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(54) **METHOD FOR SIGNALING INFORMATION BY MODIFYING MODULATION CONSTELLATIONS**

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See application file for complete search history.

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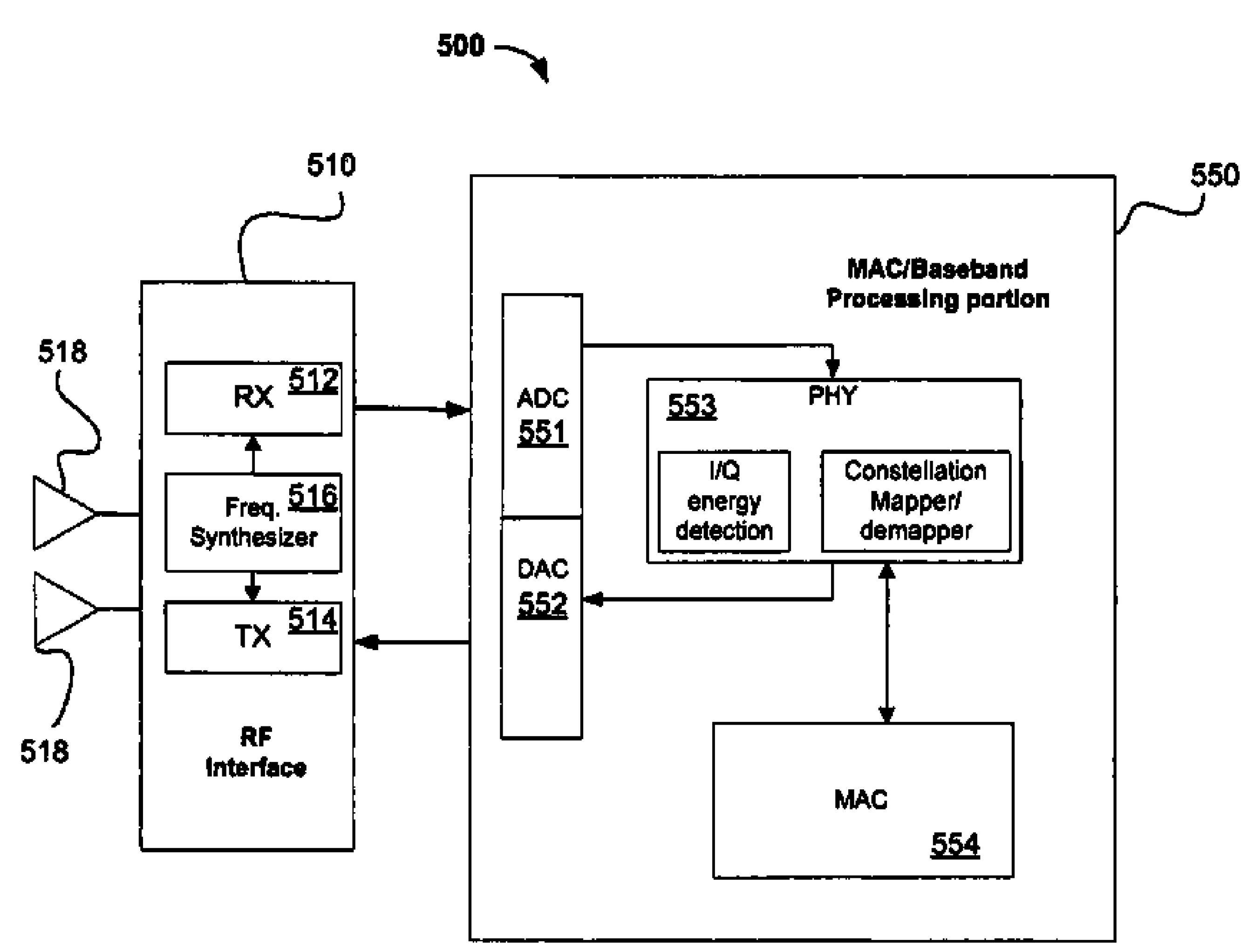
(57) **ABSTRACT**

Methods and systems for communicating in a wireless network may distinguish different types of packet structures by modifying the phase of a modulation constellation, such as a binary phase shift keying (BPSK) constellation, in a signal field. Receiving devices may identify the type of packet structure associated with a transmission or whether the signal field is present by the phase of the modulation constellation used for mapping for the signal field. In one embodiment, the phase of the modulation constellation may be determined by examining the energy of the I and Q components after Fast Fourier Transform. Various specific embodiments and variations are also disclosed.

12 Claims, 5 Drawing Sheets



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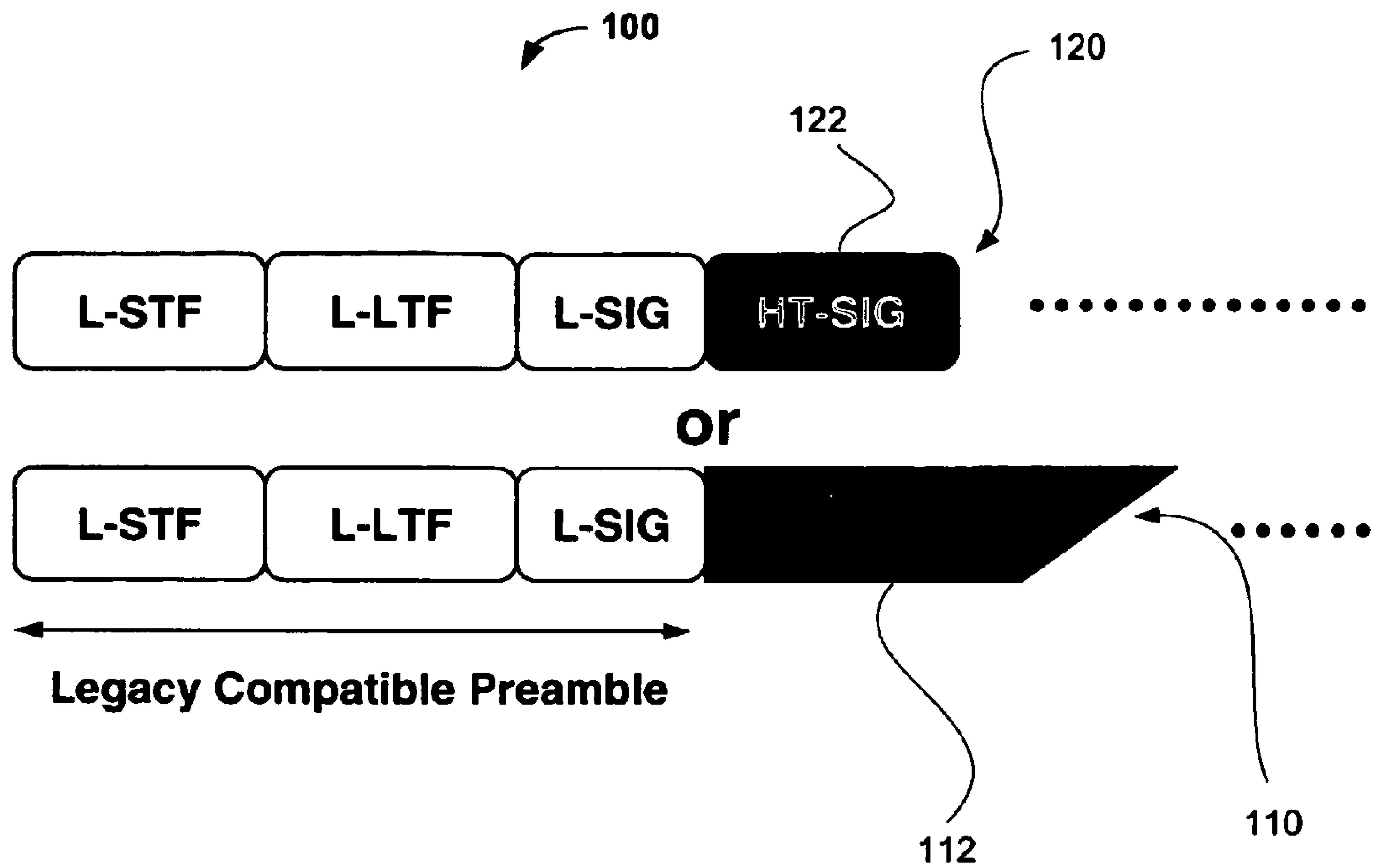
100
120
122
L-STF
L-LTF
L-SIG
HT-SIG
or
L-STF
L-LTF
L-SIG
Legacy Compatible Preamble
112
110

Fig. 1

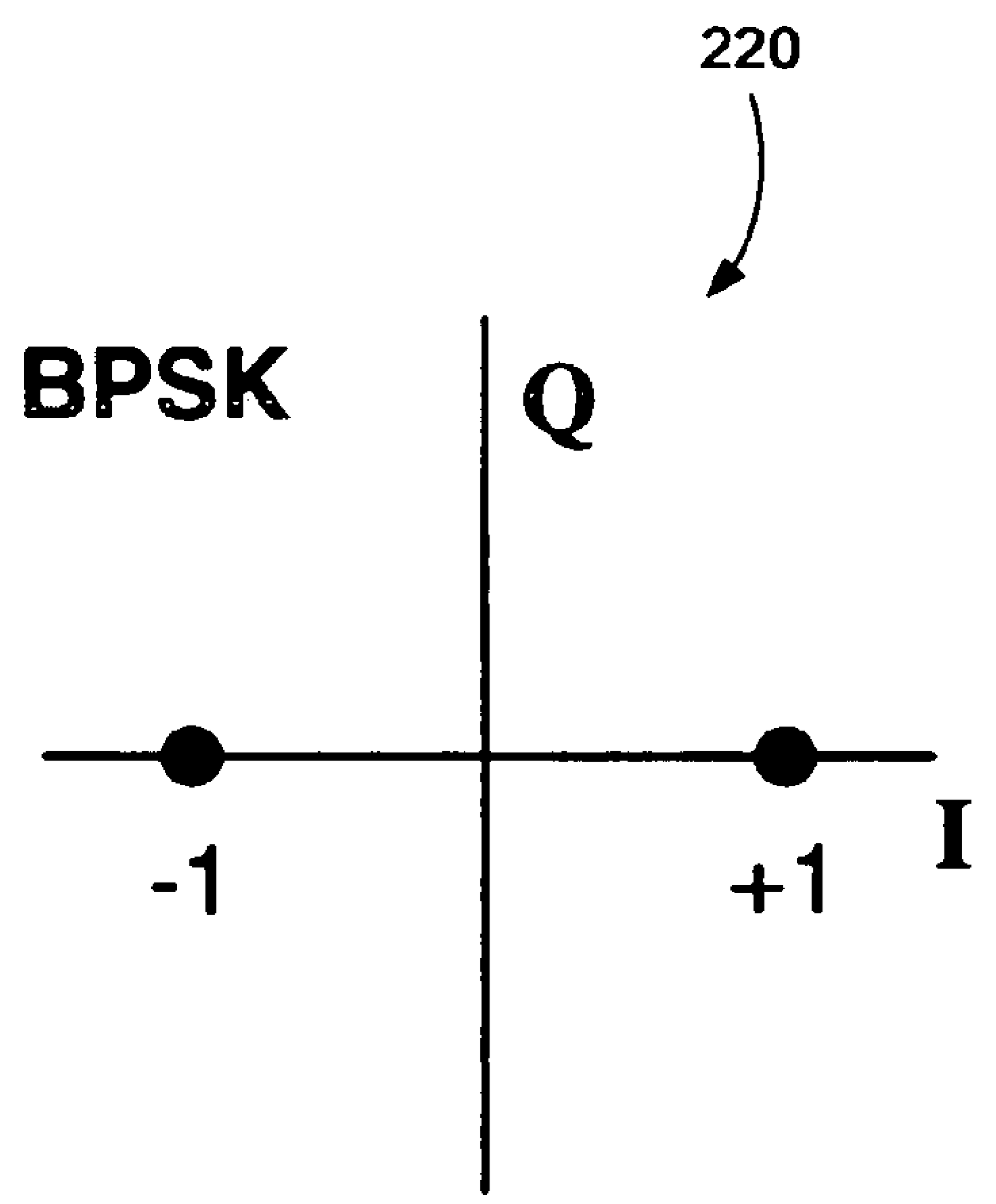

Fig. 2a

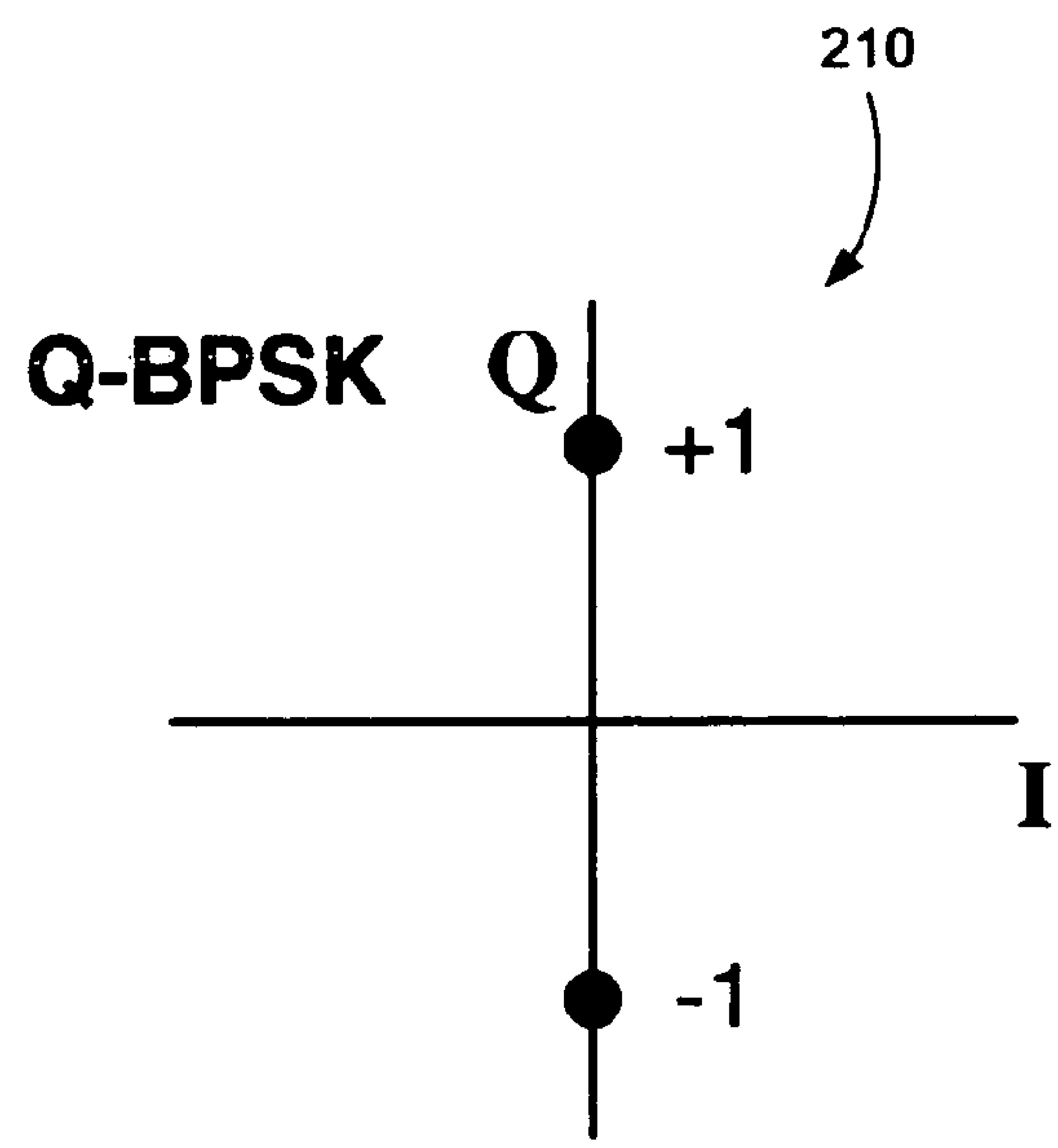

Fig. 2b

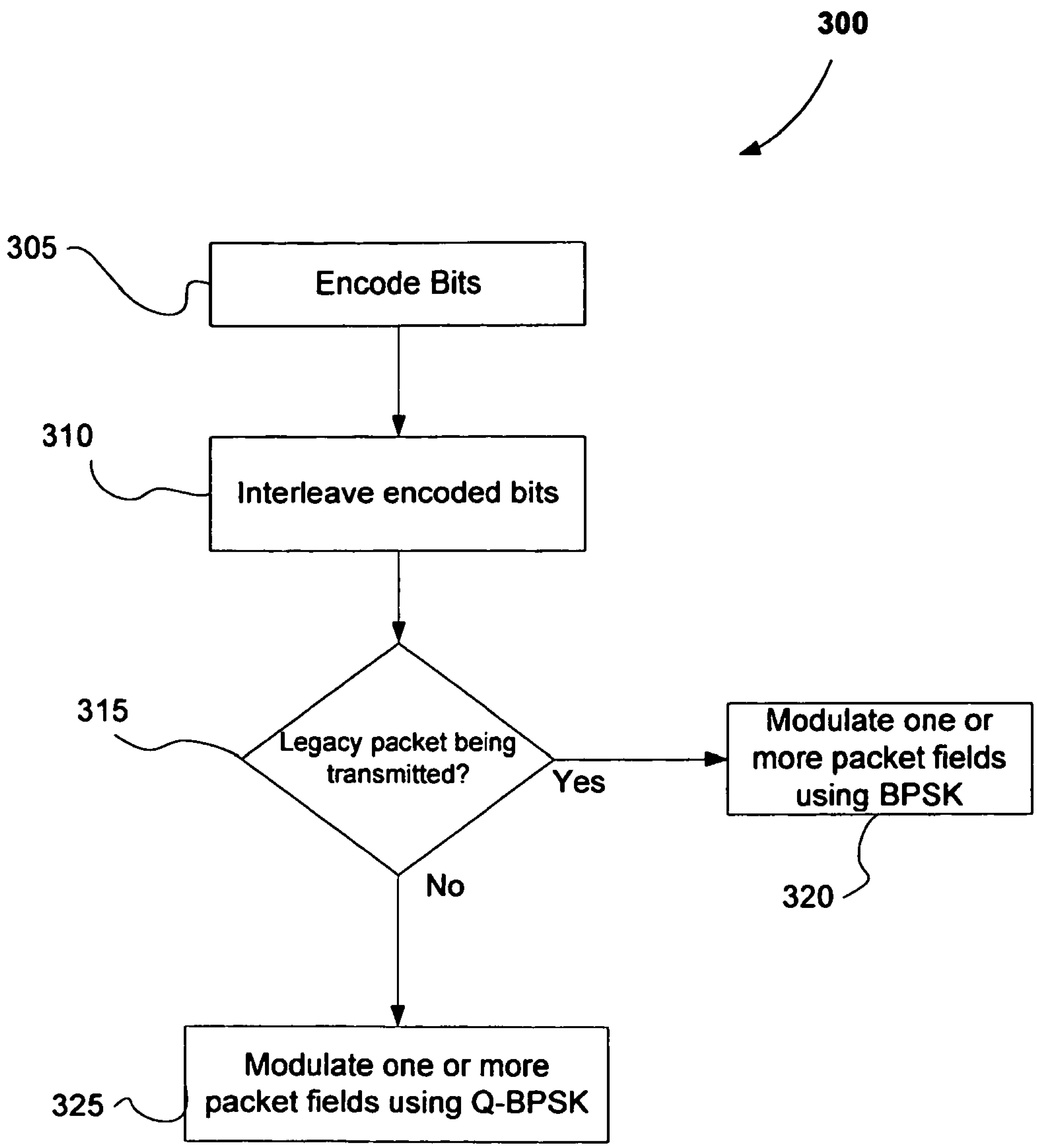
300
305
Encode Bits
310
Interleave encoded bits
315
Legacy packet being transmitted?
Yes
Modulate one or more packet fields using BPSK
320
No
325
Modulate one or more packet fields using Q-BPSK

Fig. 3

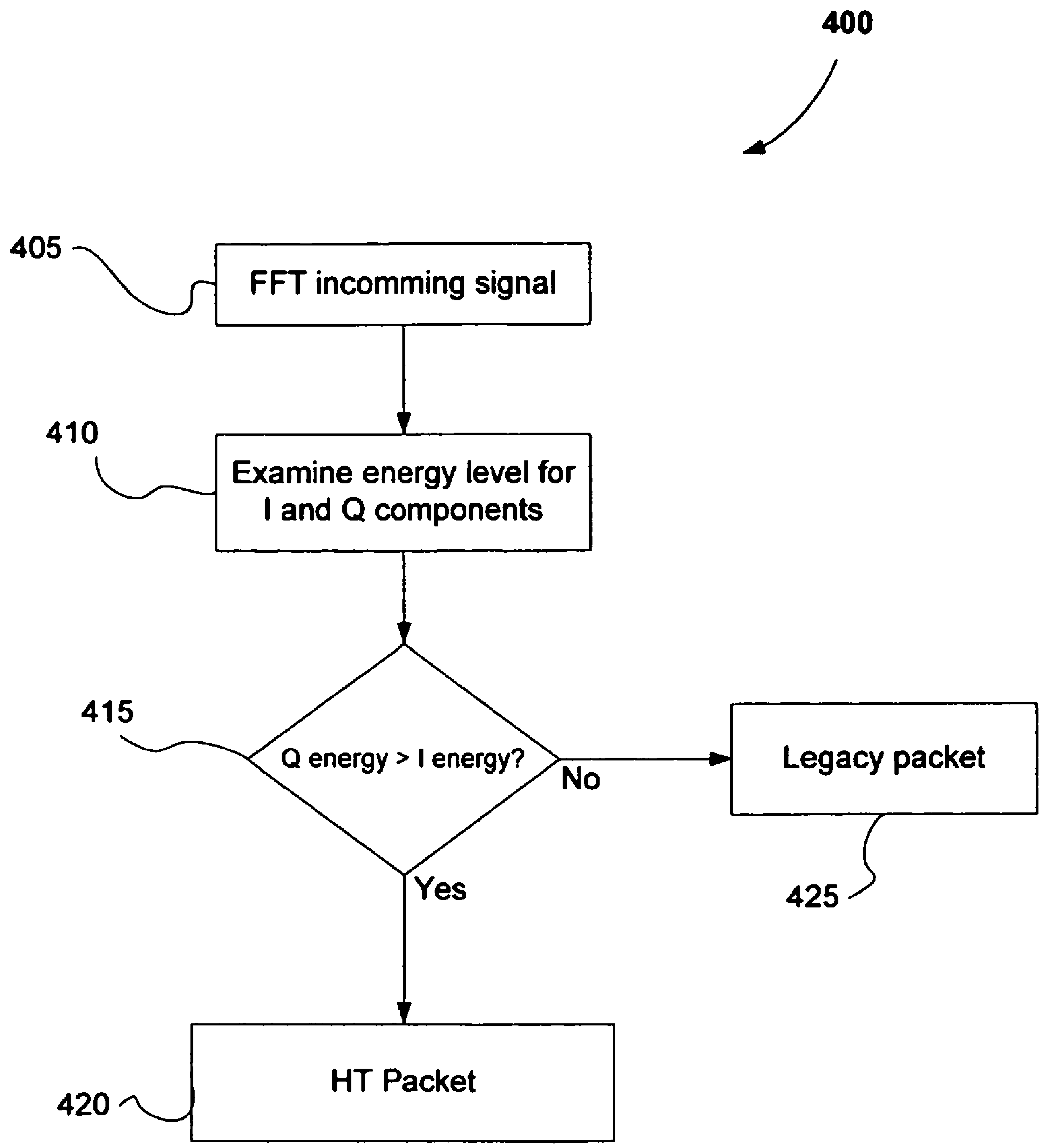
400
405
FFT incomming signal
410
Examine energy level for I and Q components
415
Q energy > I energy?
No
Legacy packet
425
Yes
420
HT Packet

Fig. 4

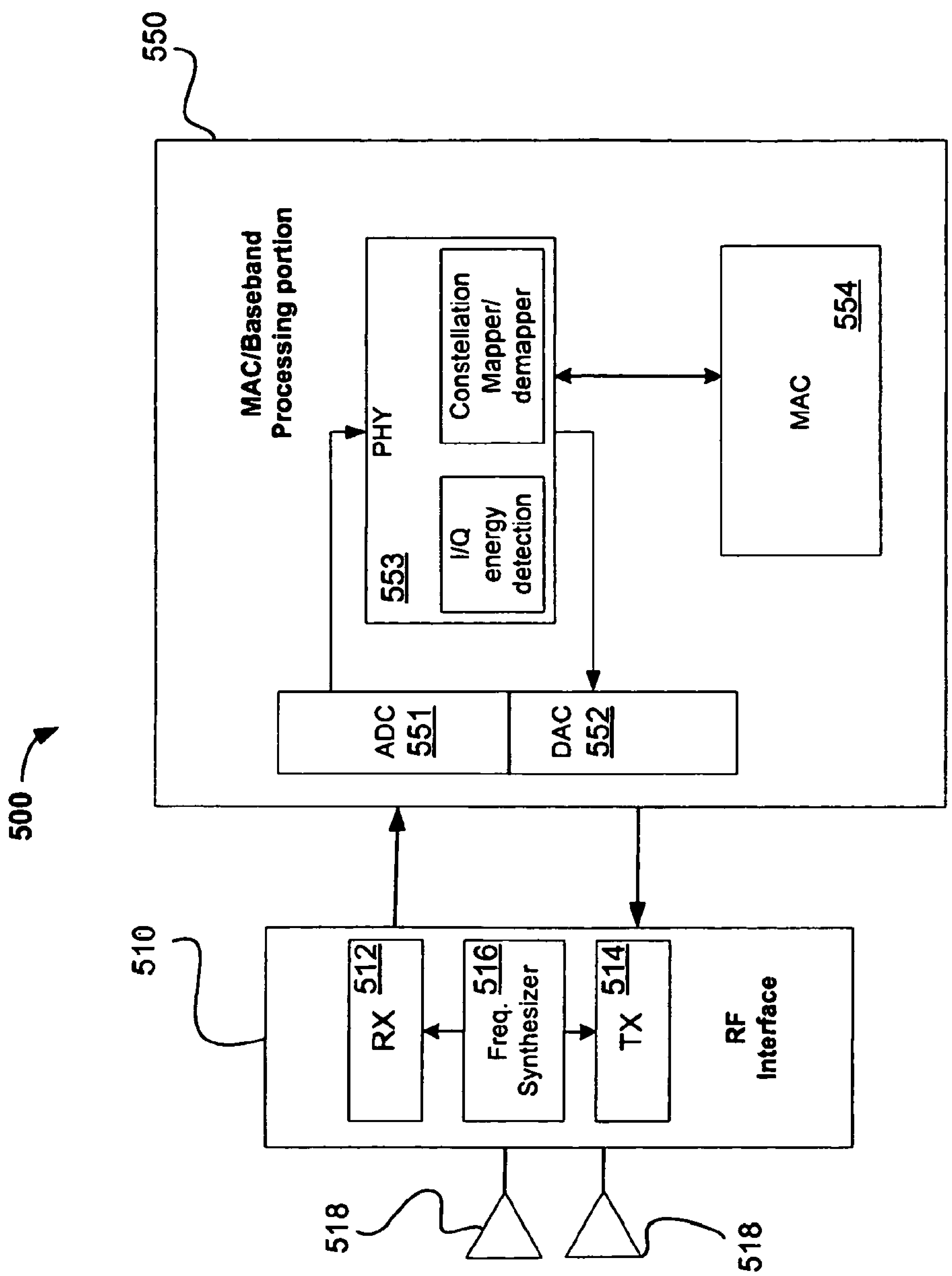
550
MAC/Baseband Processing portion
PHY
Constellation Mapper/ demapper
I/Q energy detection
553
MAC
554
ADC
551
DAC
552
500
510
RX
512
Freq. Synthesizer
516
TX
514
RF Interface
518
518

Fig. 5

METHOD FOR SIGNALING INFORMATION BY MODIFYING MODULATION CONSTELLATIONS

CROSS-REFERENCE TO RELATED APPLICATIONS

The present application is a continuation of U.S. application Ser. No. 12/319,191 filed Dec. 31, 2008 (pending) which in turn is a continuation of U.S. application Ser. No. 11/018,414 filed Dec. 20, 2004 (issued), now U.S. Pat. No. 7,474,608. Said application Ser. No. 11/018,414 claims the benefit of U.S. Provisional Application No. 60/536,071 filed Jan. 12, 2004. Said application Ser. No. 12/319,191, said application Ser. No. 11/018,414 and said Application No. 60/536,071 are hereby incorporated herein by reference in their entireties.

BACKGROUND OF THE INVENTION

In today's communications industry rapid advances in communication protocols and techniques are common. To facilitate widespread deployment of new systems, significant efforts are often made to ensure new communications techniques and systems are compatible with previous systems and devices, referred to herein as "legacy" systems or devices.

One problem associated with designing new generation systems is that, to be compatible with legacy systems, new generation systems often have to deal with limitations inherent in the legacy systems. For example, preamble training and signaling fields of packets for legacy wireless local area networks (WLANs) are already defined. To allow coexistence between legacy and new generation WLANs, it is desirable to preserve preambles having legacy compatible training and signaling fields. However, since legacy preambles may not be adequately designed to describe new generation packet structures, which may have longer lengths and/or require different training and signaling information, it can be challenging to quickly identify which type of packet structure, e.g., legacy or new generation, that follows a legacy compatible preamble.

Accordingly, a need exists to be able to quickly distinguish whether a packet having a legacy compatible preamble, may have a legacy packet structure or a newer generation packet structure. Solutions to allowing coexistence between legacy and new generation systems are therefore desired without significantly complicating or constraining the signaling in new generation packet structures.

BRIEF DESCRIPTION OF THE DRAWING

Aspects, features and advantages of the embodiments of the present invention will become apparent from the following description of the invention in reference to the appended drawing in which like numerals denote like elements and in which:

FIG. **1** shows block diagrams of two example packet structures for use with wireless networks;

FIGS. **2***a* and **2***b* show respective graphs of different phases for a modulation constellation in order to distinguish packet structures according to one embodiment of the present invention;

FIG. **3** is a flow diagram showing an exemplary method of communicating according to one embodiment of the present invention;

FIG. **4** is a flow diagram showing a method of detecting types of packet structure of a received transmission according to an embodiment of the present invention; and

FIG. **5** is a functional block diagram of an example embodiment for a wireless apparatus adapted to perform one or more of the methods of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

While the following detailed description may describe example embodiments of the present invention in relation to wireless local area networks (WLANs), the invention is not limited thereto and can be applied to other types of wireless networks or air interfaces where advantages could be obtained. Such wireless networks include, but are not limited to, those associated with wireless wide area networks (WWANs) such as general packet radio service (GPRS), enhanced GPRS (EGPRS), wideband code division multiple access (WCDMA), code division multiple access (CDMA) and CDMA 2000 systems or other similar systems, wireless metropolitan area networks (WMANs), such as wireless broadband access systems including those supported by the Worldwide Interoperability for Microwave Access (WiMAX) Forum, wireless personal area networks (WPANs) and the like.

The following inventive embodiments may be used in a variety of applications including transmitters, receivers and/or transceivers of a radio system, although the present invention is not limited in this respect. Radio systems specifically included within the scope of the present invention include, but are not limited to, network interface cards (NICs), network adaptors, mobile stations, base stations, access points (APs), gateways, bridges, hubs and radiotelephones. Further, the radio systems within the scope of the inventive embodiments may include cellular radiotelephone systems, satellite systems, personal communication systems (PCS), two-way radio systems, two-way pagers, personal computers (PCs) and related peripherals, personal digital assistants (PDAs), personal computing accessories and all existing and future arising systems which may be related in nature and to which the principles of the inventive embodiments could be suitably applied.

The following inventive embodiments are described in context of example WLANs using orthogonal frequency division multiplexing (OFDM) and/or orthogonal frequency division multiple access (OFDMA) although the invention is not limited in this respect.

The Institute of Electrical and Electronics Engineers (IEEE) finalized an initial standard for WLANs known at IEEE 802.11 (1997). This standard specifies a 2.4 GHz operating frequency with data rates of 1 and 2 Mbps using either direct sequence or frequency hopping spread spectrum. The IEEE 802.11 working group has since published three supplements to the 802.11 standard: 802.11a (OFDM in 5.8 GHz band) (ISO/IEC 8802-11: 1999), 802.11b (direct sequence in the 2.4 GHz band) (1999 and 1999 Cor.-1/2001), and 802.11g (OFDM in the 2.4 GHz band) (2003). These systems, most notably 802.11a and 802.11g utilizing OFDM, are individually or collectively referred to herein as "legacy" WLANs.

The IEEE 802.11a standard specifies an OFDM physical layer that splits an information signal across 52 separate sub-carriers to provide transmission of data. The primary purpose of the OFDM Physical Layer is to transmit MAC (medium access control) protocol data units (MPDUs) as directed by the 802.11 MAC Layer. The OFDM Physical Layer is divided into two elements: the PLCP (physical layer convergence protocol) and the PMD (physical medium dependent) sublayers. The PLCP sublayer prepares MAC protocol data units (MPDUs) for transmission and delivers incoming frames from the wireless medium to the MAC

Layer. The PLCP sublayer minimizes the dependence of the MAC layer on the PMD sublayer by mapping MPDUs into a frame format (also referred to as packet structure) suitable for transmission by the PMD.

Examples of frame formats or packet structures **100** for use in WLANs are graphically represented in FIG. **1** and may include a preamble portion for a receiver to acquire an incoming OFDM signal and synchronize the demodulator. The preamble may include one or more training fields and/or signaling fields (sometimes separately referred to as headers) including, for example, a legacy short training field (L-STF), a legacy long training field (L-LTF) and a legacy signaling field (L-SIG) **114**, **124**, which are collectively referred to herein as a legacy compatible preamble. The portion of packet structures **100** to follow the legacy compatible preamble may depend on whether the packet structure is a legacy packet structure **110** or a newer generation packet structure **120**.

For legacy packet structures **110** one or more data fields **112** typically follow the legacy compatible preamble and the rate and length (in OFDM symbols) of the legacy packet structure **110** may be determined by a receiver from the values present in the L-SIG field **114** of the legacy preamble. However, the L-SIG field **124** may not be sufficient to describe new generation packet structures **120**, such as those currently contemplated for adoption in the IEEE 802.11n standard for high throughput (HT) WLAN. By way of example, reserve bits in the L-SIG field may already be used by legacy devices for other purposes. Accordingly, additional signaling and/or training, generally depicted by HT-SIG block **122**, may be needed to define the HT packet structure and/or synchronize the demodulator to handle the HT modulation.

However, since an L-SIG field **114**, **124** may be present in all legacy compatible preambles; it may be difficult for a receiver to know whether legacy data **112** follows the signaling field **114** or whether additional HT signaling or training **122** follows the signaling filed **124**.

The long training symbols (L-LTF) that immediately precede the signal field **114**, **124** allow a receiver to accurately estimate the clock phase so that demodulation of the signal field, for example, using binary phase shift keying (BPSK), is possible.

In generating OFDM signals, encoded and/or interleaved bits may be mapped on a transmit modulation constellation, for example, constellations for BPSK, quaternary phase shift keying (QPSK), and/or various quadrature amplitude modulation (QAM) modulation schemes. An inverse Fast Fourier Transform (FFT) may then be performed on the mapped complex values to generate an array of complex values to produce an OFDM symbol and for which multiple symbols are joined together to produce an OFDM frame. On the receiving end, an FFT is performed to retrieve the originally mapped complex values which are then demapped using the corresponding constellation and converted back to bits, decoded, etc.

Turning to FIGS. **2***a* and **2***b*, in accordance with one embodiment, when the packet has a legacy packet structure (e.g., an IEEE 802.11a structure **110**; FIG. **1**), a traditional modulation constellation such as BPSK constellation **210** of FIG. **2***a* may be used for mapping complex values for one or more fields (e.g., **114**, **112**) of the legacy packet structure. Further, when the packet has a newer generation structure (e.g., IEEE 802.11n structure **120**; FIG. **1**) the one or more fields (e.g., **124**, **122**) may be modulated using a modified modulation constellation such as a BPSK constellation **220** having a phase rotation of 90 degrees as shown in FIG. **2***b*. Of course, the modified constellation **220** could be used for signaling legacy packet structures and traditional constellation **210** could be used for signaling new generation packet structures if desired. In this manner, information may be signaled to a receiver without modifying preamble structures or fields of the packets themselves.

Constellation **220** may be referred to as a BPSK-Q or Q-BPSK constellation since its coordinates (+1, −1) are positioned along the Q axis as opposed to traditional BPSK constellation **210** having coordinates (+1, −1) along the I axis.

The 90 degree rotation of a BPSK constellation is effective as it has no significant effect on the robustness of the packet field (e.g., signal field) with the modified modulation technique. However, the phase rotation for mapping values of a modulation constellation does not have to be 90 degrees and/or other types of modulation constellations such as those used for QPSK modulation and the like could also be used. Consequently, the inventive embodiments are thus not limited to any particular modulation constellation or degree of phase rotation.

Turning to FIG. **3**, a method **300** for transmitting in a wireless network may include modulating **325** one or more portions of a transmission using a modulation constellation having a modified phase in order to signal a receiving device of a type of packet structure associated with the transmission.

In certain embodiments, method **300** may include encoding bits **305** and interleaving **310** the encoded bits. If **315** a legacy packet structure is to be transmitted, one or more of the packet fields may be modulated **320** using traditional modulation constellations, such as a BPSK constellation (**210**; FIG. **2**). On the other hand, if **315** a new generation packet structure is to be transmitted, one or more of the packet fields may be modulated **325** using a modified modulation constellation, such as a Q-BPSK constellation (**220**; FIG. **2**).

In certain example embodiments, there may be two types of packet structures, a legacy packet structure substantially in conformance with an IEEE 802.11a type packet structure and a second packet structure substantially in conformance with an IEEE 802.11n type packet structure. In one example implementation, only the HT-SIG field (**122**; FIG. **1**) of an HT packet structure may be modulated using Q-BPSK however, the embodiments are not limited in this manner. Further, in certain implementations, signaling a packet type using phase rotated modulation constellations may only be used for packets which have a data payload.

For a receiver, the decision about whether the signal field is a legacy modulation or a HT field could be made by examining the amount of energy in the I and Q components after the FFT. For example, if the Q energy is greater than the I energy (the threshold for which may be set as suitably desired), then the receiver may determine the packet has an HT-SIG field. Otherwise it may be a legacy packet or visa versa. Since this decision can utilize all data modulated subcarriers, for example, at least 48 for a 20 MHz WLAN system, this affords a 17 dB processing gain resulting in a highly reliable decision. The proposed detection scheme may only be applied to the data modulated subcarriers and pilot subcarriers can be handled differently if desired.

Turning to FIG. **4**, a method **400** of receiving in a wireless network may include determining a type of packet structure associated with an incoming transmission based on an I and Q energy levels of a respective baseband signal.

In certain embodiments, method **400** may include performing **405** a FFT on a received transmission and examining **410** I and Q components after the FFT. If **415** the Q energy is significantly greater than the I energy, the associated packet field is determined **420** to be an HT-SIG field. Otherwise, it is identified **425** as being a legacy packet. The FFT values may then be demapped using the corresponding modulation constellations and converted back to bits, decoded, etc.

In an example implementation, the I and Q energy levels are used to determine whether a phase of a binary phase shift keying (BPSK) constellation used to map the HT-SIG field has been rotated although the embodiments are not limited in this respect.

Turning to FIG. **5**, an example apparatus **500** for use in a wireless network may include a host processing circuit **550** may be any component or combination of components and/or machine readable code adapted to perform one or more of the methods described herein. In one example implementation, circuit **550** may include a baseband processing circuit **553** to modulate bits for at least a portion of a transmission using a modulation constellation having a modified phase in order to signal a receiving device of a type of packet structure associated with a transmission. Alternatively or in addition, baseband processing circuit **553** may be configured to detect energy levels of data modulated subcarriers as previously described. Apparatus **500** may also include a medium access controller circuit **554** and/or a radio frequency (RF) interface **510** if desired.

Host processing circuit **550** and/or RF interface **510** may include any hardware, software and/or firmware components necessary for physical (PHY) link layer processing and/or RF processing of respective receive/transmit signals for supporting the various air interfaces.

Apparatus **500** may be a wireless mobile station such as a cell phone, personal digital assistant, computer, personal entertainment device, wireless router, a network access station such as a WLAN access point (AP) or other equipment and/or wireless network adaptor therefore. Accordingly, the functions and/or specific configurations of apparatus **500** could be varied as suitably desired.

The components and features of apparatus **500** may be implemented using any combination of discrete circuitry, application specific integrated circuits (ASICs), logic gates and/or single chip architectures. Further, the features of apparatus **500** may be implemented using microcontrollers, programmable logic arrays and/or microprocessors or any combination of the foregoing where suitably appropriate.

It should be appreciated that apparatus **500** shown in the block diagram of FIG. **5** is only one functionally descriptive example of many potential implementations. Accordingly, division, omission or inclusion of block functions depicted in the accompanying figures does not infer that the hardware components, circuits, software and/or elements for implementing these functions would necessarily be combined, divided, omitted, or included in embodiments of the present invention.

Embodiments of apparatus **500** may be implemented using single input single output (SISO) systems. However, certain alternative implementations may use multiple input multiple output (MIMO) architectures having multiple antennas **518**, **519**.

Unless contrary to physical possibility, the inventors envision the methods described herein may be performed in any sequence and/or in any combination; and the components of respective embodiments may be combined in any manner.

Although there have been described example embodiments of this novel invention, many variations and modifications are possible without departing from the scope of the invention. Accordingly the inventive embodiments are not limited by the specific disclosure above, but rather should be limited only by the scope of the appended claims and their legal equivalents.

The invention claimed is:

1. A method of decoding encoded information by a wireless communication device, comprising:
- receiving a data unit including encoded information comprising one or more variable length low density parity check (LDPC) codewords from a network device;
- decoding a length of the encoded information from a header of the data unit;
- determining, based at least in part on the decoded length, the length of each of the one or more LDPC codewords; and
- decoding the one or more LDPC codewords.

2. The method of claim **1**, wherein decoding the one or more LDPC codewords comprises, for each of the one or more LDPC codewords:
- determining a plurality of variable node values; and
- determining a plurality of check node values, corresponding to parity check relationships, based on the variable node values and a parity check matrix.

3. The method of claim **1**, wherein decoding the one or more LDPC codewords comprises using a Bahl, Cocke, Jelinek and Raviv (BCJR) algorithm.

4. The method of claim **1**, wherein decoding the one or more LDPC codewords comprises using a min-sum algorithm.

5. The method of claim **1**, wherein decoding the one or more LDPC codewords comprises using a plurality of decoding iterations.

6. The method of claim **5**, wherein the plurality of decoding iterations consist of eight decoding iterations.

7. A wireless communication device, including a memory and one or more antennas, the device capable to:
- receive a data unit including encoded information comprising one or more variable length low density parity check (LDPC) codewords from a network device;
- decode a length of the encoded information from a header of the data unit;
- determine, based at least in part on the decoded length, the length of each of the one or more LDPC codewords; and
- decode the one or more LDPC codewords.

8. The device of claim **7**, wherein the device is further capable to decode the one or more LDPC codewords, for each of the one or more LDPC codewords, by being configured to:
- determine a plurality of variable node values; and
- determine a plurality of check node values, corresponding to parity check relationships, based on the variable node values and a parity check matrix.

9. The device of claim **7**, wherein the device is further capable to decode the one or more LDPC codewords via a Bahl, Cocke, Jelinek and Raviv (BCJR) algorithm.

10. The device of claim **7**, wherein the device is further capable to decode one or more LDPC codewords via a min-sum algorithm.

11. The device of claim **7**, wherein the device is further capable to decode the one or more LDPC codewords via a plurality of decoding iterations.

12. The device of claim **11**, wherein the plurality of decoding iterations consists of eight decoding iterations.

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