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(54) **SYSTEM AND METHOD FOR SCRAMBLING THE PHASE OF THE CARRIERS IN A MULTICARRIER COMMUNICATIONS SYSTEM**

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This patent is subject to a terminal disclaimer.

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H04B 17/00 (2006.01)

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(58) **Field of Classification Search** 375/220, 375/222, 219, 226, 260, 327, 362; 370/203, 370/342, 206
See application file for complete search history.

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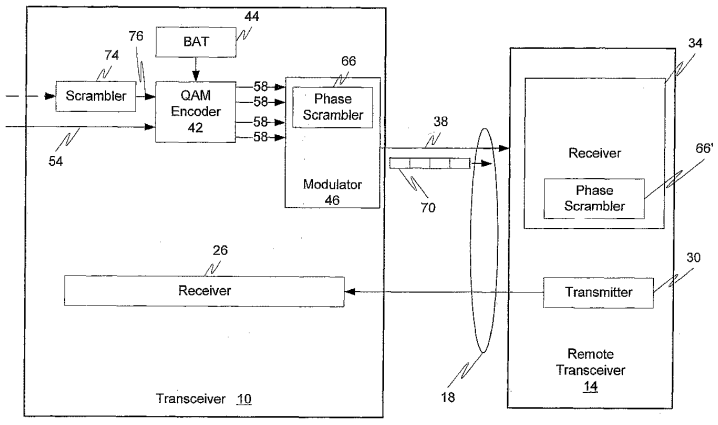
(57) **ABSTRACT**

A system and method that scrambles the phase characteristic of a carrier signal are described. The scrambling of the phase characteristic of each carrier signal includes associating a value with each carrier signal and computing a phase shift for each carrier signal based on the value associated with that carrier signal. The value is determined independently of any input bit value carried by that carrier signal. The phase shift computed for each carrier signal is combined with the phase characteristic of that carrier signal so as to substantially scramble the phase characteristic of the carrier signals. Bits of an input signal are modulated onto the carrier signals having the substantially scrambled phase characteristic to produce a transmission signal with a reduced PAR.

39 Claims, 2 Drawing Sheets



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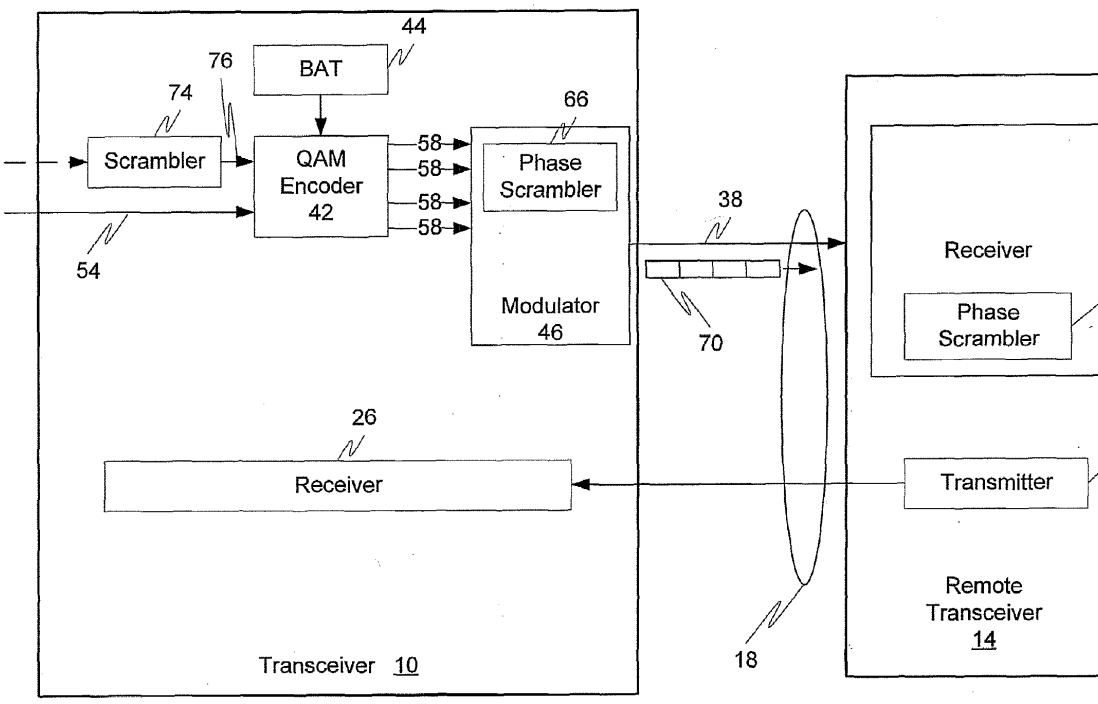

Fig. 1

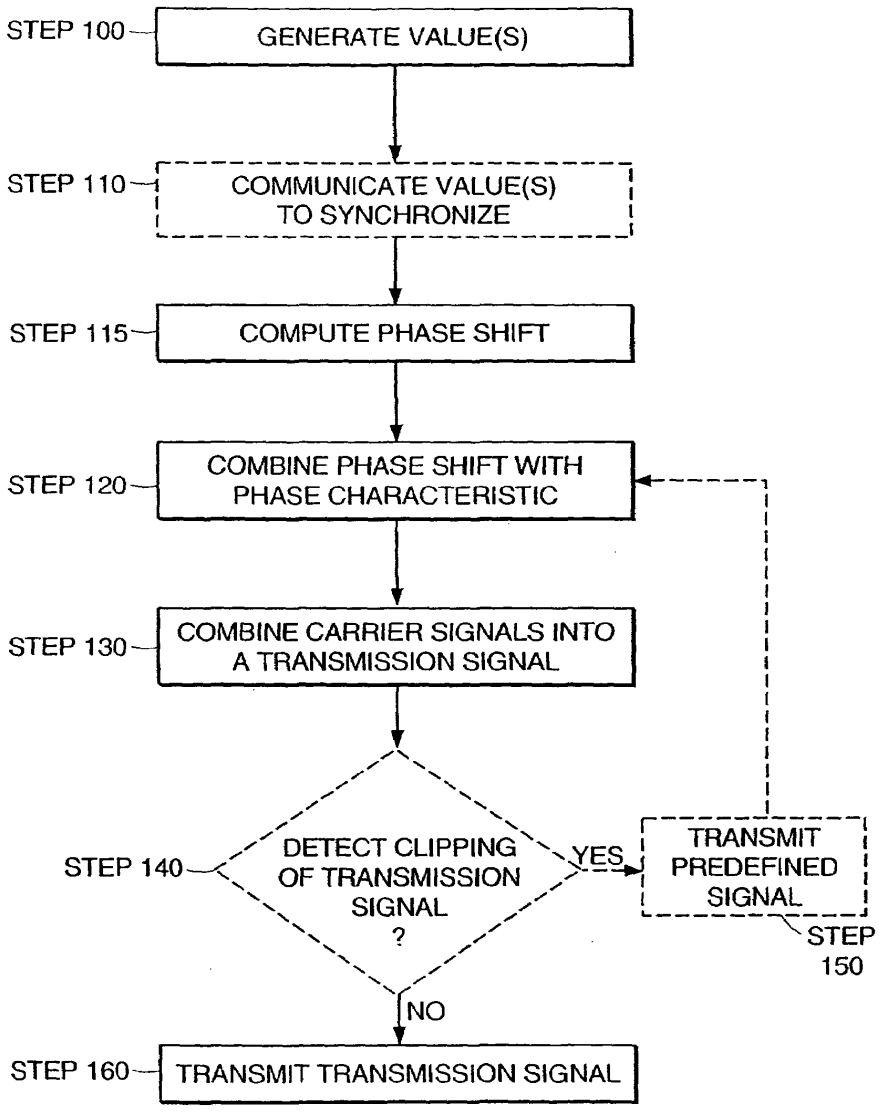

FIG. 2

SYSTEM AND METHOD FOR SCRAMBLING THE PHASE OF THE CARRIERS IN A MULTICARRIER COMMUNICATIONS SYSTEM

RELATED APPLICATION

This application claims the benefit of the filing date of copending U.S. Provisional Application, Ser. No. 60/164,134, filed Nov. 9, 1999, entitled "A Method For Randomizing The Phase Of The Carriers In A Multicarrier Communications System To Reduce The Peak To Average Power Ratio Of The Transmitted Signal," the entirety of which provisional application is incorporated by reference herein.

FIELD OF THE INVENTION

This invention relates to communications systems using multicarrier modulation. More particularly, the invention relates to multicarrier communications systems that lower the peak-to-average power ratio (PAR) of transmitted signals.

BACKGROUND OF THE INVENTION

In a conventional multicarrier communications system, transmitters communicate over a communication channel using multicarrier modulation or Discrete Multitone Modulation (DMT). Carrier signals (carriers) or sub-channels spaced within a usable frequency band of the communication channel are modulated at a symbol (i.e., block) transmission rate of the system. An input signal, which includes input data bits, is sent to a DMT transmitter, such as a DMT modem. The DMT transmitter typically modulates the phase characteristic, or phase, and amplitude of the carrier signals using an Inverse Fast Fourier Transform (IFFT) to generate a time domain signal, or transmission signal, that represents the input signal. The DMT transmitter transmits the transmission signal, which is a linear combination of the multiple carriers, to a DMT receiver over the communication channel.

The phase and amplitude of the carrier signals of DMT transmission signal can be considered random because the phase and amplitude result from the modulation of an arbitrary sequence of input data bits comprising the transmitted information. Therefore, under the condition that the modulated data bit stream is random, the DMT transmission signal can be approximated as having a Gaussian probability distribution. A bit scrambler is often used in the DMT transmitter to scramble the input data bits before the bits are modulated to assure that the transmitted data bits are random and, consequently, that the modulation of those bits produces a DMT transmission signal with a Gaussian probability distribution.

With an appropriate allocation of transmit power levels to the carriers or sub-channels, such a system provides a desirable performance. Further, generating a transmission signal with a Gaussian probability distribution is important in order to transmit a transmission signal with a low peak-to-average ratio (PAR), or peak-to-average power ratio. The PAR of a transmission signal is the ratio of the instantaneous peak value (i.e., maximum magnitude) of a signal parameter (e.g., voltage, current, phase, frequency, power) to the time-averaged value of the signal parameter. In DMT systems, the PAR of the transmitted signal is determined by the probability of the random transmission signal reaching a certain peak voltage during the time interval required for a certain number of symbols. An example of the PAR of a transmission signal transmitted from a DMT transmitter is 14.5 dB, which is equivalent to having a 1E-7 probability of clipping. The PAR of a transmission signal transmitted and received in a DMT communication system is an important consideration in the design of the DMT communication system because the PAR of a signal affects the communication system's total power consumption and component linearity requirements of the system.

If the phase of the modulated carriers is not random, then the PAR can increase greatly. Examples of cases where the phases of the modulated carrier signals are not random are when bit scramblers are not used, multiple carrier signals are used to modulate the same input data bits, and the constellation maps, which are mappings of input data bits to the phase of a carrier signal, used for modulation are not random enough (i.e., a zero value for a data bit corresponds to a 90 degree phase characteristic of the DMT carrier signal and a one value for a data bit corresponds to a −90 degree phase characteristic of the DMT carrier signal). An increased PAR can result in a system with high power consumption and/or with high probability of clipping the transmission signal. Thus, there remains a need for a system and method that can effectively scramble the phase of the modulated carrier signals in order to provide a low PAR for the transmission signal.

SUMMARY OF THE INVENTION

The present invention features a system and method that scrambles the phase characteristics of the modulated carrier signals in a transmission signal. In one aspect, a value is associated with each carrier signal. A phase shift is computed for each carrier signal based on the value associated with that carrier signal. The value is determined independently of any input bit value carried by that carrier signal. The phase shift computed for each carrier signal is combined with the phase characteristic of that carrier signal to substantially scramble the phase characteristics of the carrier signals.

In one embodiment, the input bit stream is modulated onto the carrier signals having the substantially scrambled phase characteristic to produce a transmission signal with a reduced peak-to-average power ratio (PAR). The value is derived from a predetermined parameter, such as a random number generator, a carrier number, a DMT symbol count, a superframe count, and a hyperframe count. In another embodiment, a predetermined transmission signal is transmitted when the amplitude of the transmission signal exceeds a certain level.

In another aspect, the invention features a method wherein a value is associated with each carrier signal. The value is determined independently of any input bit value carried by that carrier signal. A phase shift for each carrier signal is computed based on the value associated with that carrier signal. The transmission signal is demodulated using the phase shift computed for each carrier signal.

In another aspect, the invention features a system comprising a phase scrambler that computes a phase shift for each carrier signal based on a value associated with that carrier signal. The phase scrambler also combines the phase shift computed for each carrier signal with the phase characteristic of that carrier signal to substantially scramble the phase characteristic of the carrier signals. In one embodiment, a modulator, in communication with the phase scrambler, modulates bits of an input signal onto the carrier signals

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