DESIGN OF WAVELET PACKET BASED MODEL FOR MULTI CARRIER MODULATION

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Abstract:
In current scenario Multi-Carrier modulation (MCM) is considered an effective technique for both wire and wireless communications. It divides the entire bandwidth into several parallel sub-channels. This splitting is by dividing the transmit data into several parallel low-bit-rate data streams and then to modulate the carriers corresponding to those sub-channels. Though MCM technique uses Orthogonal Frequency Division Multiplexing (OFDM) model, it is very sensitive to Carrier Frequency Offset (CFO), that leads to a severe distortion in subcarrier orthogonality and causes inter channel interference (ICI). In this paper, Wavelet Packet Transform is designed for the model of MCM as a novel alternative to the most exiting Orthogonal Frequency Division Multiplexing (OFDM) technique, because of its time frequency representation and lower side lobes in transmitted signals, that reduces inter carrier interference (ICI), and inter symbol interference (ISI). Performance analysis is investigated for such model. Simulation results show a significant enhancement in terms of spectral efficiency.

Key words: Multi-Carrier modulation (MCM), Orthogonal Frequency Division Multiplexing (OFDM), Wavelet packet based Multi-Carrier modulation (WPMCM), Discrete Wavelet Packet Transform (DWPT).

1. Introduction

Wireless communication provides high data rate and improved quality of communication by using MCM techniques. Multicarrier Modulation (MCM) technique [1] is used in data delivery systems over the phone line, digital radio and television, and wireless networking systems. It has already been accepted for the wireless local area network standards IEEE 802.11a, High Performance LAN type 2 (HIPERLAN/2), and Mobile Multimedia Access Communication (MMAC) Systems. [2]. MCM is a block-oriented modulation scheme, which results in a relative longer symbol duration and produces greater immunity to impulse noise and inter symbol interference (ISI). Because of such advantages, MCM is considered a promising technique in digital subscriber line (xDSL), digital video/audio broadcasting, and wireless communications [1], [3]. The independence among subchannels simplifies the design of the equalizer and provides an easy method for transmitter optimization. It also utilizes cyclic prefix (CP) in guard band interval to cancel ISI caused by multipath wireless channel. However, CP requires extra bandwidth which makes OFDM spectrally inefficient [4]. Therefore, WPNM, a DWPT based MCM scheme, is proposed as a solution to this problem. WPNM provides better spectral shaping than DFT-based MCM scheme. It is also spectrally efficient as does not utilize cyclic prefix. Wavelet packet based MCM (WPMCM) systems have overall the same capabilities as OFDM systems with some improved performance.
This paper is organized as follows. In Section II, the concept of MCM has been discussed. In section III, the Wavelet based model has been designed for MCM. Section IV, has shown the comparison result among OFDM and WPNM performance. Finally, section V, concludes the work.

2. Multi Carrier Modulation

MCM is an efficient transmission technique for wireless communication system as it divides the original frequency band into several narrow bands, and making the system less sensitive to wide-band impulse noise and fast channel fades as compared to the single carrier modulation technique. Some of the advantages are given for MCM.

* In multicarrier modulation (MCM), a transmitted bitstream is divided into many different substreams, which are to be sent in parallel over many subchannels;
* The parallel subchannels are typically orthogonal under ideal conditions for propagation;
* The data rate on each of the subcarriers is much lower than the total data rate;
* The bandwidth of subchannels is usually much less than the coherence bandwidth of the wireless channel, so that the ISI on each subchannel is small;
* MCM can be efficiently implemented digitally using the FFT (Fast Fourier Transform) techniques, yielding the so-called orthogonal frequency division multiplexing (OFDM);
* Digital audio and video broadcasting and Mobile wireless broadband communications;
* Wireless local area networks (WLAN) - IEEE802.11a, g;
* Fixed wireless broadband services;

OFDM for MCM: In OFDM it can simultaneously transmitted N data symbols through N sub-carriers, thus reducing the symbol rate to 1/Nth of the original symbol rate[4]. In OFDM, Orthogonal subcarriers allow their spectrums to overlap which achieves the high spectral efficiency. As long as the subcarriers preserve their orthogonality, adjacent subcarriers do not interfere with each other.

![Block diagram of OFDM system using multipath channel](image)

The OFDM transmitter output signal can be represented by[4] :

\[
S(t) = \frac{1}{\sqrt{N}} \sum_{k=0}^{N-1} X_k e^{j2\pi kn/N} \quad (1)
\]

\[
= \frac{1}{\sqrt{N}} \sum_{k=0}^{N-1} X_k e^{j2\pi kn\Delta t}, \quad n = 0, 1, 2, \ldots, N - 1, (2)
\]

Frequencies \(f_k = k/N\Delta t\) should be orthogonal, \(t_n = n\Delta t\) and \(\Delta t\) is the symbol duration of the serial data sequence \(X_k\) where \(N\) is the number of subcarrier and \(1/\sqrt{N}\) is the scaling factor. In OFDM system, the signal is converted from frequency domain to its time domain at the transmitter side by using, Inverse Fourier Fast Transform (IFFT) algorithm and from time domain to frequency domain at receiver side using Fast Fourier Transform (FFT) algorithm.

Many works have been done using orthogonal frequency division multiplexing [8-9], but this requires sharp filtering and is not spectrally efficient. More bandwidth-efficient implementation (OFDM) overlaps the transmitted substreams such that they can be separated at the receiver.
3. Design of WPMCM Model

WPT gives better signal representation, with balanced resolution at any time and. In this case the wavelet and scaling functions are represented by high pass \( g[n] \) and low pass \( h[n] \) quadrature mirror filter (QMF) of length \( L \). The filters are represented by [5]:

\[
g[L - 1 - n] = (-1)^n h[n] \tag{3}
\]

Furthermore, they also have adjoins or duals which are their complex conjugate time reversed variants given by:

\[
h'[n] = h^*[-n] \text{and} \ g'[n] = g^*[-n] \tag{4}
\]

The pair \( \{h[n], g[n]\} \) is called the synthesis filter-pair and is used to generate the wavelet packet carriers for modulation of data at the transmitter end and the combination \( \{h'[n], g'[n]\} \) is called the analysis filter-pair and is used to derive the wavelet packet carrier duals for demodulation of data at the receiver end. Denoting the magnitude responses of these four filters in the frequency domain as \( H(\omega), G(\omega), H'(\omega) \) and \( G'(\omega) \) the filters have been shown to satisfy the perfect reconstruction conditions.

\[
r^* (b + \pi) r (b) + q^* (b + \pi) q (b) = 0 \tag{5}
\]

\[
r^* (b) r (b) + q^* (b) q (b) = 0 \tag{6}
\]

The wavelet packet bases \( \{Y_p^t\} \) obtained from these QMF filters can be derived recursively through a MRA as

\[
Y_{2p}^t(t) = \sqrt{2} \sum_{n} h[n] Y_p^t(2t - n) \tag{7}
\]

\[
Y_{2p+1}^t(t) = \sqrt{2} \sum_{n} g[n] Y_p^t(2t - n) \tag{8}
\]

where, the superscript \( p \) stands for subcarrier index at any given tree depth \( l \). The number of WPT subcarriers \( M \) that can be derived from \( l \) iterations is given by \( M = 2^l \). As we require perfect reconstruction and hence the orthogonal subcarriers. These can only be generated by filters that fulfil the orthogonality constraint. The WPMCM subcarriers are mutually orthogonal if they satisfy the following condition [6-7]:

\[
(Y_p^t(t), Y_i^t(t)) = \sum_{k} Y_k^p(t), Y_k^i(t) = \delta(p - i)
\]

The synthesis filter bank algorithm is used in calculating the IDWPT at transmitter and the analysis filter bank algorithm is used in calculating the DWPT at the receiver. A three level WPT-MCM structure is shown:

\[\text{Fig-2. Model of MCM based on Wavelet Packet Transform}\]
4. Result & Discussion

The result is shown in fig. 3. The performance of BER shows the efficiency of the proposed model. In this case the comparison among OFDM based model and WPMCM based model has been done. Various modulation schemes such as BPSK, QPSK, and QAM have been considered. The AWGN channel is considered for the proposed model.

![Comparison of BER Vs EbNoDB between WPNM and OFDM over AWGN channel](image.png)

Fig-3. Comparison of BER VS EbN0 between WPNM and OFDM in AWGN channel

5. Conclusion

This is the investigation of the proposed model for multi carrier modulation. The comparison of OFDM and WPMCM system has been investigated using different types of modulation techniques such as BPSK, QPSK, QAM-4 over AWGN channel etc. From the figure also it has been observed that the QAM modulation is giving better result than that of BPSK and QPSK modulation. For different type of channels may be investigated along with the use of various wavelets. This has been given for future scope.

References