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Performance Comparison of Wavelet Packet Modulation and OFDM over Mobile Communication Channel

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Abstract

Success of Orthogonal Frequency Division Multiplexing (OFDM) has proved that Multi carrier modulation is an efficient solution for mobile communication. Wavelet Packet based Multi-Carrier Modulation (WPMCM) offers an alternative to the well-established OFDM as an efficient multicarrier modulation technique. Wavelet Packet Modulation (WPM) is a new type of modulation for transmission of multicarrier signal on mobile channel that uses orthogonal wavelet bases other than sine functions. It has strong advantage of being generic transmission scheme whose actual characteristics can be widely customized to fulfill several requirements and constraints of advanced mobile communication systems.

In this paper, a detailed study is given on the mobile channel environment and the Bit Error Rate (BER) performance comparison between the OFDM mobile communication system and the WPM mobile communication system are analyzed. The analysis is simulated over an AWGN channel, and other Multipath fading channels like time invariant frequency selective channel and time variant frequency selective channel.

Keywords: Bit error rate (BER), Mobile channel, Orthogonal Frequency Division Multiplexing (OFDM), Wavelet Packet Modulation (WPM).

Introduction

Although the principle of multicarrier modulation is not recent, its actual use in commercial systems started when the technology required to implement it became available at a reasonable cost. Similarly, the idea of using a better transform than Fourier as the core of a multicarrier system has been recently introduced. This better transform uses orthogonal wavelet bases and it is known as Wavelet Packet Modulation [1]. However, very little interest has been given to the alternative methods. With the current demand for enhanced performance in mobile communication systems, it's high time we looked forward to the possible advantages that wavelet-based modulation could have over OFDM systems.

The mobile propagation channel is highly unpredictable and suffers from major effects of fading. Due to these effects, the transmitted signal from a mobile transmitter system may get distorted or may totally fade out [2]. So the biggest challenge for a mobile communication system is to overcome the effect of fading in a mobile radio channel.

OFDM is one of the multicarrier transmission methods to solve the problem of fading and it also achieves a higher-rate wireless mobile radio transmission. In order to apply the OFDM technology in mobile communication, the OFDM mobile communication system needs to make use of a cyclic prefix [3]. The cyclic prefix technique was introduced to overcome the fading effects in the mobile radio channel. OFDM based mobile communication system has already been implement and used as a part of the fourth generation (4G) mobile phone mobile communication technology standards. The cyclic prefix technique introduces a big disadvantage in the form of increasing the bandwidth requirement of the mobile communication system. This problem is considered a major problem in mobile communication because bandwidth is the most sought after resource in the world of wireless radio communication.

Wavelet packet modulation is one of the multicarrier modulation methods using discrete wavelet transform (DWT). In wavelet packet based mobile communication systems, the orthogonality is provided by orthogonal wavelet filters (filter banks) [4]. The characteristic of a multicarrier modulated signal is directly dependent on the set of waveforms of which it uses. Hence, its sensitivity to non-linear amplifiers, multipath channel distortion or synchronization error might give better values than an OFDM signal. Moreover, the greatest advantage of WPM lies in its flexibility. Also, new generation mobile communication systems have to be designed to dynamically deploy the instantaneous

propagation conditions. This has led to the study of reconfigurable systems that can optimize performance according to the current channel response. The wavelet based mobile communication system is ideal for fulfilling these challenging demands of the new generation mobile communication standards [5]. The wavelet packet signals overlap in both, time and frequency domain. Due to time overlapping, WPM systems don't use a cyclic prefix that is commonly used in OFDM systems. This enhances the bandwidth efficiency compared to conventional OFDM based mobile communication systems.

Mobile Communication Channel

The mobile radio communication channel places fundamental limitations on the performance of wireless mobile communication systems. The transmission path between the transmitter and the receiver can vary from simple line-of-sight to one that is severely obstructed by buildings, mountains, and foliage. Unlike wired channels that are stationary and predictable, mobile radio channels are extremely random and do not offer easy analysis [6]. Even the speed of motion impacts how rapidly the signal level fades as a mobile terminal moves in space. Modelling the radio channel has historically been one of the most difficult parts of mobile radio system design, and is typically done in a statistical fashion, based on measurements made specifically for an intended communication system or spectrum allocation.

Small Scale Fading And Multipath

Small-scale fading, or simply fading, is used to describe the rapid fluctuation of the amplitude of a mobile radio signal over a short period of time or travel distance, so that large-scale path loss effects may be ignored. Fading is caused by interference between two or more versions of the transmitted signal which arrive at the receiver at slightly different times. These waves, called multipath waves, combine at the receiver antenna to give a resultant signal which can vary widely in amplitude and phase, depending on the distribution of the intensity and relative propagation time of the waves and the bandwidth of the transmitted signal [6]. In terms of mobile communication large scale path losses can be ignored as the major contributor of fading are the multipath waves at the mobile receivers.

Impulse response model of a multipath channel

The small-scale variations of a mobile radio signal can be directly related to the impulse response of the mobile radio channel. The impulse response is a wideband channel characterization and contains all information necessary to simulate or analyze any type of mobile radio transmission through the channel. This stems from the fact that a mobile radio channel may be modelled as a linear filter with a time varying impulse response, where the time variation is due to receiver motion in space. The filtering nature of the channel is caused by the summation of amplitudes and delays of the multiple arriving waves at any instant of time. The impulse response is a useful characterization of the channel, since it may be used to predict and compare the performance of many different mobile communication systems and transmission bandwidths for a particular mobile channel condition.

Types of small scale fading

Fading is nothing but deviation of attenuation of a signal when passed through the mobile radio channel. The type of fading experienced by the signal propagating through the channel depends on the nature of transmitted signal w.r.t. characteristics of the channel. Depending on the relation between signal parameters (bandwidth and symbol period) and channel parameters (Doppler spread and rms delay spread), different signals undergoes different types of fading. Time dispersion and frequency dispersion mechanisms of radio channel are responsible for four possible effects which are flat fading, frequency selective fading, fast fading and time selective fading. But in mobile communication the major contributor to small scale fading is the frequency selective fading channel model. In a frequency selective channel, the bandwidth of the transmitter signal is always greater than the bandwidth of the mobile radio channel and the delay spread is always greater than the symbol period of the transmitted signal.

System Model

In order to provide a comparative analysis between WPM and OFDM in mobile communication, two separate mobile communication models, in which one is based on OFDM and the other one is based on WPM were designed.

OFDM based mobile communication model

The input digital voice signal which is in the binary form is applied to the input of the M-ary QAM modulator. The M-ary QAM modulator generates QAM symbols which are then sent to a serial to parallel converter. M-ary QAM does not have constant energy per symbol nor does it have constant distance between possible symbol states. It reasons that particular values of Si(t) will be detected with higher probability than others [7]. Hence by proper modelling of the multipath mobile channel certain symbols can be made to be detected with higher probabilities and therefore M-ary QAM is the preferred choice in a mobile communication system. Additionally M-ary QAM `has good power and bandwidth efficiency. The serial to parallel converter produces multiple streams of data at a lower rate and then Inverse Fast Fourier Transform (IFFT) is applied to all the streams of data along with the presence of extra bits in the form of cyclic prefix. The cyclic prefix is added in order to handle the multipath fading problem in

a mobile radio channel. This usually reduces the bandwidth efficiency of the communication system. The IFFT produces data streams which are orthogonal to each other in the frequency domain and this is the backbone of the whole communication system. Each stream of data after passing through IFFT block is then passed through a parallel to serial block which produces a single stream of data which is transmitted over the mobile propagation channel. The impairments caused by Additive White Gaussian Noise (AWGN) and frequency selective fading in the mobile propagation channel have been considered in the designed communication model. The signal after passing through the mobile channel is recovered back through a reversal process in which we again make use of parallel to serial and serial to parallel interchangeably and instead of IFFT we now apply Fast Fourier Transform (FFT) in the reversal process. The cyclic prefix is also removed in order to recover the original QAM symbols as they were produced in the modulation section of the communication model. In order to recover the original voice siganl, M-ary QAM demodulator block is used.

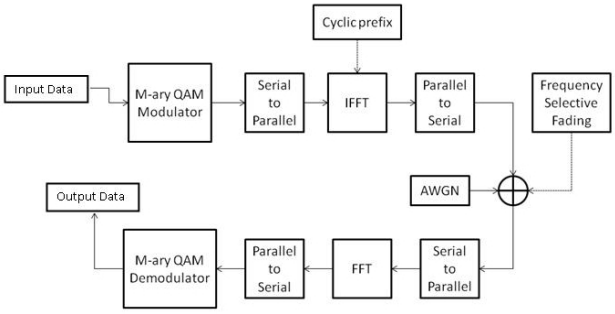
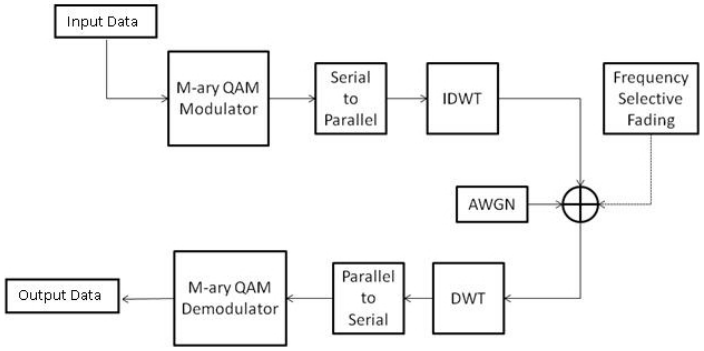


Figure 1: OFDM Mobile Communication Model

WPM based mobile communication model

The input voice signal which is in the binary form is applied to the input of the M-ary QAM modulator. The M-ary QAM modulator generates QAM symbols which are then sent to a serial to parallel converter. The serial to parallel converter produces multiple streams of data at a lower rate and then Inverse Discrete Wavelet Transform (IDWT) is applied to all the streams of data. There is a need to insert cyclic prefix in this model of communication system. Hence the streams of data are free of any extra bits of data in the form of cyclic prefix and this enhances the bandwidth efficiency of the communication system. The IDWT produces data streams which are orthogonal to each other in the frequency as well as the time domain and this is the backbone of the whole communication system. As the orthogonality is obtained in both the domain using IDWT, this further enhances the performance of the WPM based communication system. After passing each stream of data through IDWT block we get a single stream of data which is transmitted over the mobile propagation channel. The impairments caused by Additive White Gaussian Noise (AWGN) and frequency selective fading in the mobile propagation channel have been considered in the designed communication model. The signal after passing through the mobile channel is recovered back through a reversal process in which we again make use of parallel to serial and serial to parallel interchangeably and instead of IDWT we now apply Discrete Wavelet Transform (DWT) in the reversal process. In order to recover the original digital voice signal, M-ary QAM demodulator block is used. The block recovers the original voice signal which was transmitted in the digital form at the receiver side.



Performance Analysis

The performance of OFDM in an AWGN, time invariant frequency selective and time variant frequency selective mobile channel was evaluated by plotting the Bit Error Rate (BER) of the OFDM based mobile communication system for different values of signal to noise ratio using MATLAB software. The obtained simulated results in MATLAB are shown in figure 3 and figure 4.

The performance of WPM in an AWGN, time invariant frequency selective and time variant frequency selective mobile channel was evaluated by plotting the Bit Error Rate (BER) of the WPM based mobile communication system for different values of signal to noise ratio using MATLAB software. The obtained simulated result in MATLAB is shown in figure 5 and figure 6.

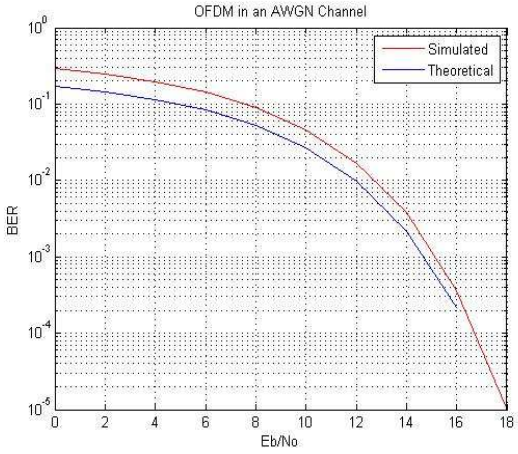


Figure 3: Performance of OFDM mobile communication system in an AWGN channel

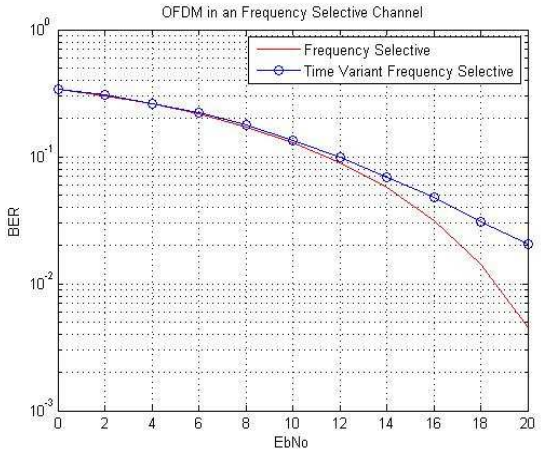


Figure 4: Performance of OFDM mobile communication system in a frequency selective channel

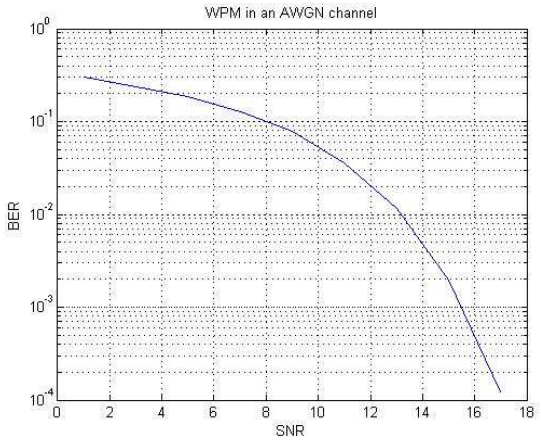


Figure 5: Performance of WPM mobile communication system in an AWGN channel

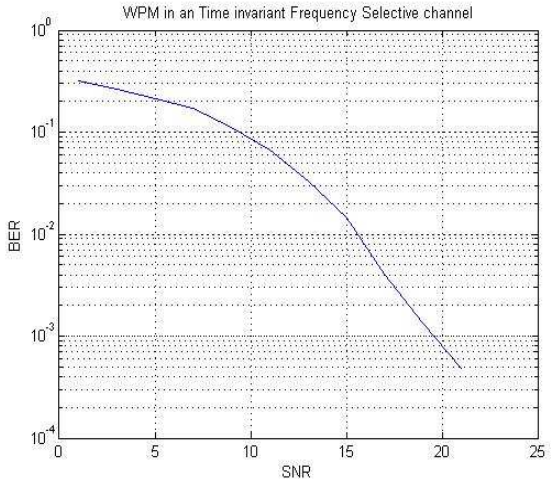


Figure 6: Performance of WPM mobile communication system in a Time invariant frequency selective channel

It has been observed that as the signal to noise ratio is increased the bit error rate reduces in a non-linear manner in presence of AWGN and both variants of frequency selective channel in the OFDM based mobile communication system. The fall in the bit error rate has been observed to be more in case of time invariant frequency selective channel than the time variant frequency selective channel.

Conclusion

The simulation of the OFDM mobile communication system and the WPM mobile communication system has been achieved using MATLAB software. Three different types of mobile propagation channels have been considered for simulation of the various mobile communication systems.

Firstly, the OFDM mobile communication system and the WPM mobile communication system were simulated in the presence of an AWGN channel and it has been concluded from the simulation diagrams that the performance of both the system in such a mobile propagation channel is similar and approximately it's considered equal.

Secondly, both the system were simulated in the presence of a time invariant frequency selective channel and it has been concluded from the simulation diagrams that the performance of WPM system is better than the OFDM system (i.e. the decrease in the bit error rate is more in WPM in comparison to OFDM with the increase in signal to noise ratio) in such a mobile propagation channel.

Thirdly, the OFDM mobile communication system was simulated in the presence of a time variant frequency selective channel and it has been concluded from the simulation diagrams that the performance of

OFDM system deteriorates at a faster rate in comparison to the WPM mobile communication system. The multipath time delays in the mobile communication channel causes this overall deterioration in performance in time variant frequency selective channel.

The time variant frequency selective channel closely resembles the actual mobile propagation channel behavior and hence from the performance analysis we can conclude that WPM based mobile communication system is the future of mobile communication and in the coming years the WPM based mobile communication system will start replacing the current OFDM based mobile communication system being used in the current generation of mobile communication standards.

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