Performance of BER in mobile communication using WPM

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ABSTRACT

Numerous objectives motivate the current research on Wavelet Packet Modulation (WPM). Firstly, 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. The wavelet packet signals overlap in both, time and frequency domain. Due to time overlapping, WPM systems don't use a cyclic prefix (CP) that is commonly used in OFDM systems. This enhances the bandwidth efficiency compared to conventional OFDM systems.

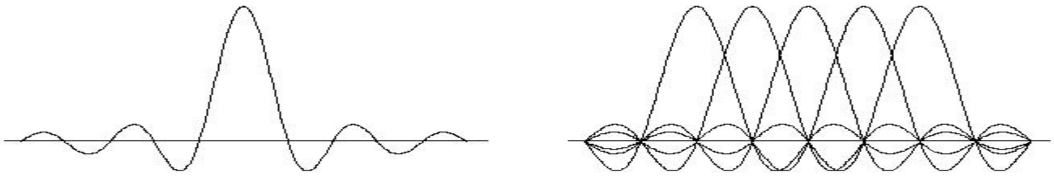
In this research paper, a thorough study is based on the mobile channel environment and the Bit Error Rate (BER) over signal to noise ratio performance comparison between the OFDM mobile communication system and the WPM mobile communication system are analyze. The study is simulated over an AWGN channel, multipath fading channels (time variant, time invariant), and BER performance of OFDM for various constellation points, BER performance of Wavelet families.

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

1. INTRODUCTION

The widely used wireless communication technologies have lead to the huge employment of radio resource which is in fact allocated in a limited fashion. This limitation usually affects the performance of various wireless communication services. Besides that, the dynamic nature of mobile radio link also limits the performance of wireless communication. Hence, communication system design becomes an important thing to guarantee the quality of services of each wireless mobile technology. 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]. On the other hand, especially small interest has been given to the alternative methods with the current demand for enhanced performance in mobile communication systems, its 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 fading effects, the transmitted signal from a mobile transmitter system may get distorted or it may totally fade out [3]. Thus this is the biggest challenge for a mobile communication system to overcome the effect of fading in a mobile radio channel. OFDM is one of the multicarrier transmission methods which solves the problem of fading effects and also achieves a higher- rate wireless mobile radio transmission. In order to apply the OFDM technology in mobile communication, the OFDM mobile communication system should make use of a cyclic prefix [5]. 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. The cyclic prefix technique introduces a big disadvantage in the form of increasing the bandwidth requirement of the mobile communication system [7]. 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) [8]. 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. Furthermore, the greatest advantage of WPM is in its flexibility. The wavelet based mobile communication system is superlative for fulfilling these challenging demands of the new generation mobile communication standards [11]. Wavelet theory is applicable to several subjects. All wavelet transforms may be consider forms of time frequency representation for continuous time (analog) signals and so are related to harmonic analysis. Nearly all virtually useful discrete wavelet transforms use discrete time filter banks and these kinds of filter banks are called the wavelet and scaling coefficients in wavelets nomenclature [12].

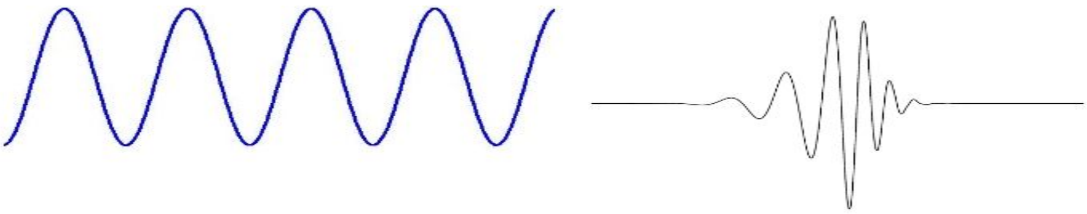
1.1 OFDM



(a) (b)

Figure 1 Spectrum of (a) OFDM sub channel (b) OFDM channel

1.2 Wavelet



(a) (b)

Figure 2 (a) Wave (b) Wavelet

A wavelet is a small wave whose energy is concentrated in time and gives a tool for the analysis of transient, or time varying phenomena which is as shown in fig 1. Though it has the oscillating wave like characteristic it also has the ability to allow time and frequency analysis at the same time with a flexible mathematical foundation.

Wavelet expansion

A signal F(t) can be better analyzed if expressed as a linear decomposition by,

$$F(t) = \sum_{l} a_l \ \psi_l \qquad (1)$$

Where l is the integer index for the finite or infinite sum, a_1 are the real valued expansion coefficients, and ψ_1 is a set of real valued functions of t called the expansion set. The set is called a basis, if the expansion is unique.

For the wavelet expansion, consider a two parameter system as

$$F(t) = \sum_{j} \sum_{k} a_{j,k} \psi_{j,k}(t) \qquad (2)$$

Where both j and k are integer indices and $\psi_{j,k}(t)$ are the wavelet expansion functions that usually form an orthogonal basis. The set of expansion coefficients $a_{j,k}$ are called discrete wavelet transform and eq.(2) is known as inverse transform.

1.3 Wavelet Transform vs. Fourier Transform

The traditional Fourier Transform only provides spectral information about a signal and only works for stationary signals while many real world signals are non-stationary and need to be processed in real time. The problem with Short Time Fourier Transform can be attributed to the Heisenberg uncertainty principle which states that it is impossible for one to obtain the time instance at which frequencies exist but, one can obtain the frequency bands existing in a time interval. Also the resolution window used in STFT is of constant length whereas with Wavelet transform multi resolution analysis is possible i.e. it can

- Analyze the signal at different frequencies with different resolutions.
- Have good time resolution and poor frequency resolution at high frequencies.
- Have good frequency resolution and poor time resolution at low frequencies.

Also it is more suitable for short duration of high frequency and long duration of low frequency components. Wavelet transforms, unlike Fourier transform, do not have a single set of basis functions, which utilizes just the sine and cosine functions. Rather, they have an infinite set of possible basis functions. Thus wavelet analysis makes it feasible to acquire information that can be alienated by other time-frequency methods such as Fourier analysis.

2. COMMUNICATION SYSTEM MODEL

2.1 OFDM based mobile communication model

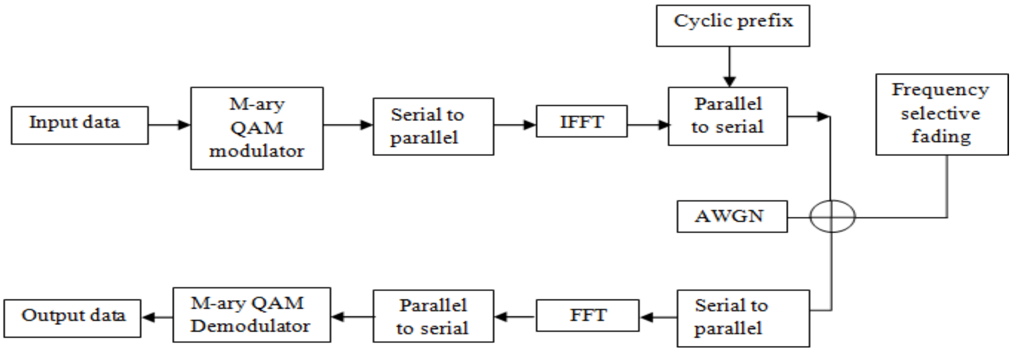


Figure 3 OFDM based mobile communication model

As shown in fig 3.the working of the OFDM mobile communication model has been described below in steps:

- The input digital data which is in the binary form is applied to the input of the M-ary QAM modulator. In mobile communication, the input is in the form of digital voice signal which obtained by passing an analog voice signal through an analog to digital converter.
- The M-ary QAM modulator generates QAM symbols which are then sent to a serial to parallel converter. M-ary QAM neither have constant energy per symbol nor have constant distance between possible symbol states. It reasons that particular values of Si(t) will be detected with higher probability than others. And therefore the multipath mobile channel's certain symbols can be made to be detected with higher probabilities by proper modeling and therefore M-ary QAM is the preferred choice in a mobile communication system. Additionally, M-ary QAM modulator is having 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 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.
- After passing each stream of data through IFFT block then it is passed through a parallel to serial block which gives a single stream of data which is then transmitted over the mobile propagation channel.
- The impairments caused by Additive White Gaussian Noise and frequency selective fading in the mobile propagation channel have been considered in the designing of communication model.
- After passing the complete signal through the mobile channel is recovered back through a reversal process in which again parallel to serial and serial to parallel is used interchangeably and instead of IFFT, Fast Fourier Transform (FFT) is applied in the reverse process.
- In order to recover the original QAM symbols, the cyclic prefix are also removed which were produced in the modulation section of the communication model.
- Finally to get the original digital data back, 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.

2.2 WPM based mobile communication model

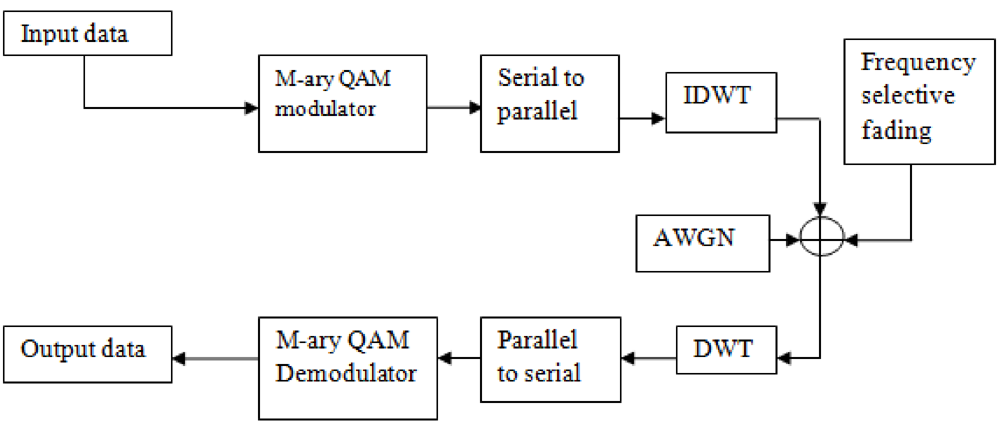


Figure 4 WPM based mobile communication model

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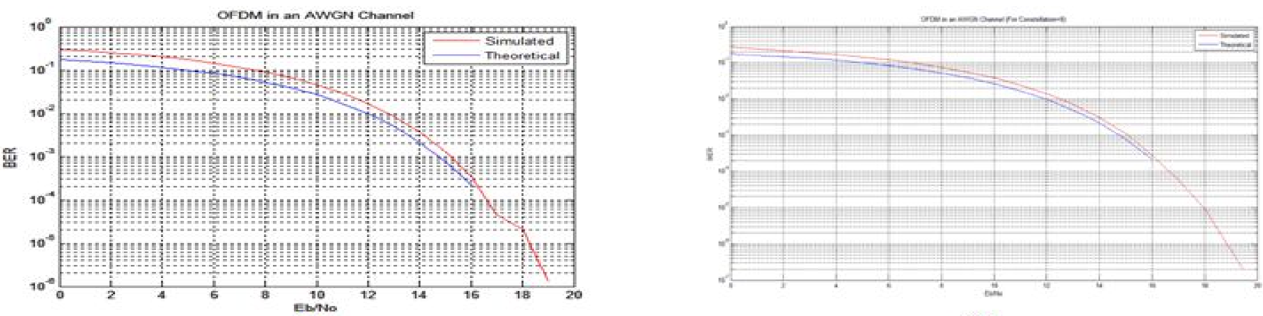
As shown in fig.4 the working of the WPM mobile communication model has been described below:

- The input digital data which is in the binary form is applied to the input of the M-ary QAM modulator. In mobile communication, the input is in the form of digital voice signal which obtained by passing an analog voice signal through an analog to digital converter.
- The QAM symbols which are generated by M-ary QAM modulator are 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 no need to insert cyclic prefix in this model of communication system as done in the OFDM mobile communication model. Hence the streams of data are free of any extra bits of data in the form of cyclic prefix which 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 in the time domain and this is the backbone of the whole communication system. As the orthogonality is obtained in both the domain (frequency and time domain) using IDWT, this further enhances the performance of the WPM based communication system.
- After passing each stream of data through IDWT block a single stream of data is obtained, which is then transmitted over the mobile propagation channel.
- The impairments caused by Additive White Gaussian Noise and frequency selective fading in the mobile propagation channel have been considered in the designing of communication model.
- After passing the complete signal through the mobile channel is recovered back through a reversal process in which again parallel to serial and serial to parallel is used interchangeably and instead of IDWT Discrete Wavelet Transform is applied in the reverse process.
- Finally to get the original digital data, 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 and WPM based mobile communication system in an AWGN and Frequency selective channel is provided for different values of signal to noise ratio using MATLAB software. The obtained simulated results are for constellation point 4 and 8 are shown in below figure.

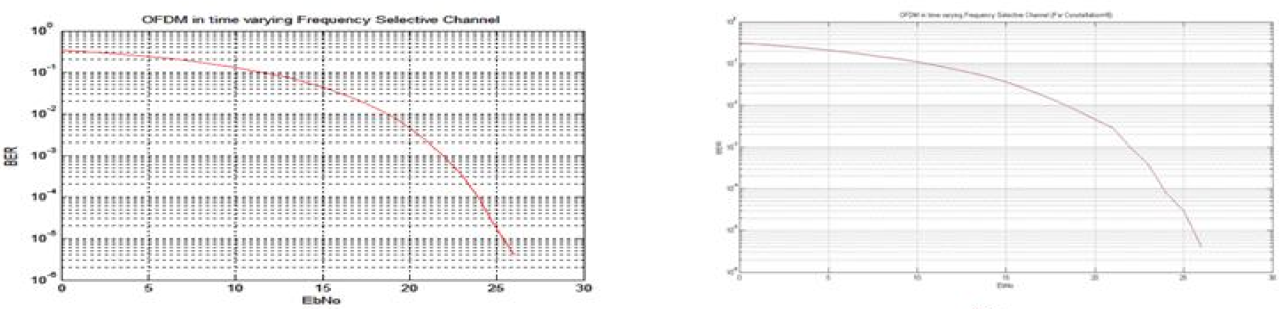
2.3Performance of OFDM in an AWGN Channel



(a) (b)

Figure 5 Performance of OFDM mobile communication system in an AWGN channel
(a) For constellation number=4 b) For constellation number=8

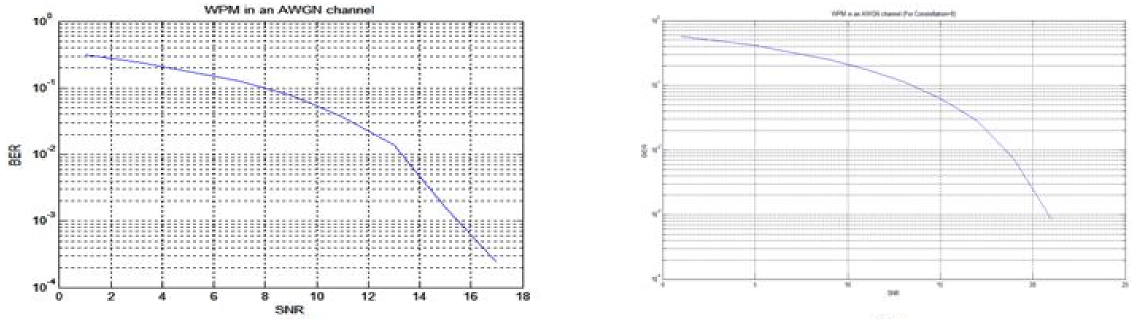
2.4Performance of OFDM in Frequency Selective Channel



(a) (b)

Figure 6 Performance of OFDM mobile communication system in a frequency selective channel
a) For constellation number=4 b) For constellation number=8

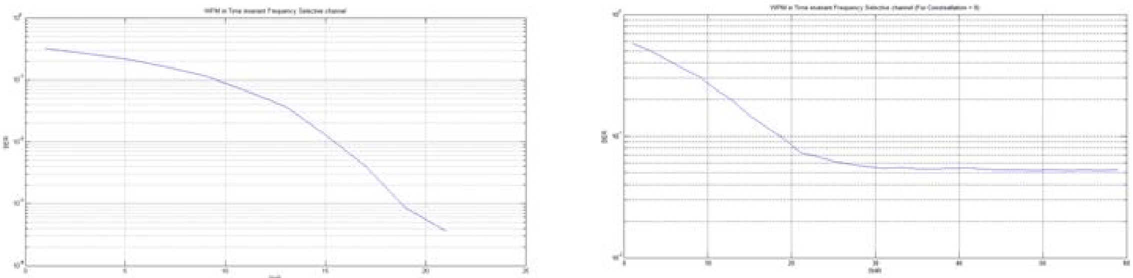
2.5Performance of WPM in an AWGN Channel



(a) (b)

Figure 7 Performance of WPM mobile communication system in an AWGN channel
a) For constellation number=4 b) For constellation number=8

2.6Performance of WPM in a Frequency Selective Channel



(a) (b)

Figure 8 Performance of WPM mobile communication system in a Time invariant frequency selective channel.
(a) For constellation number=4 b) For constellation number=8

2.7BER Performance of OFDM (for constellation= 4, 16, 64, 256)

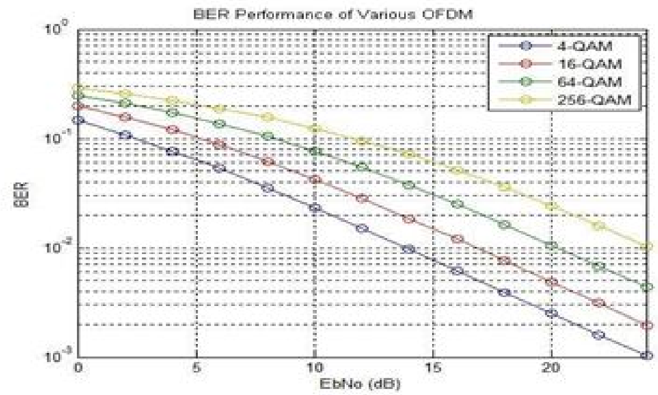


Figure 9 BER Performance of OFDM (For constellation= 4, 16, 64, 256)

2.8 BER Performance of WPM family

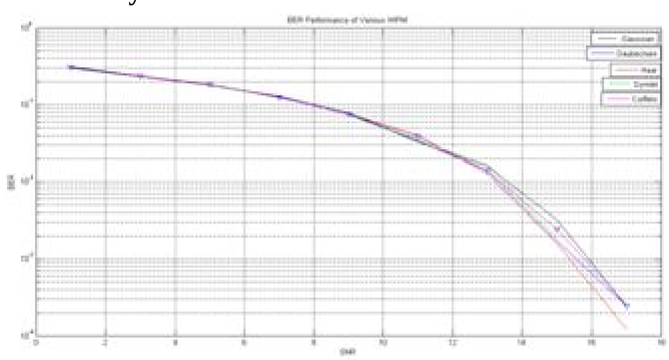


Figure 10 BER Performance between WPM families

Table 1: Performance comparison

Parameters	OFDM	WPM
For QAM constellation points=4		
Number of Sub bands	64	64
Number of Symbols	128	128
QAM constellation points	4	4
Cyclic Prefix	32 symbols	No
Wavelet	No	Daubechies-4
Fall in BER(AWGN channel)	15.71dB	15.73dB
Fall in BER(Multipath channel)	8.52 dB	10.73 dB
For QAM constellation points=8		
Number of Sub bands	64	64
Number of Symbols	128	128
QAM constellation points	8	8
Cyclic Prefix	32 symbols	No
Wavelet	No	Daubechies-8
Fall in BER(AWGN channel)	16.23dB	16.27dB
Fall in BER(Multipath channel)	10.04 dB	12.19 dB

3. CONCLUSION

The simulation of the BER performance of OFDM mobile communication system and the WPM mobile communication system has been achieved using MATLAB software for constellation point 4 and 8.

- The mobile communication system by using OFDM and WPM both systems was simulated in the presence of an AWGN channel concluded performance of both systems is approximately considered equal.
- 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 decrease in the bit error rate is more in WPM in comparison to OFDM with the increase in signal to noise ratio.
- The performance of both OFDM and WPM are compared for constellation points 4 and 8, where increase in the number of constellation provide superior performance of signal to noise ratio and from all the other wavelets daubechies wavelet state better performance.

4. FUTURE SCOPE

The time variant frequency selective channel strongly resembles the actual mobile propagation channel behavior and hence from the performance analysis it states 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 existing OFDM based mobile communication system being used in the current generation of mobile communication standards.

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