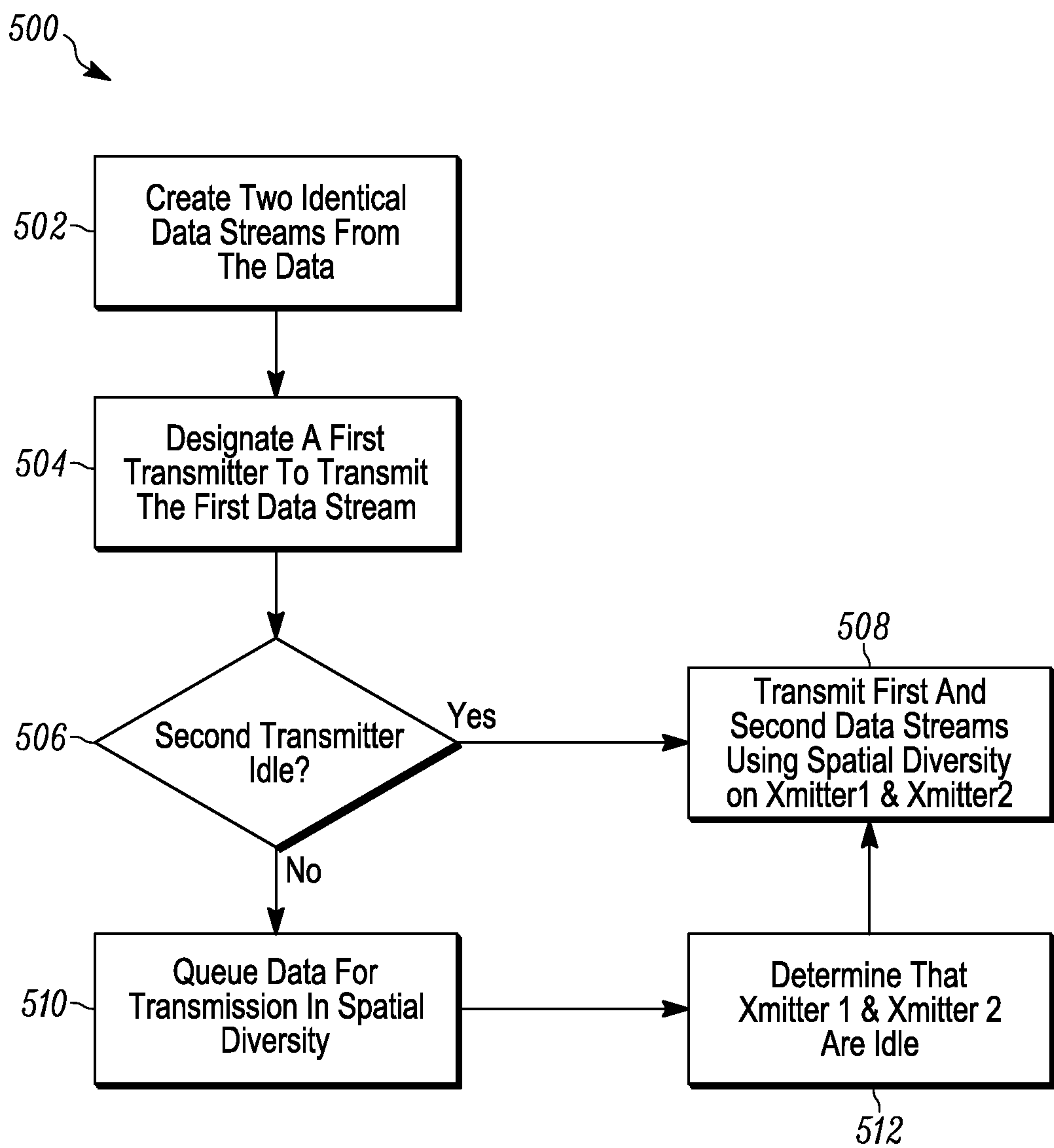


FIG. 5

1

METHOD AND APPARATUS FOR SELECTIVELY TRANSMITTING DATA USING SPATIAL DIVERSITY

FIELD OF THE DISCLOSURE

The present disclosure relates generally to communicating data using diversity transmissions and more particularly to selectively transmitting data using spatial diversity.

BACKGROUND

Next generation wireless systems make use of multiple transmitters and receivers (i.e., multiple antenna systems) in a mobile device and in a base station. Multiple antenna systems are also known as Multiple Input, Multiple Output (MIMO) systems. The availability of multiple transmitters and receivers provides for communicating data over multiple paths or streams in the uplink and downlink directions. For example, in a MIMO system, spatial diversity can be used to make data transmission more robust or reliable. More specifically, using spatial diversity, robustness or reliability is increased by transmitting the same data redundantly over the same channel using multiple antennas. In other words, the transmitting device creates multiple data streams of the same data and transmits the multiple streams over the same channel using different antennas.

Consequently, a recipient device (also referred to herein simply as a recipient) receives two or more copies of the same data. Because the recipient has two or more copies of the data, the recipient can correct errors that occurred in the original transmission without requesting a data retransmission, thereby increasing robustness. However, robustness comes at a cost of increased battery consumption when implementing spatial diversity since multiple transmitters are used to drive multiple antennas. Thus, if at all possible, transmissions using spatial diversity should be selectively performed.

Accordingly, there is a need for methods and apparatus for selectively transmitting data using spatial diversity.

BRIEF DESCRIPTION OF THE FIGURES

The accompanying figures, where like reference numerals refer to identical or functionally similar elements throughout the separate views, together with the detailed description below, are incorporated in and form part of the specification, and serve to further illustrate embodiments of concepts that include the claimed invention, and explain various principles and advantages of those embodiments.

FIG. 1 is a block diagram illustrating one example of a next generation wireless network in which embodiments of the present teaching operate.

FIG. 2 is block diagram illustrating one example of an electronic device in which embodiments of the present teachings operate.

FIG. 3 is a logical flowchart illustrating a method for determining whether to transmit control data using diversity, in accordance with an embodiment.

FIG. 4 is a logical flowchart illustrating a method for determining whether to transmit payload data using diversity, in accordance with an embodiment.

FIG. 5 is a logical flowchart illustrating a method for transmitting priority payload data and control data using diversity, in accordance with an embodiment.

Skilled artisans will appreciate that elements in the figures are illustrated for simplicity and clarity and have not nec-

2

essarily been drawn to scale. For example, the dimensions of some of the elements in the figures may be exaggerated relative to other elements to help improve understanding of embodiments of the present invention.

The apparatus and method components have been represented where appropriate by conventional symbols in the drawings, showing only those specific details that are pertinent to understanding the embodiments of the present invention so as not to obscure the disclosure with details that will be readily apparent to those of ordinary skill in the art having the benefit of the description herein.

DETAILED DESCRIPTION

Generally speaking, pursuant to the various embodiments, the present disclosure provides a method and apparatus for selectively transmitting data using spatial diversity, wherein the type of data that is transmitted is a criteria for the spatial diversity transmissions. For example, spatial diversity is used during data transmissions when the data type is priority data such as priority control data or priority payload data, or when at least one diversity transmit criteria is met.

More particularly, in accordance with the teachings herein, a method performed in a communication device having multiple transmitters, for transmitting data using spatial diversity comprises: determining a type of data to be transmitted; determining whether the type of data meets a data type criteria, which comprises determining whether the data includes priority data; and transmitting the data using spatial diversity when the type of data meets the data type criteria.

Also in an accordance with teachings herein, an electronic device that selectively transmits data using spatial diversity comprises: at least two transmitters; a controller coupled to the at least two transmitters, wherein the controller is configured to determine a type of data to be transmitted, determine that the type of data is priority data, and, responsively, control the at least two transmitters to transmit the priority data using spatial diversity.

In accordance with still another embodiment a computer-readable storage element having computer readable code stored thereon for programming a computer to perform a method for selectively transmitting data using spatial diversity, the method comprising: determining whether to transmit the data using spatial diversity based on whether the data includes priority data; and transmitting the data using spatial diversity when it is determined that the data includes priority data. In accordance embodiments, the data is transmitted using spatial diversity when the data includes priority control data or priority payload data.

In another embodiment, the method further comprises determining whether to transmit the data using spatial diversity based on whether a diversity transmit criteria is met; and transmitting the data using spatial diversity upon determining that the diversity transmit criteria is met, which comprises determining that one of: an electronic device performing the transmitting is using a timing advance; output power at the electronic device exceeds a first threshold; a sensor indicates an impaired antenna element in the electronic device; a received signal strength indicator (RSSI) value is less than a second threshold; or a signal to noise ratio (SNR) value is less than a third threshold.

Referring now to the drawings, and in particular to FIG. 1, a next generation multiple antenna network or system 100 is shown, that is adapted in accordance with the present teachings as described herein. The system 100 includes infrastructure equipment comprising an infrastructure elec-

3

tronic device **102** and a wireless electronic device **104**. In general, as used herein, devices such as **102** and **104**, being “configured,” “operative” or “adapted” means that such devices are implemented using one or more hardware devices such as memory devices, network interfaces such as transceivers, and/or processors that are operatively coupled, for example, as is shown in FIG. 2. The memory devices, network interfaces, and/or processors, when programmed (e.g., using software or firmware), form the means for these system elements to implement their desired functionality, for example, as illustrated by reference to the methods shown in FIGS. 3-5.

In an embodiment, network **100** is a 3rd Generation Partnership Project (3GPP) network, such as a Long Term Evolution (LTE) network **100**, meaning that network infrastructure equipment, e.g., **102**, and wireless devices, e.g., **104**, operating within the system **100** operate in conformance with at least portions of one or more standards documents developed by 3GPP, such as one or more LTE standards documents developed by 3GPP. Although the system **100** is described as a 3GPP LTE system, the present teachings can be incorporated into other types of multiple antenna systems such as WiMax systems, Evolved High Speed Packet Access (HSPA+) systems, Wireless Local Area Network (WLAN) 802.11n systems, etc.

The system **100** network infrastructure equipment includes an Evolved Packet Core (EPC), which functions as the network core. The EPC is coupled to an Evolved Universal Terrestrial Radio Access Network (E-UTRAN), which serves as the access network for one or more wireless devices **104** that communicate using the system **100**. The E-UTRAN includes one or more eNodeBs (eNBs) **102**, which are the LTE equivalent of base stations. At least one eNB **102** includes multiple antenna elements (also referred to herein as antennas), e.g., **106** and **108** operatively coupled to multiple transmitters and/or multiple receivers.

In this embodiment, the electronic device **104** comprises a portable wireless communication device such as a radio telephone, a tablet computer, a personal digital assistant, a gaming console, a remote controller, an electronic book reader, or any other type of electronic device capable of interconnecting with a telecommunications network via the eNB **102**. The communication device **104** is used to establish connections with the eNB **102** to communicate data. Data, as used herein, means any type of information that can be transferred or communicated between two or more devices operating in a communication system, such as the system **100**. Accordingly, data includes information such as, by way of example, voice data, control data, video data, QoS data, etc. In this illustrated embodiment, the wireless device **104** includes multiple antenna elements, e.g., **110** and **112** operatively coupled to multiple transmitters and/or multiple receivers.

An expectation of networks such as LTE and other next generation networks is providing higher data rates and more reliable and robust data transmissions than predecessor networks. To this end, electronic devices (e.g., **102**, **104**) within some next generation wireless networks use the multiple antenna elements (e.g., **106**, **108**, **110**, **112**) to perform spatial diversity to communicate multiple redundant data streams between the electronic devices over the same channel within signals **114**, **116**. A channel is the logical representation of radio frequency (RF) resources carrying the data streams; and the channel is characterized by a transmit or receive frequency and a capacity, such as bandwidth in Hz or data rate in bits per second. In another example, the channel is referred to as a link, a Radio

4

Frequency (RF) link, or a wireless communication path. A signal is a waveform (such as a radio wave) that carries a data stream, and a data stream is a sequence of digitally encoded data units (such as data packets containing data), which is used to transmit or receive information. As explained below, spatial diversity is performed to transmit data in accordance with the present teachings.

In the uplink direction (i.e., from a wireless device to the network infrastructure), for example, antenna **110** transmits data comprising the stream **114**, which is intended for at least one of the antennas such as antenna **106**, and antenna **112** transmits data comprising the stream **116**, which is intended for at least one of the antennas such as antenna **108**. In this example, the communication device **104** transmits data streams to the eNB **102**, but in actual systems the eNB **102** also transmits data streams in the downlink direction to the communication device **104**. In that alternative example, the antenna **106** transmits a data stream intended for antenna **110**, and the antenna **108** transmits a data stream intended for antenna **112**. Moreover, the streams **114**, **116** are shown as being transmitted directly from antennas **110**, **112** to antennas **106**, **108**. However, in actual systems, when transmissions occur in the uplink or downlink direction using spatial diversity, the receiving antennas also receive indirect components of the transmitted streams. Thus, in this particular example, in the uplink direction, each of the antennas **106**, **108** might receive signals emanating from both antennas **110**, **112**. The eNB **102** would then be configured to reconstruct the transmitted data from the multiple received direct and indirect streams.

When a next generation system includes multiple antennas, the multiple antennas are used, in one example, to provide more reliable transmissions. This is done through spatial diversity. More particularly, the multiple antennas **110**, **112** transmit a copy of the same data to the eNB **102**. Because the eNB **102** has two copies of data to work with, the eNB **102** is able to correct any errors that have occurred during transmission. By correcting errors through the use of transmitting redundant information, systems using spatial diversity provide a more reliable link.

Turning now to FIG. 2, which shows a block diagram of an electronic device **200** that implements embodiments of the present teachings. In one embodiment, the electronic device **200** is a portable wireless communication device, such as the communication device **104**. In another embodiment, the electronic device **200** comprises network or infrastructure equipment, such as the eNB **102**. Accordingly, where the description refers to a “communication device **200**”, it should be realized that the description also applies to an infrastructure electronic device unless otherwise indicated. In accordance with the present teachings, electronic device **200** selectively transmits data using spatial diversity and includes: at least two transmitters, such as is included in transceivers **208**, **210** (which also each includes a receiver); a controller **216**; two or more radio antennas **202**, **204**; a filter and switch network **206**; two or more power amplifiers **226**, **228**; and one or more sensors **230**. Only a limited number of transmitters, amplifiers, and antenna elements are shown for the sake of simplicity. However, it should be realized that additional such components may be present in a commercial embodiment of the electronic device **200**. As shown the baseband controller **216** is coupled to the transceivers **208** and **210** and to the sensors **230**. The transceivers **208** and **210** are coupled to a filter and switch network **206** in a receive path. The transceivers **208** and **210** are also

5

coupled to power amplifiers **226** and **228**, respectively, in a transmit path. The antennas **202**, **204** are coupled to the filter and switch network **206**.

The controller **216**, in one embodiment, comprises a baseband processor **216**. In the following description, the terms “controller” and “baseband processor” are, thereby, used interchangeably. For example, baseband processor **216** is comprised of one or more integrated circuit chips having data processing hardware, a memory (e.g., random access memory (RAM)) and firmware or software used to configure, e.g., program, the baseband processor to perform a number of radio control functions that require an antenna element for data communications. The functions include, but are not limited to: encoding and decoding digital data; generating or parsing out certain control data such as acknowledges (ACKs), not-acknowledges (NACKs), channel quality indicators (CQIs), etc.; implementing timing advances; controlling power level measurements, sensor reading, and signal strength (e.g., RSSI, SNR) analysis; etc.

During a transmit operation, the baseband processor **216** receives data, for instance, audio (e.g., voice) data from a microphone, video data from a recording device, or other data from an application in the electronic device. The baseband processor **216** supplies a digital information signal containing the data (also referred herein as a data stream) to one or both of the transmitters within transceivers **208**, **210**. In an embodiment, each transmitter is configured to transmit signals within a particular frequency range (for instance in a certain frequency band). Accordingly, the processing device selects the one or more transmitters based on the frequency band within which the channel falls, which is used to transmit the data stream).

Upon receiving the data stream, the transmitter (e.g., within transceiver **208**, **210**) is configured to modulate the data stream onto a carrier signal. The power amplifier (**226**, **228**) amplifies the modulated signal. The filter and switch network **206** is configured to filter unwanted frequency components from the amplified signal and provide the filtered signal to the correct antenna element(s), and may further including hardware for tuning the antenna elements to improve the efficiency of power transfer between the antenna element and the transmitter. The antenna element (**202**, **204**) is an electric device that sends the filtered signal as a radio wave signal to an antenna element in a receiving device.

During a receive operation the reverse signal processing is performed, the antenna element (**202**, **204**) receives (i.e., picks up) a signal having a data stream. The filter and switch network **206** removes unwanted frequency components from the signal. The receiver (included in the transceiver **208**, **210**) demodulates the signal, and the baseband controller **216** decodes the demodulated system to enable other components in the electronic device **200**, for instance, to prepare the received data for storage and/or presentation to a user. The particular signal processing (e.g., the types of modulation/demodulation, encoding/decoding, control data generation, etc.) depends at least in part on the particular wireless access technology used by the devices within the wireless network. Examples of wireless access technology implemented by the electronic device **200** include one or more of Global System for Mobile Communication (GSM), Coded Division Multiple Access (CDMA), LTE, to name a few.

The at least one sensor **230** is configured to communicate sensed data to the baseband processor **216**. In one embodiment, sensed data includes information concerning the immediate environment in which the communication device

6

200 operates which affects signal quality. Examples of sensed data includes, but is not limited to, whether a user's hand is covering an antenna, or whether the user is holding the communication device **200** in such a way that antenna transmission capability is impaired. Such antenna impairment degrades the signal transmissions of communication device **200**.

We now turn to a detailed description of the functionality of the system **200** elements in accordance with teachings herein and by reference to the remaining figures. FIGS. **3-5** are logical flowcharts illustrating methods performed in an electronic device, such as the electronic device **200**, for selectively transmitting data using spatial diversity. “Selectively” transmitting using spatial diversity means that the electronic device transmits using spatial diversity upon determining that one or more criteria are met, for example as described below with respect to the remaining FIGS. **3-5**. In an embodiment, at least some of the functionality illustrated by reference to FIGS. **3-5** is performed by the baseband processor **216** as described in detail below.

Turning now to method **300** illustrated in FIG. **3**, at **302**, the baseband processor **216** determines that there is data to be transmitted over the air to the eNB **102**. Using the remainder of method **300**, the baseband processor **216** determines the type of the data and determines whether the data type meets a data type or other criteria for transmission using spatial diversity. More particularly, in accordance with the present teachings, only certain data including “priority data” (such as certain types of control data or certain types of payload data) or data that meets a diversity transmit criteria are transmitted using spatial diversity, in order to preserve battery life and network resources. Priority data means certain types of data as designated in some manner in or by the communication device **200** as having a higher importance or priority level over other types of data. In an embodiment, the controller is configured to determine that the data meets the data type criteria when the data comprises one of: priority control data (such as an ACK, NACK or CQI data type); or priority payload data such as voice.

Generally, there are two types of data that are transmitted within messaging (also known as messages, packets, data-grams, frames, superframes, and the like) between the communication device **104** and the eNB **102**. These two types of data (i.e., data types) are control data and payload data. As used herein, the term control data refers to information sent between devices within a network to control aspects of a communication session such as session establishment, maintenance, or tear down, status of channels over which messages are transported, status of messages sent between the devices, etc. A communication session is a logical representation of a group of communication exchanges, e.g., messaging, between multiple devices. The term payload data refers to media sent between multiple devices, wherein media includes, but is not limited to, voice, video, text, etc. Messages that contain control data are referred to herein as control messages; and messages that contain payload data are referred to herein as payload messages. Control message types include automatic repeat request (ARQ), ACK, NACK, precoding matrix indicator (PMI), rank indicator (RI), CQI, as well as other types. Control messages also include, in one example, overhead messages.

In one illustrative implementation, control data is used for administering various aspects of a communication session between the communication device **104** and the eNB **102**. Because control messages are used for administering a communication session, if a sender of a payload message

does not receive a proper control message response, the sender, in one example, retransmits the payload message. For instance, if the eNB 102 sends a payload message and mistranslates a responsive ACK message as a NACK because of a poor original transmission, the eNB 102 will resend the originally transmitted payload. When the eNB 102 has to unnecessarily retransmit payload, valuable wireless resources and valuable battery resources in the communication device 104 are unnecessarily used because of the poor transmission of the responding control message. For this reason, among others, it is advantageous to communicate some messages in general including specific control messages types such as ACKs, NACKs and CQI control messages or specific payload messages, using spatial diversity.

Returning to FIG. 3, upon determining if there is data to be transmitted at 302, the baseband processor 216 determines, using method 300: whether the type of data meets a data type criteria, comprising determining whether the data includes priority control data; or whether the data meets some other criteria, for diversity transmission. A data type criteria means a criteria that identifies a particular type of data that is transmitted using spatial diversity, such as priority data, e.g., priority control data or priority payload data. In an embodiment, determining, at 304, whether the data includes priority data comprises first determining whether the data includes control data. For instance, in one implementation scenario, the baseband processor 216 includes a protocol stack that generates control message types that supports wireless communication within an LTE or WiMax network. Such control message types include, but are not limited to ACKs, NACKs, CQIs, hybrid automatic repeat requests (HARQ), etc. As such, the baseband processor 216 knows that control data is being transmitted and also knows the type of control data being transmitted and proceeds to function block 310 of method 300.

Alternatively, the baseband processor 216 determines that the data to be transmitted is payload data. Accordingly, the electronic device, at 306, performs the algorithm of FIG. 4 to determine whether the payload data meets a data type or other criteria that would allow transmission using spatial diversity. For example, the baseband processor 216 receives digital data from an application in the electronic device, such as a video data from a video or camera application within the electronic device 200, and determines that this is payload data. In another implementation scenario, the baseband processor receives analog data such as voice data from a microphone within the electronic device 200 and, thus, determines that this is payload data.

In an embodiment, only certain control message types meet the data type or other criteria, and the electronic device 200 transmits only some control data using spatial diversity. For example, the electronic device transmits only particular types of control data termed herein as “priority” control data using spatial diversity. In this embodiment, the data is transmitted using spatial diversity (at 324) when the data includes priority control data. Accordingly, determining whether the type of data meets the data type criteria (for transmitting using spatial diversity at 324) further comprises determining (at 310) whether the data includes priority data, which comprises determining whether the data includes priority control data, wherein the priority control data is transmitted using spatial diversity. The baseband processor 216 is programmed, e.g., by a system administrator, to know which control data is priority control data. In an embodiment, priority control data comprises one of an acknowledge message, a not-acknowledge message or a channel quality

indicator message type. Other control messages such as requests for information or non-critical status reports are, in one example, not designated as priority control data.

In a further embodiment, when the control data is not priority control data, the baseband processor 216 uses additional criteria (termed herein as “diversity transmit criteria”) to determine whether to transmit the control data using spatial diversity. Diversity transmit criteria is any criteria, other than the type of data, that an electronic device considers in determining whether to transmit data using spatial diversity. In accordance with this embodiment, the baseband processor 216 determines (e.g., using functions 312-320, which will be described in further detail below) whether a diversity transmit criteria is met, and transmits the control data, at 324, using spatial diversity when one or more diversity transmit criteria is met (as determined by the particular algorithm implemented in the communication device 200) and when the type of data meets a data type criteria (which in this case is being control data but may also be, for instance, certain payload data such as priority payload data). Determining whether the diversity transmit criteria is met, in one example, comprises at least one of determining whether the communication device is implementing a timing advance when transmitting; determining whether output power at the communication device exceeds a first threshold; determining whether a sensor indicates an impaired antenna element in the communication device; determining whether an RSSI value is less than a second threshold; or determining whether an SNR value is less than a third threshold. The eNB 102, in another example, sends a message to the communication device 200 with instructions on which messages should be sent using spatial diversity.

More particularly, at 312, the baseband controller determines whether the electronic device is transmitting using a timing advance. The communication device 200 transmits using a timing advance when the eNB 102 has determined that the communication device 200 needs to advance its timing. Transmissions between a communication device, such as communication device 200, and a base station, such as the eNB 102, are typically synchronized. The eNB 102 determines based on this timing where, for example, a particular time slot or frame begins and ends. The communication device 200 times its transmissions so that particular data falls within an assigned time frame.

When, however, the communication device 200 is a long distance from the eNB 102, it takes a longer time for a signal to travel from the communication device 200 to the eNB 102. This longer travel time skews the synchronization between the communication device 200 and the eNB 102. Thus, the eNB 102 commands or instructs the communication device 200 to advance its timing (transmit using a timing advance) to overcome the signal travel time delay. Thus, when the communication device 200 is using a timing advance, this indicates that the communication device is a relatively long distance from the eNB 102, which indicates that the signal between the eNB 102 and the communication device 200 is less robust. Therefore, the need for implementing a timing advance in the communication device 200 serves as a proxy for signal quality.

In other words, when the eNB 102 requests that the communication device 200 advance its timing, this indicates that the signal quality between the communication device 200 and the eNB 102 is probably declining and a control message transmitted under these circumstances is more likely to be dropped. In these circumstances when the communication device 200 transmits data redundantly using

spatial diversity, the recipient is more likely to successfully recreate the transmitted data. Accordingly, when the baseband processor determines that the communication device **200** is transmitting using a timing advance, the control data is transmitted using spatial diversity, at **324**. Otherwise, the method **300** moves to block **314**.

At **314** the baseband processor **216** determines whether the output power of the communication device **200** is above a first threshold. The communication device **200**, in one example, determines its output power. In another example, the communication device **200** receives parameters from the eNB **102** which indicate what the output power of the communication device **200** should be. Regardless of how the output power is determined, if the output power of the communication device **200** exceeds the first threshold, this indicates that the communication device **200** has increased its output power to maintain a stable communication session with the eNB **102**. In one example, the communication device **200** increases its output power because its signal is fading. Accordingly, when at **314** the baseband processor **216** determines that the output power of the communication device **200** is above the first threshold this indicates, in one example, that the signal quality between the communication device **200** and the eNB **102** is poor. Thus, at **324**, the baseband processor **216** transmits the control data using spatial diversity in order to ensure that the eNB **102** receives the control data.

When, at **314**, the baseband processor **216** determines that the output power of the communication device **200** is not above the first threshold, at **316** the baseband processor **216** determines whether the RSSI of the communication device **200** is below a second threshold. RSSI is a measure of received signal strength in a wireless environment in IEEE 802.11 systems, for example, and can be measured using hardware in a receiver. When the RSSI of the communication device **200** drops below the second threshold, this indicates that the signal between the communication device **200** and the eNB **102** is weak. Because the signal is weak, it is more likely that control data may be lost in transmission. Thus, it would be advantageous to redundantly transmit control data using spatial diversity when the RSSI is below the second threshold. Accordingly, at **324** the baseband processor **216** transmits the data using spatial diversity.

When, at **316**, the baseband processor **216** determines that the RSSI of the communication device **200** is not below the second threshold, at **318** the baseband processor **216** determines if the SNR is lower than a third threshold. SNR is used to compare the level of a desired signal to the level of background noise and is defined, in one example implementation, as the ratio of signal power to noise power. When, at **318**, the baseband processor **216** determines that the SNR of the communication device **200** is less than the third threshold this indicates, in one example, that the signal between the communication device **200** and the eNB **102** is experiencing an inordinate amount of interference. Thus, it would be advantageous to redundantly transmit the data using spatial diversity. Accordingly, at **324**, the baseband processor **216** transmits the data using spatial diversity **324**.

As mentioned above, the baseband processor **216** communicates with sensors **230** located in various locations of the communication device **200**. The sensors **230** communicate data to the baseband processor **216**, which includes information concerning the immediate environment in which the communication device **200** is operating that affects signal quality. This information includes, but is not limited to, whether a user's hand is covering an antenna or that the user is holding the communication device **200** in

such a way that antenna transmission capability is impaired or blocked. This antenna impairment degrades the signal transmissions of the communication device **200** and increases the likelihood that data will not be successfully transmitted. Thus, it is advantageous to transmit the data using spatial diversity when the sensors **230** indicate an antenna is impaired. Accordingly, at **320**, when the baseband processor **216** determines that the sensors **230** indicate that an antenna is impaired, at **324** the baseband processor **216** transmits the data using spatial diversity at **324**. If none of the data type or transmit diversity criteria are met or the correct combination of diversity transmit criteria is not met (depending on the algorithm), the baseband processor **216**, at **322**, transmits the data without using spatial diversity.

As previously explained, because transmitting in diversity requires transmitting data using more than one antenna, transmitting data using diversity typically consumes more battery power than transmitting without using diversity. Accordingly, in other embodiments, the baseband processor **216** determines whether to transmit using diversity based on the same diversity transmit criteria shown in the flow diagram **300**, but the baseband processor **216** makes the determination in a different manner. For example, in one embodiment the baseband processor **216** determines the output power level, the RSSI and the SNR of the communication device **200** and combines these values into one aggregate value and compares the aggregate value against a single threshold instead of three different thresholds. The baseband processor **216** transmits data using spatial diversity depending on the result of this comparison.

In another embodiment, the SNR and the RSSI level of the communication device **200** are combined into an aggregate value and compared against a first alternate threshold, and the output power is compared against a second alternate threshold. If the aggregate value of the SNR and RSSI level is below the first alternate threshold, and/or the output power is above the second alternate threshold, the communication device **200** transmits using spatial diversity. In another embodiment, the output power, RSSI and SNR is combined in various ways and compared against various thresholds. The communication device **200** transmits using spatial diversity based on these comparisons. In still other embodiments, the various threshold values are raised or lowered, which would affect whether or not the communication device **200** would be more likely to transmit using spatial diversity. Moreover, FIG. 3 illustrates one example order in which the baseband processor considers diversity transmit criteria. However, such consideration is not limited to this specific order. Moreover, simultaneous consideration of multiple of the above diversity transmit criteria and/or consideration of diversity transmit criteria not specifically mentioned is not precluded from the scope of the present teachings.

Turning back to **304**, when the baseband processor **216** determines that the data to be transmitted is not control data, at **306** the baseband processor **216** performs the method **400** of FIG. 4. FIG. 4 illustrates a logical flowchart of a method **400** for determining whether to transmit payload data using spatial diversity. In one embodiment, the method **400** executes on the baseband processor **216**. In accordance with the present teachings, determining whether the data includes priority data comprises determining whether the data includes priority payload data, wherein only the priority payload data is transmitted using spatial diversity. Priority payload data means only certain types of payload data as designated in some manner in or by the communication device **200**. As with priority control data, the baseband

11

processor **216** is programmed in one embodiment, e.g., by a system administrator, to know which payload data is priority payload data.

In one example, the priority payload data includes priority voice data. Accordingly, at **402**, the baseband processor **216** determines whether the payload data is voice data. When the payload data is voice data, at **408** the baseband processor **216** determines if the voice data is priority voice data. In one example, priority voice data is voice data requiring a higher QoS than regular voice data, or the priority voice data is associated with an emergency call that must have a clear voice channel. When the voice data is priority voice data, at **414** the baseband processor **216** transmits the data using spatial diversity. One example of priority voice data includes examining the first syllables of a transmission. For example, when public safety officers are responding over the air with “SHOOT” or “DON’T SHOOT”, the transmission of the first syllables are critical. Therefore, the communication device **200** transmits, in one example, the beginning of a voice data stream with spatial diversity including critical syllables, and then transmits without diversity after a threshold of, for example, two seconds.

When, at **408**, the baseband processor **216** determines that the voice data is not priority voice data, at **410** the baseband processor **216** determines whether certain diversity transmit criteria are met. If one or more diversity transmit criteria are met, as determined by the algorithm that the communication device **200** performs at block **410**, the communication device **200** transmits the data using spatial diversity, at **414**. Otherwise, the communication device **200** transmits the data without using spatial diversity, at **416**. In one embodiment, determining whether diversity transmit criteria are met includes determining whether: the communication device **200** is transmitting using a timing advance, the output power level of the communication device **200** is above a first threshold, the RSSI level of the communication device **200** is below a second threshold, the SNR level of the communication **200** is below a third threshold, or sensors **230** indicate an antenna is impaired. When any of these or other diversity transmit criteria are met, at **414** the baseband processor **216** transmits the voice data using spatial diversity.

In other embodiments, the determination of whether the diversity transmit criteria is met is performed in a different order. In still other examples, the baseband processor **216** determines whether to transmit using spatial diversity based on the same criteria, but the determination is made in a different manner. For example, different diversity transmit criteria or different aggregates of the diversity transmit criteria are compared against one or more thresholds to determine whether or not to transmit using spatial diversity. Also, values of the thresholds are raised or lowered, in different embodiments, to affect when transmission using spatial diversity occurs.

When, at **402**, the baseband processor **216** determines that the payload data is not voice data, at **404** the baseband processor **216** determines whether the payload data is other priority payload data. For example, some priority payload data is of greater importance or more significant than other payload data and should, therefore, be sent on a more reliable data stream. Priority payload data includes, for example, data tagged as part of an emergency message, messages from certain users, such as, public service officials, or data from an active crime scene. Because priority payload data includes messages that should be reliably delivered, in one example, priority payload data may be transmitted using

12

spatial diversity to further increase the likelihood that the priority payload data is delivered.

When, at **404**, the baseband processor **216** determines that the payload data is other priority payload data, the baseband processor **216** at **412** determines if all priority payload data should be transmitted using spatial diversity. When, at **412**, the baseband processor **216** determines that all priority payload should be transmitted using spatial diversity, at **414** the baseband processor **216** transmits the priority payload data using spatial diversity. When, at **412**, the baseband processor **216** determines that not all priority payload data should be transmitted using spatial diversity, the baseband processor **216** performs **410** to determine whether diversity transmit criteria are met. If one or more diversity transmit criteria are met, as determined by the algorithm that the communication device **200** performs at block **410**, the communication device **200** transmits the data using spatial diversity, at **414**. Otherwise, the communication device **200** transmits the data without using spatial diversity, at **416**.

FIG. **5** shows one example of a logical flow chart illustrating a method **500** of transmitting priority payload data or control data using spatial diversity. When a next generation system includes multiple antennas, the multiple antennas are used, in one example, to provide more reliable transmissions. This is done through spatial diversity. More particularly, two or more antennas transmit a copy of the same data. In an embodiment, transmitting data using spatial diversity includes transmitting the data using at least two of multiple transmitters, for example, the transceivers **208**, **210** of the communication device **200**. In one embodiment, transmitting data using at least two of the multiple transmitters comprises: creating identical first and second streams of the data; designating a first transmitter to transmit the first stream of a channel; and determining when a second transmitter is idle to transmit the second stream over the same channel; and transmitting the first and second streams of the data using the first transmitter and the second transmitter when the second transmitter is idle.

Returning to FIG. **5**, in one example, the method **500** is executed on the baseband processor **216**. Upon invocation, the communication device **200** has determined, for instance using the algorithms represented in FIG. **3** or FIG. **4** (at blocks **324** and **414** respectively), that the data should be transmitted using spatial diversity. In an embodiment, transmitting the data using at least two transmitters comprises creating identical first and second streams of the data (at **502**). Further, at **504**, in one example, the baseband processor **216** designates the first transmitter to transmit the first stream on a channel on which, for example, the two transmitters are configured to transmit data.

At **506**, the baseband processor **216** determines if the second transmitter is idle to transmit the data over the channel. An idle transmitter, in one example, is a transmitter that is not currently transmitting data, and an active transmitter is a transmitter that is currently transmitting data. The baseband processor **216** transmits the first and second streams of the data using the first transmitter and the second transmitter (at **508**) when the baseband processor **216** determines that the second transmitter is idle (at **506**). When the baseband processor **216** determines at **506** that the second transmitter is active, the baseband processor **216** requests an uplink schedule grant. An uplink schedule grant, in one embodiment, is a way for the baseband processor **216** to queue the data for transmission in spatial diversity (at **510**) using both transmitters at a later time. Thus, when the baseband processor **216** determines that the first and second transmitter are idle (at **512**), the baseband processor **216**

13

transmits the first and second streams of the data using the first transmitter and the second transmitter (at 508). The eNB 102 receives the first and second streams and reconstructs the original single stream from the first and second streams. Because the eNB 102 has two copies of the original stream to work with, the eNB 102 is able to correct any errors that have occurred during transmission. By correcting errors through the use of transmitting redundant information, systems using spatial diversity provide a more reliable link.

By implementing embodiments disclosed by these teachings, significant benefits are realized over the current state-of-the-art in that data meeting a certain data type criteria are transmitted using spatial diversity. In one embodiment, these criteria include whether the data is control data or priority payload data. Further determinations are made to further distinguish the type of data to be transmitted, and the conditions under which the data is transmitted. Thus, in accordance with the present teachings, data is transmitted using diversity when these criteria are met and, in some examples, when conditions dictate that the data should be transmitted, such as by considering one or more diversity transmit criteria, alone or in combination. Accordingly, the extra battery power consumed to transmit data using spatial diversity is only used when the data type, and in some examples, the transmission conditions indicate that the data should be transmitted using spatial diversity.

Those skilled in the art, however, will recognize and appreciate that the specifics of this example are merely illustrative of some embodiments and that the teachings set forth herein are applicable in a variety of alternative settings. For example, since the teachings described do not depend on the method being executed only in the baseband processor 216, they can be applied to any type of controller, baseband processor, or integrated circuit of a wireless device although a baseband processor disposed in a wireless device or infrastructure device, such as is shown in the disclosed embodiments. As such, other alternative implementations of using different types of controllers and wireless devices are contemplated and are within the scope of the various teachings described.

In the foregoing specification, specific embodiments have been described. However, one of ordinary skill in the art appreciates that various modifications and changes can be made without departing from the scope of the invention as set forth in the claims below. Accordingly, the specification and figures are to be regarded in an illustrative rather than a restrictive sense, and all such modifications are intended to be included within the scope of present teachings.

The benefits, advantages, solutions to problems, and any element(s) that may cause any benefit, advantage, or solution to occur or become more pronounced are not to be construed as a critical, required, or essential features or elements of any or all the claims. The invention is defined solely by the appended claims including any amendments made during the pendency of this application and all equivalents of those claims as issued.

Moreover in this document, relational terms such as first and second, top and bottom, and the like may be used solely to distinguish one entity or action from another entity or action without necessarily requiring or implying any actual such relationship or order between such entities or actions. The terms “comprises,” “comprising,” “has,” “having,” “includes,” “including,” “contains,” “containing” or any other variation thereof, are intended to cover a non-exclusive inclusion, such that a process, method, article, or apparatus that comprises, has, includes, contains a list of elements does not include only those elements but includes other elements

14

not expressly listed or inherent to such process, method, article, or apparatus. An element preceded by “comprises . . . a”, “has . . . a”, “includes . . . a”, “contains . . . a” does not, without more constraints, preclude the existence of additional identical elements in the process, method, article, or apparatus that comprises, has, includes, contains the element. The terms “a” and “an” are defined as one or more unless explicitly stated otherwise herein. The terms “substantially”, “essentially”, “approximately”, “about” or any other version thereof, are defined as being close to as understood by one of ordinary skill in the art, and in one non-limiting embodiment the term is defined to be within 10%, in another embodiment within 5%, in another embodiment within 1% and in another embodiment within 0.5%. The term “coupled” as used herein is defined as connected, although not necessarily directly and not necessarily mechanically. A device or structure that is “configured” in a certain way is configured in at least that way, but is also configured in ways that are not listed.

It will be appreciated that some embodiments may be comprised of one or more generic or specialized processors (or “processing devices”) such as microprocessors, digital signal processors, customized processors and field programmable gate arrays (FPGAs) and unique stored program instructions (including both software and firmware) that control the one or more processors to implement, in conjunction with certain non-processor circuits, some, most, or all of the functions of the method and/or apparatus described herein. Alternatively, some or all functions could be implemented by a state machine that has no stored program instructions, or in one or more application specific integrated circuits (ASICs), in which each function or some combinations of certain of the functions are implemented as custom logic. Of course, a combination of the two approaches could be used. Both the state machine and ASIC are considered herein as a “processing device” for purposes of the foregoing discussion and claim language.

Moreover, an embodiment can be implemented as a computer-readable storage medium having computer readable code stored thereon for programming a computer (e.g., comprising a processor) to perform a method as described and claimed herein. Examples of such computer-readable storage mediums include, but are not limited to, a hard disk, a CD-ROM, an optical storage device, a magnetic storage device, a ROM (Read Only Memory), a PROM (Programmable Read Only Memory), an EPROM (Erasable Programmable Read Only Memory), an EEPROM (Electrically Erasable Programmable Read Only Memory) and a Flash memory. Further, it is expected that one of ordinary skill, notwithstanding possibly significant effort and many design choices motivated by, for example, available time, current technology, and economic considerations, when guided by the concepts and principles disclosed herein will be readily capable of generating such software instructions and programs and ICs with minimal experimentation.

The Abstract of the Disclosure is provided to allow the reader to quickly ascertain the nature of the technical disclosure. It is submitted with the understanding that it will not be used to interpret or limit the scope or meaning of the claims. In addition, in the foregoing Detailed Description, it can be seen that various features are grouped together in various embodiments for the purpose of streamlining the disclosure. This method of disclosure is not to be interpreted as reflecting an intention that the claimed embodiments require more features than are expressly recited in each claim. Rather, as the following claims reflect, inventive subject matter lies in less than all features of a single

15

disclosed embodiment. Thus the following claims are hereby incorporated into the Detailed Description, with each claim standing on its own as a separately claimed subject matter.

We claim:

1. A method for selectively transmitting data using spatial diversity, the method comprising:

determining, by a controller of a portable communication device having multiple transmitters, that data is to be transmitted to a base station device using one or more of the multiple transmitters;

identifying, based on data type criteria and by the controller of the portable communication device, a data type of the data to be transmitted as payload data;

determining that the payload data includes voice data comprising a plurality of portions of audio data from a voice data stream;

identifying, based on priority level criteria and by the controller of the portable communication device, a first portion of audio data as priority voice data, the first portion of audio data being defined in relation to a second portion of audio data by the priority level criteria that includes a time threshold from a start of the voice data stream;

identifying, based on the priority level criteria and by the controller of the portable communication device, the second portion of audio data as non-priority voice data;

transmitting, responsive to identifying the first portion of audio data as priority voice data, the first portion of audio data to the base station using spatial diversity by transmitting the first portion of audio data using at least two of the multiple transmitters of the portable communication device; and

transmitting, responsive to identifying the second portion of audio data as non-priority voice data, the second portion of audio data to the base station device without using spatial diversity by transmitting the second portion of audio data using one of the multiple transmitters of the portable communication device.

2. The method of claim 1, further comprising:

transmitting other priority payload data using spatial diversity by transmitting the other priority payload data using at least two of the multiple transmitters of the portable communication device; or

transmitting other non-priority payload data without using spatial diversity by transmitting the other non-priority payload data using one of the multiple transmitters of the portable communication device.

3. The method of claim 2, further comprising identifying, based on the priority level criteria and by the controller of the portable communication device, other payload data as the priority payload data or the non-priority payload data for transmission by the portable communication device.

4. The method of claim 1, further comprising:

determining whether at least one diversity transmit criteria is met; and

transmitting, responsive to determining that the at least one diversity transmit criteria is met, other non-priority payload data using spatial diversity by transmitting the other non-priority payload data using at least two of the multiple transmitters of the portable communication device.

5. The method of claim 4, wherein determining whether the at least one diversity transmit criteria is met comprises at least one of:

determining whether the portable communication device is implementing a timing advance to transmit;

16

determining whether an output power level of the one or more transmitters exceeds a first threshold;

determining whether a sensor indicates impairment of an antenna element of the portable communication device;

determining whether a received signal strength indicator value is less than a second threshold; or

determining whether a signal to noise ratio value is less than a third threshold.

6. The method of claim 1, wherein transmitting the first portion of audio data using spatial diversity comprises:

creating, based on the first portion of audio data, first and second streams of the first portion of audio data that are identical;

designating a first transmitter of the multiple transmitters by which to transmit the first stream over a channel;

determining when a second transmitter of the multiple transmitters is idle to facilitate transmission of the second stream over the channel;

activating, in response to determining that the second transmitter is idle, the second transmitter to enable transmission over the channel; and

transmitting the first and second streams of the first portion of audio data using the first transmitter and the second transmitter, respectively.

7. The method of claim 6, further comprising:

determining that the second transmitter is not idle; and

requesting, in response to determining that the second transmitter is not idle, an uplink schedule grant effective to queue the second stream for subsequent transmission by the second transmitter.

8. An electronic device that selectively transmits data using spatial diversity, the electronic device comprising:

at least two transmitters;

a controller coupled to the at least two transmitters, the controller is configured to:

determine that data of the electronic device is to be transmitted;

identify, based on data type criteria, a data type of the data to be transmitted as payload data;

determine that the payload data includes voice data comprising a plurality of portions of audio data from a voice data stream;

identify, based on priority level criteria, a first portion of audio data as priority voice data, the first portion of audio data being defined in relation to a second portion of audio data by the priority level criteria that includes a time threshold from a start of the voice data stream;

identify, based on the priority level criteria, the second portion of audio data as non-priority voice data;

transmit, responsive to identifying the first portion of audio data as priority voice data, the first portion of audio data using spatial diversity by transmitting the first portion of audio data using at least two of the transmitters of the electronic device; and

transmit, responsive to identifying the second portion of audio data as non-priority voice data, the second portion of audio data without using spatial diversity by transmitting the second portion of audio data using one of the transmitters of the electronic device.

9. The electronic device of claim 8, wherein the controller is further configured to:

transmit other priority payload data using spatial diversity by transmitting the other priority payload data using at least two of the transmitters of the electronic device; or

17

transmit other non-priority payload data without using spatial diversity by transmitting the other non-priority payload data using one of the transmitters of the electronic device.

10. The electronic device of claim 9, wherein the controller is further configured to identify, based on the priority level criteria, other payload data as the priority payload data or the non-priority payload data for transmission by the electronic device.

11. The electronic device of claim 8, wherein the controller is further configured to:

determine whether at least one diversity transmit criteria is met; and

transmit, responsive to determining that the at least one diversity transmit criteria is met, other non-priority payload data using spatial diversity by transmitting the other non-priority payload data using at least two of the multiple transmitters of the electronic device.

12. The electronic device of claim 11, wherein to determine whether the at least one diversity transmit criteria is met the controller is configured to:

determine whether the electronic device is implementing a timing advance to transmit;

determine whether an output power level of the one or more transmitters exceeds a first threshold;

determine whether a sensor indicates impairment of an antenna element of the electronic device;

determine whether a received signal strength indicator value is less than a second threshold; or

determine whether a signal to noise ratio value is less than a third threshold.

13. The electronic device of claim 8, wherein to transmit the first portion of audio data using spatial diversity the controller is configured to:

create, based on the first portion of audio data, first and second streams of the first portion of audio data that are identical;

designate a first transmitter of the transmitters by which to transmit the first stream over a channel;

determine when a second transmitter of the multiple transmitters is idle to facilitate transmission of the second stream over the channel;

activate, in response to determining that the second transmitter is idle, the second transmitter to enable transmission over the channel; and

transmit the first and second streams of the first portion of audio data using the first transmitter and the second transmitter, respectively.

14. The electronic device of claim 13, wherein the controller is configured to request, in response to determining that the second transmitter is not idle, an uplink schedule grant effective to queue the second stream for subsequent transmission by the second transmitter.

15. A hardware-based computer-readable memory device storing processor-executable code that, responsive to execution by a controller of a portable communication device, causes the controller to implement operations for selectively transmitting data using spatial diversity, the operations comprising:

determining that data is to be transmitted using multiple transmitters of the portable communication device;

identifying, based on data type criteria, a data type of the data to be transmitted as payload data;

determining that the payload data includes voice data comprising a plurality of portions of audio data from a voice data stream;

18

identifying, based on priority level criteria, a first portion of audio data as priority voice data, the first portion of audio data being defined in relation to a second portion of audio data by the priority level criteria that includes a time threshold from a start of the voice data stream;

identifying, based on the priority level criteria, the second portion of audio data as non-priority voice data;

transmitting, responsive to identifying the first portion of audio data as priority voice data, the first portion of audio data to the base station using spatial diversity by transmitting the first portion of audio data using at least two of the multiple transmitters of the portable communication device; and

transmitting, responsive to identifying the second portion of audio data as non-priority voice data, the second portion of audio data without using spatial diversity by transmitting the second portion of audio data using one of the multiple transmitters of the portable communication device.

16. The hardware-based computer-readable memory device of claim 15, wherein the operations implemented by the controller further comprise:

transmitting other priority payload data using spatial diversity by transmitting the other priority payload data using at least two of the transmitters of the portable communication device; or

transmitting other non-priority payload data without using spatial diversity by transmitting the other non-priority payload data using one of the transmitters of the portable communication device.

17. The hardware-based computer-readable memory device of claim 16, wherein the operations implemented by the controller further comprise identifying, based on the priority level criteria, other payload data as the priority payload data or the non-priority payload data for transmission by the portable communication device.

18. The hardware-based computer-readable memory device of claim 15, wherein the operations implemented by the controller further comprise:

determining whether at least one diversity transmit criteria is met; and

transmitting, responsive to determining that the at least one diversity transmit criteria is met, other non-priority payload data using spatial diversity by transmitting the other non-priority payload data using at least two of the multiple transmitters of the portable communication device.

19. The hardware-based computer-readable memory device of claim 18, wherein the operations to determine whether the at least one diversity transmit criteria comprise one of:

determining whether the portable communication device is implementing a timing advance to transmit;

determining whether an output power level of the one or more transmitters exceeds a first threshold;

determining whether a sensor indicates impairment of an antenna element of the portable communication device;

determining whether a received signal strength indicator value is less than a second threshold; or

determining whether a signal to noise ratio value is less than a third threshold.

20. The hardware-based computer-readable memory device of claim 15, wherein to transmit the first portion of audio data using spatial diversity the operations implemented by the controller further comprise:

creating, based on the first portion of audio data, first and second streams of the first portion of audio data that are identical;
designating a first transmitter of the transmitters by which to transmit the first stream over a channel; 5
determining when a second transmitter of the multiple transmitters is idle to facilitate transmission of the second stream over the channel;
activating, in response to determining that the second transmitter is idle, the second transmitter to enable 10
transmission over the channel; and
transmitting the first and second streams of the first portion of audio data using the first transmitter and the second transmitter, respectively.

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UNITED STATES PATENT AND TRADEMARK OFFICE
CERTIFICATE OF CORRECTION

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APPLICATION NO. : 13/692520
DATED : November 7, 2017
INVENTOR(S) : Klomsdorf et al.

Page 1 of 1

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

In the Claims

Column 16, Line 57 after “diversity” before “transmitting” delete “y” insert --by--

Signed and Sealed this
Nineteenth Day of December, 2017



Joseph Matal
*Performing the Functions and Duties of the
Under Secretary of Commerce for Intellectual Property and
Director of the United States Patent and Trademark Office*