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(54) METHOD AND APPARATUS FOR VARYING THE NUMBER OF PILOT TONES IN A MULTIPLE ANTENNA COMMUNICATION SYSTEM

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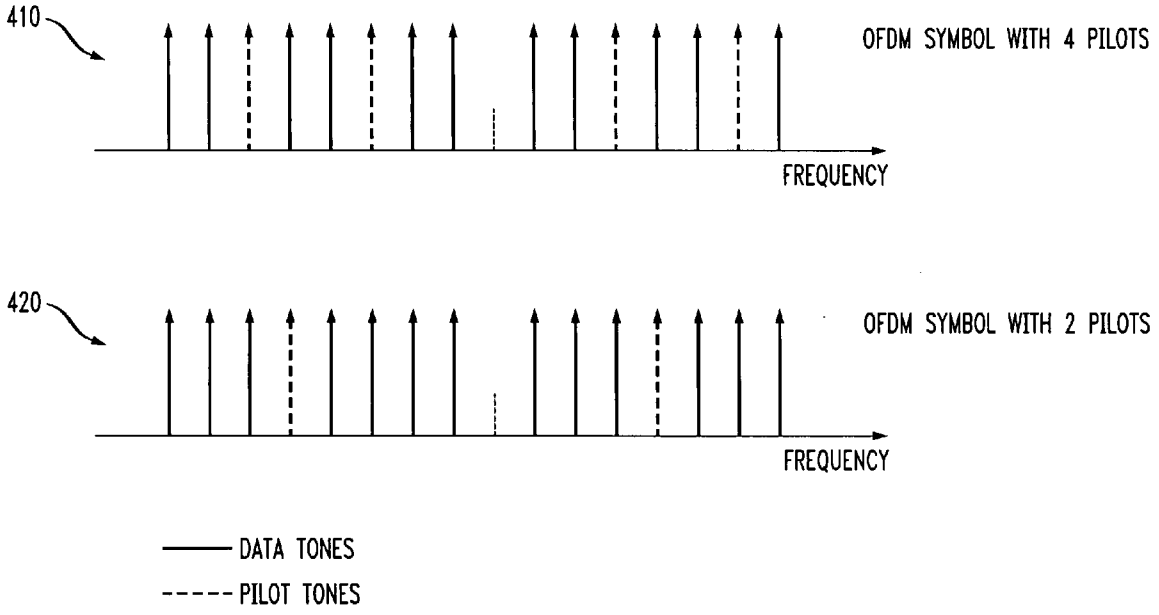
(57) **ABSTRACT**

Methods and apparatus are provided for varying the number of pilot tones in a multiple antenna communication system. Data is transmitted in a multiple antenna communication system by selecting a number of pilot tones to be employed to transmit the data; and transmitting an indication of the selected number of pilot tones in a preamble of a packet containing the data. Data is received in a multiple antenna communication system by receiving a preamble having an indication of a number of pilot tones embedded in the data; and processing the received data based on the indicated number of pilot tones. The indication of the selected number of pilot tones can be transmitted, for example, in a SIGNAL field of an exemplary IEEE 802.11 preamble. The number of pilot tones can be selected, for example, based on one or more of (i) a delay spread of a channel; (ii) the SNR at the receiver; or (iii) a number of antennas at a receiver.



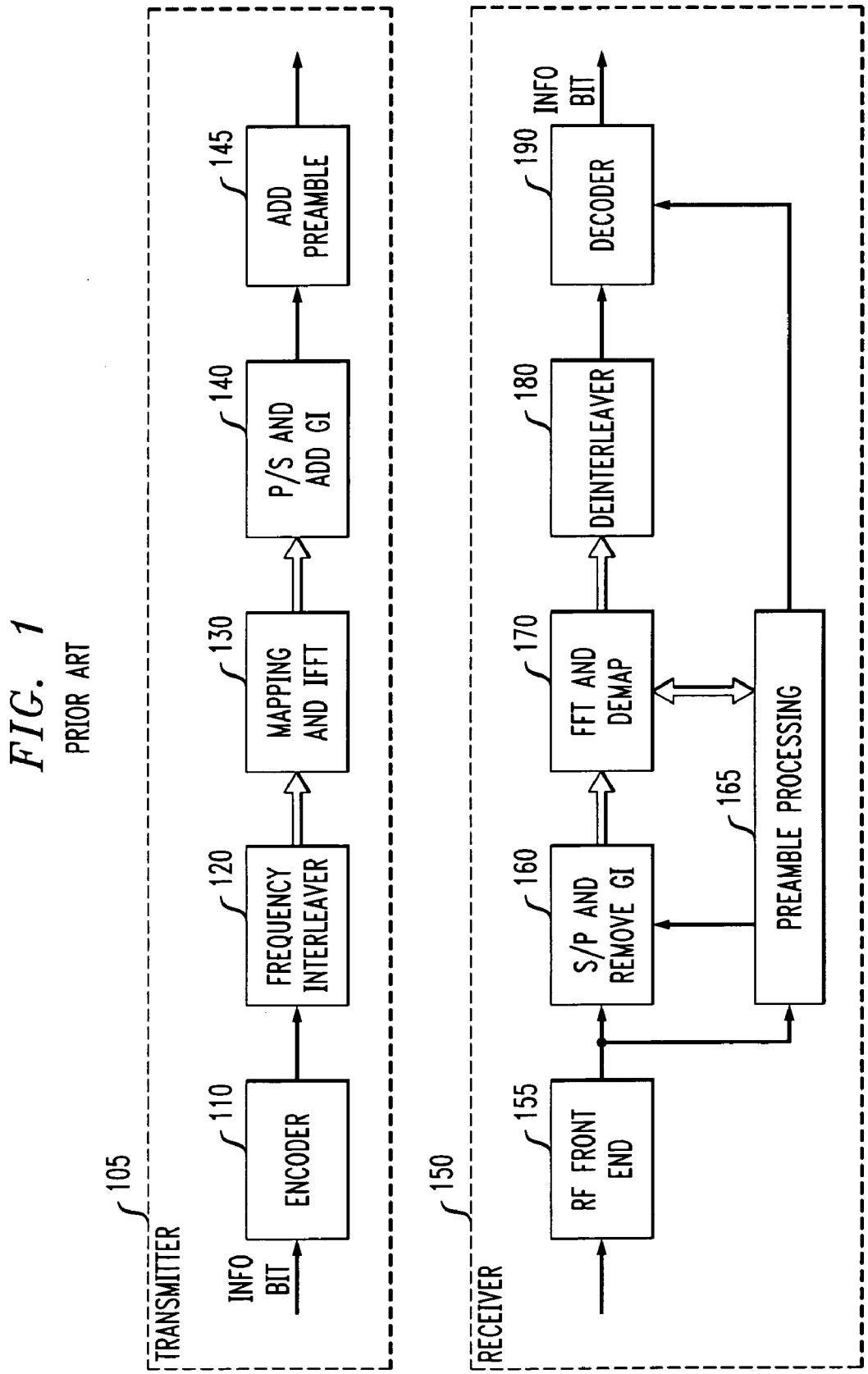


FIG. 1
PRIOR ART

FIG. 2

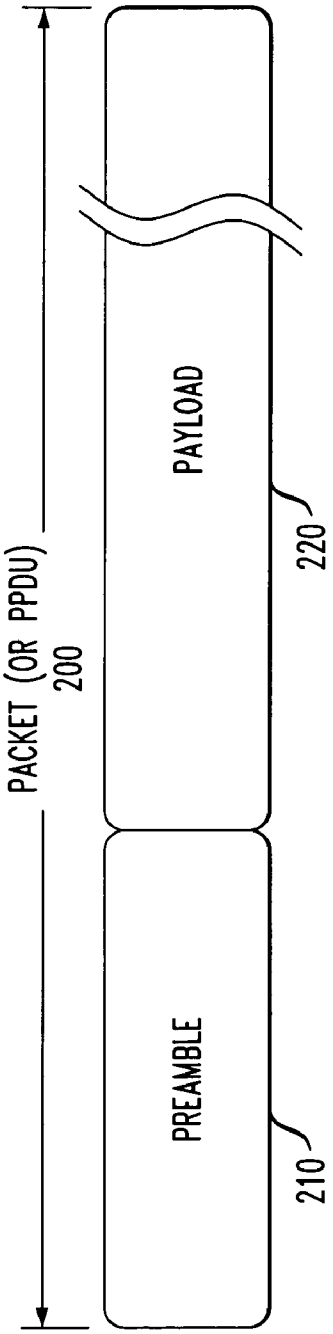


FIG. 3

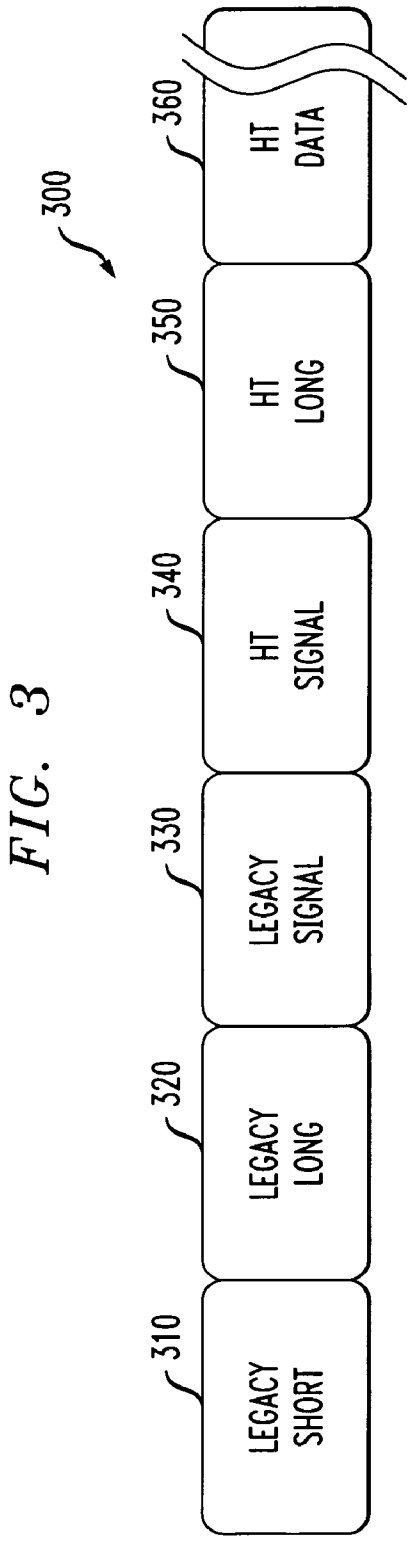
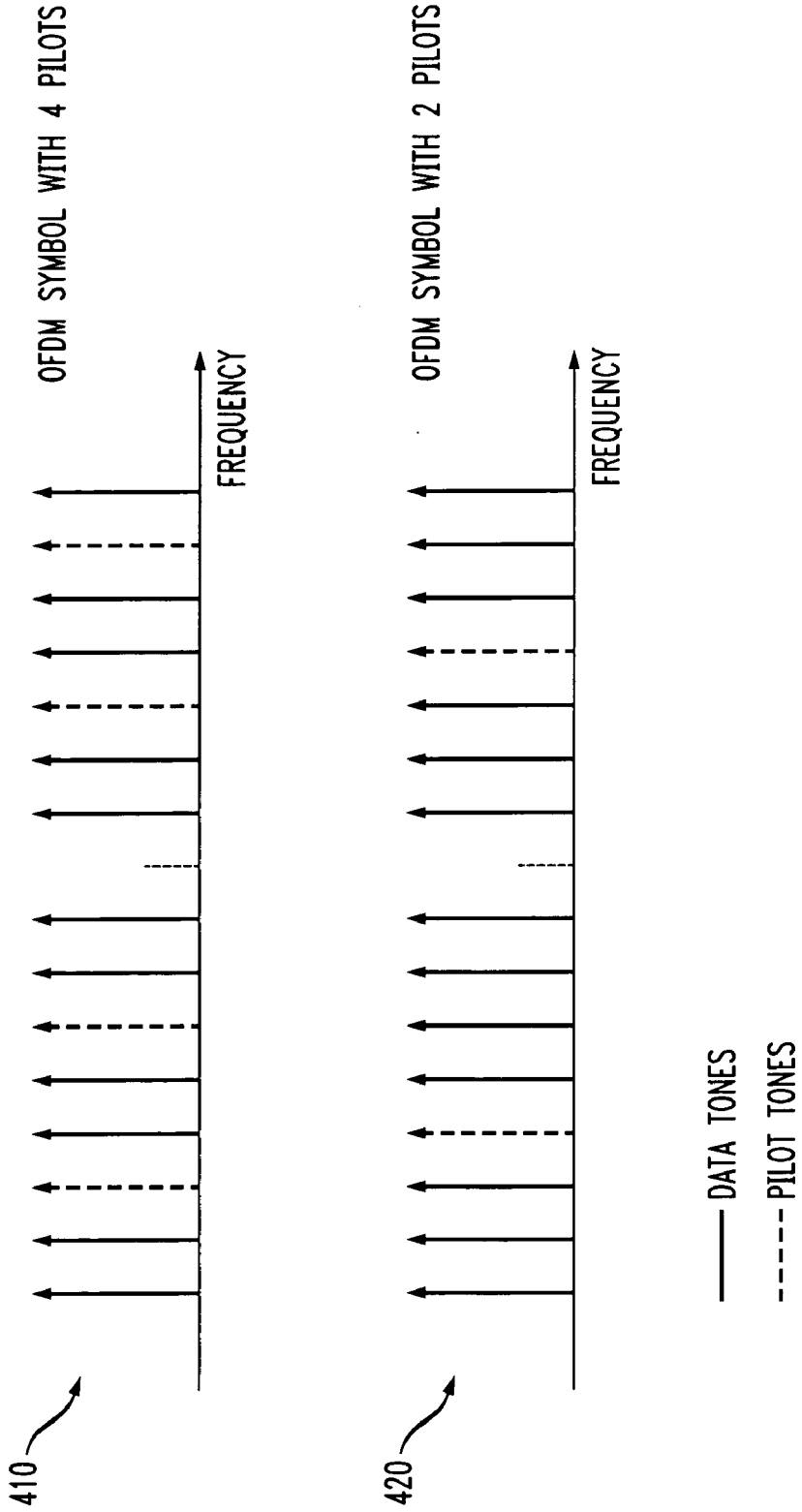


FIG. 4



METHOD AND APPARATUS FOR VARYING THE NUMBER OF PILOT TONES IN A MULTIPLE ANTENNA COMMUNICATION SYSTEM

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] The present application claims priority to U.S. Provisional Patent Application Ser. No. 60/608,472, filed Sep. 9, 2004, incorporated by reference herein.

FIELD OF THE INVENTION

[0002] The present invention relates generally to multiple antenna wireless communication systems, and more particularly, to phase and frequency offset estimation techniques for a multiple antenna communication system.

BACKGROUND OF THE INVENTION

[0003] Multiple transmit and receive antennas have been proposed to provide both increased robustness and capacity in next generation Wireless Local Area Network (WLAN) systems. The increased robustness can be achieved through techniques that exploit the spatial diversity and additional gain introduced in a system with multiple antennas. The increased capacity can be achieved in multipath fading environments with bandwidth efficient Multiple Input Multiple Output (MIMO) techniques. A multiple antenna communication system increases the data rate in a given channel bandwidth by transmitting separate data streams on multiple transmit antennas. Each receiver receives a combination of these data streams on multiple receive antennas.

[0004] In order to properly receive the different data streams, receivers in a multiple antenna communication system must acquire the channel matrix through training. This is generally achieved by using a specific training symbol, or preamble, to perform synchronization and channel estimation. The preamble helps the receiver (i) estimate the power of the received signal to set an automatic gain control (AGC) function; (ii) acquire the timing offset to perform optimal placement of a Fast Fourier Transform (FFT) window; (iii) estimate the frequency offset between the transmitter and receiver, and correct for the frequency offset prior to FFT demodulation; and (iv) estimate the channel transfer function to help demap the Quadrature Amplitude Modulation (QAM) symbols after the FFT has been performed.

[0005] In addition, a number of pilot tones are embedded in the OFDM data symbols to estimate the phase noise and residual frequency offset. Phase noise at the local oscillators of the transmitter and receiver creates a common phase error (CPE) at the FFT output that generally needs to be corrected for every OFDM symbol. Residual frequency offset at the input of the FFT also creates CPE.

[0006] In general, the accuracy of the CPE estimation increases with the number of pilots, thereby reducing the packet error rate, and increasing the reliability of the transmission. A greater number of pilots, however, reduces the effective data rate, since actual data is now replaced by pilots (which are known at both the transmitter and the receiver). The number of pilots needed to meet a certain packet error rate (PER) at the receiver is a function of several parameters, including the delay spread of the channel, the signal-to-noise ratio (SNR) at the receiver, and the number of antennas at the receiver. If the channel has a low delay spread, then the frequency selectivity of the channel is low as well, and thus a fewer number of pilots are required. On the other hand, a larger number of pilots would be required for a channel exhibiting a larger delay spread. If the SNR at the receiver is low, larger number of pilots are needed to get an accurate estimate of the CPE. Likewise, if there are diversity antennas present at the receiver, and the RF chains are fed from a single LO source, then Maximal Ratio combining (MRC) can be used at the receiver to improve the accuracy of the estimate of the CPE. Thus, the accuracy of the CPE estimate can be improved with diversity antennas and fewer pilots are needed to achieve the same level of performance.

[0007] A need therefore exists for methods and apparatus for varying the number of pilot tones in a multiple antenna communication system

SUMMARY OF THE INVENTION

[0008] Generally, methods and apparatus are provided for varying the number of pilot tones in a multiple antenna communication system. According to one aspect of the invention, data is transmitted in a multiple antenna communication system by selecting a number of pilot tones to be employed to transmit the data; and transmitting an indication of the selected number of pilot tones in a preamble of a packet containing the data. The indication of the selected number of pilot tones can be transmitted, for example, in a SIGNAL field of an exemplary IEEE 802.11 preamble. The number of pilot tones can be selected, for example, based on one or more of (i) a delay spread of a channel; (ii) the SNR at the receiver; or (iii) a number of antennas at a receiver.

[0009] According to another aspect of the invention, data is received in a multiple antenna communication system by receiving a preamble having an indication of a number of pilot tones embedded in the data; and processing the received data based on the indicated number of pilot tones.

[0010] A more complete understanding of the present invention, as well as further features and advantages of the present invention, will be obtained by reference to the following detailed description and drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] **FIG. 1** is a schematic block diagram of a conventional 802.11 a/g transceiver;

[0012] **FIG. 2** illustrates a typical packet format for an exemplary IEEE 802.11 or another IP-based OFDM system;

[0013] **FIG. 3** illustrates an exemplary format of the preamble of **FIG. 2** for IEEE 802.11n; and

[0014] **FIG. 4** illustrates an exemplary OFDM symbol with four pilot tones and an exemplary OFDM symbol with two pilot tones.

DETAILED DESCRIPTION

[0015] The present invention recognizes that the optimum number of pilots varies with operating parameters. Thus, the present invention provides methods and apparatus for varying the number of pilot tones to help maximize data transfer

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