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(54) Title: HIERARCHICAL PREAMBLE CONSTRUCTIONS FOR OFDMA BASED ON COMPLEMENTARY SEQUENCES

(57) Abstract: A method of implementing OFDMA systems with enhanced preamble properties is presented. The transmit powers boosted during a preamble transmission, by utilizing preambles with a low Peak-to-Average Power Ratio (PAPR) property, as opposed to higher PAPR during the data portion of the transmission. Further, sets of preambles satisfying good PAPR properties in OFDMA systems are presented. The preambles satisfy a low Peak-to-Average Power Ratio (PAPR) property for numerous subsets of the usable subcarrier set. A method for generating a hierarchical set of preamble for OFDMA communication systems is described. The method hinges on the good PAPR properties of Golay's complementary sequences, and on hierarchical construction methods of larger complementary sequences out of smaller ones.

HIERARCHICAL PREAMBLE CONSTRUCTIONS FOR OFDMA BASED ON COMPLEMENTARY SEQUENCES

FIELD OF THE INVENTION

The present invention relates to Orthogonal Frequency Division Multiple Access (OFDMA) systems, and in particular to construction of preambles for transmission of message bursts.

BACKGROUND OF THE INVENTION

The Orthogonal Frequency Division Multiple Access (OFDMA) systems are similar to Orthogonal Frequency Division Multiplex (OFDM) systems in the sense that the information is spread over multiple subcarriers in the frequency domain and is transmitted after converting the information to the time domain using a Fourier transform. The amount of subcarriers available to a system is determined by a ratio of the assigned frequency channel to the frequency spacing between the subcarriers. The main difference between OFDM and OFDMA is that with OFDM a single transmitter uses a whole range of subcarriers to transmit its information, while in OFDMA different transmitters are assigned disjoint sets of subcarriers, and each user sends his information on the subcarriers assigned to him.

The amount of subcarriers assigned to each transmitter may vary according to the traffic demands of each user in a multiple access system. The assignment is usually performed in groups of subcarriers, denoted as subchannels. The OFDMA idea became popular recently in the context of wireless access systems. There are several variants of division of the subcarriers into subchannels, starting from irregular methods such as in IEEE802.16a [4] and in DVB-RCT [5], through contiguous clusters of subcarriers [3] and concluding with regularly interleaved sets.

In burst communication systems each transmission typically starts with a preamble, which is used for synchronization and channel estimation. Usually such preamble is structured as one or two OFDM symbols with predefined values

modulating each of the subcarriers. The set of predefined values is chosen to satisfy several criteria. One is that all the values have the same modulus, to ease the channel estimation. Only the values corresponding to the assigned subcarriers are non-zero. Another criterion is that the preamble time domain waveform has a low Peak-to-Average Power Ratio (PAPR) property, to avoid excessive distortion in the power amplifier.

Typically OFDM systems produce high PAPR waveforms, since at each time instant numerous data-dependent contributions add up to a Gaussian-like waveform. As a result, the OFDM transmitters utilize their power amplifiers at a small fraction of their peak output, typically at 8-11 dB backoff. By using as a preamble, a carefully crafted set of subcarrier modulation values, the PAPR of the preamble can be kept at about 3 dB, significantly less than the values typical to data. This property is beneficial in that during the channel estimation phase the signal experiences smaller distortion, resulting in a more accurate estimate.

The preambles in OFDMA systems are designed do excite only the subcarriers that are assigned to the user. The OFDMA adds a new twist to the problem, since not only a single preamble with good PAPR properties needs to be designed, but rather a family of preambles for each subset of subcarriers that can be allocated to a single transmitter.

PRIOR ART

There are several recent works searching for families of waveforms with low PAPR. One set of waveforms is based on Golay's complementary sequences, which have the property that their Fourier transform has a PAPR of at most 2, which is equivalent to 3 dB. Van Nee has shown [1] how to use sets of complementary sequences in conjunction with OFDM modulation for conveying information with low PAPR waveforms. This invention was implemented in the "Magic Wand" wireless ATM demonstrator [2]. In this work the aim was to achieve low PAPR property for the data portion of the signal rather than for the preamble. Similarly, Awater and van Nee, in US patent 6,005,840, disclose an OFDM transmitter system that uses complementary codes to reduce the power-to-average power (PAP) ratio of the transmitted signal. Sets of complementary sequences are also used to convey

information in time domain, which is not OFDM, in a popular 802.11b Wireless LAN standard, where a dual property is used. The low PAPR of the Fourier transform in frequency domain results in better immunity to interference and to multipath.

In all the above applications the goal is to convey data by selecting one out of several sequences, all the sequences having the same length. By contrast, in OFDMA systems, a set of sequences of different sizes is needed, each corresponding to a possible allocation of a different subcarrier set to each user.

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SUMMARY OF THE INVENTION

Therefore, it is a principal object of the present invention to create a hierarchical set of preambles of different size in order to serve as low-Peak-to-Average Power Ratio (PAPR) preambles for an Orthogonal Frequency Division Multiple Access (OFDMA) system.

A method is disclosed of implementing OFDMA systems with enhanced preamble properties. The transmit power is boosted during a preamble transmission, by utilizing preambles with a low Peak-to-Average Power Ratio (PAPR) property, as opposed to higher PAPR during the data portion of the transmission. Further, sets of preambles satisfying good PAPR properties in OFDMA systems are presented. The preambles satisfy a low Peak-to-Average Power Ratio (PAPR) property for numerous subsets of the usable subcarrier set. A method for generating a hierarchical set of preambles for OFDMA communication systems is described. The method hinges on the good PAPR properties of Golay's complementary sequences, and on hierarchical construction methods of larger complementary sequences out of smaller ones.

BRIEF DESCRIPTION OF THE DRAWINGS

These and further features and advantages of the invention will become more clearly understood in the light of the ensuing description of a preferred embodiment thereof, given by way of example only, with reference to the accompanying drawings, wherein:

Fig. 1 is a flow chart illustrating a method of constructing a sequence of values to be used for modulating the subcarriers of a preamble in an OFDMA system, constructed in accordance with the principles of the present invention.

Figs. 2a and 2b are illustrations of time domain effect, incurred without and with boosting of a low-PAPR preamble, respectively, constructed in accordance with the principles of the present invention.

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