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BER IMPROVEMENT OF WIRELESS LAN IEEE 802.11 STANDARD USING WAVELET PACKET TRANSFORMS

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Abstract

High data rates and spectral efficiency is the main requirements for wireless communication systems. Orthogonal Frequency Division Multiplexing (OFDM) is a special form of multi carrier transmission used to achieve high data rates of the various WLAN standards. WLAN uses an Inverse Fast Fourier Transform (IFFT) at the transmitter to modulate a high bit-rate signal onto a number of carriers and ensure orthogonality between the carriers. The FFT-OFDM has a disadvantage that it is inherently inflexible and requires a complex IFFT core. Recently, Wavelet Packet Transform is proposed as an alternate to FFT. It is a multiplexing method in which data is assigned to wavelet sub bands having different time and frequency resolutions. This paper presents a BER analysis of Fourier-based OFDM (FFT-OFDM) and Wavelet Packet based OFDM (WPT-OFDM) in WLAN standard (IEEE 802.11a). The performance of FFT and WPT OFDM for various modulation techniques such as PSK, DPSK and QAM for varying values of M was evaluated in AWGN Channel.

Keywords:
WLAN, OFDM, FFT, WPT, BER

1. INTRODUCTION

The nature of WLAN applications demands high data rates. The channel distortions at high data rate are significant and the idea of multiple carrier transmission is used for combating the hostility of such channels. OFDM is a special form of multi carrier transmission and is the underlying technology of the various WLAN standards. OFDM has been adopted into several European wireless communications applications such as the digital audio broadcast (DAB) and terrestrial digital video broadcast (DVB-T) systems [1]. Both wireless LAN standards IEEE 802.11a and the new European Telecommunications Standard Institute's (ETSI) HiperLAN/2 Uses OFDM as the modulation scheme [2, 3]. One of the main reasons for using OFDM for Wireless LANs is relatively small amount of delay spread encountered in such applications [4]. OFDM requires a cyclic prefix to remove inter symbol interference (ISI). This causes overhead and this overhead may be sometimes much large for the system to be effective. However in WPT-OFDM, the modulation and demodulation are implemented by wavelets rather than by Fourier Transform. The subject of wavelets is considered a major breakthrough in mathematical science and provides a common link between mathematicians and engineers. In the past few decades, interest in wavelets has experienced explosive growth due to formal development by Alorlet and Grossman [5] [6], Meyer [7], Daubechies [8], and Mallat [9]. Many of the basic ideas comprising wavelet theory are not new and the wavelet and wavelet packet transforms are a unification of such ideas. Some current applications of this theory are in areas such as WiMax Traffic forecasting [10], subband coding, image compression, time-frequency localization, decomposition and reconstruction, and information storage and retrieval.

Over the last few decades much work has been done in applying time-frequency transforms to the problem of signal representation and classification. Most recently, the emergence of wavelet theory has motivated a considerable amount of research in transient and non-stationary signal analysis [11]-[14].

2. FAST FOURIER TRANSFORM(FFT) OFDM

Fig.1 shows the block diagram of FFT based OFDM transceiver. The input digital data is processed by M-ary QAM or PSK modulator to map the data with N subcarriers. After serial to parallel conversion of modulated data, Fourier transform is applied to it. The output of IFFT is the sum of the information signals in the discrete time domain as following,

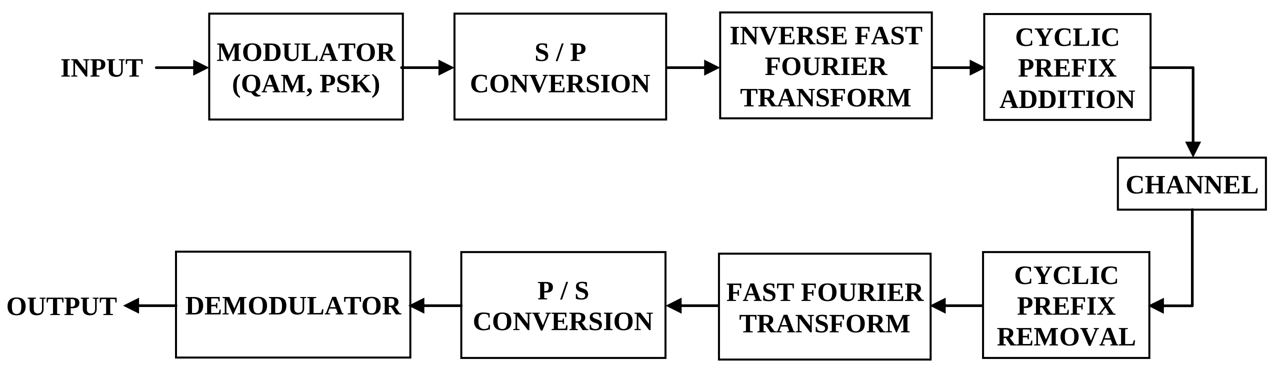

Fig.1. An FFT–OFDM Transceiver

$$x_k = \frac{1}{N}\sum_{m=0}^{N-1} X_m e^{j2\pi km/N} \tag{1}$$

where, $\{x_k|0 \le k \le N-1\}$ is a sequence in the discrete time domain, $\{Xm|0 \le m \le N-1\}$ are complex numbers in discrete frequency domain. The cyclic prefix (CP) is added before transmission to minimize the inter-symbol interference.

At the receiver side, the process is reversed to obtain and decoded the data. The output of FFT is the sum of the received signal in frequency domain as follows,

$$X_m = \sum_{k=0}^{N-1} x_k e^{-j2\pi km/N} \tag{2}$$

3. WAVELET PACKET TRANSFORM (WPT) OFDM

Wavelet Transform decomposes the spectrum of a signal non-uniformly. However, the decomposition is limited to the lowpass part of the signal only. There are already a variety of wavelets available including both orthogonal and biorthogonal wavelets [15, 16], many of which can in fact be described entirely on the basis of linear algebras [17, 18]. An evaluation of some of the existing wavelets in terms of their applications can be found in [19]. A typical good pair of wavelet filters often possesses a maximum number of balanced vanishing moments such as, for instance, the so-called biorthogonal Coifman wavelets recently proposed by Tian and Wells [20]. Such wavelet systems are in general very useful in image, sound or video related applications due to the high order of consecutive vanishing moments associated with these systems. Wavelet packet transform applied on a data stream divides the data into its high frequency and low frequency components. These two procedures are shown in Fig.2.

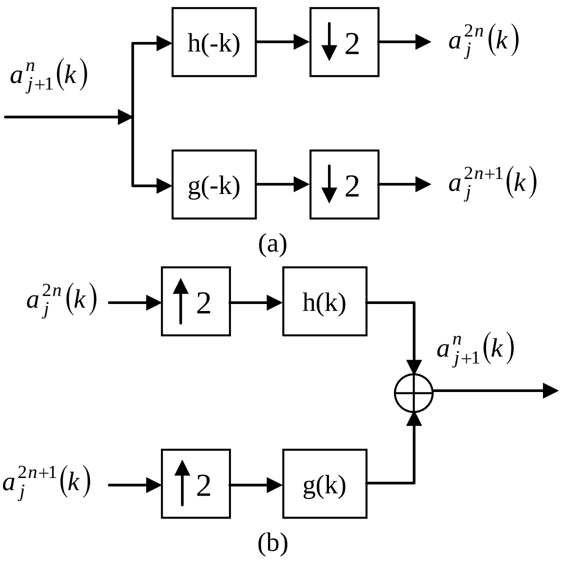

Fig.2. Single stage of (a) Wavelet Packet Transform (b) Inverse Wavelet Packet Transform

Let 'a' be the vector having elements $ak = a(k)$, where $a(k)$ is the original discrete time sequence that we wish to decompose via the wavelet packet method then the step involved is the convolution of $a(k)$ with $h(k)$ and $g(k)$ followed by a decimation by two and for inverse WPT, the steps are reversed. Therefore WPT is equivalent to filtering a signal with a lowpass and highpass filter bank, while the IWPT is equivalent to combining a lowpass and highpass signal into one signal. The WPM transceiver as used in OFDM is illustrated in Fig.3. The incoming signal is first converted from serial to parallel form and then modulated. There is upsampling of signal in each iteration of inverse wavelet packet transformation (IWPT). Now the signal is decompose one with HPF and the other with LPF. The outputs of HPF and LPF branches are then subsequently added.

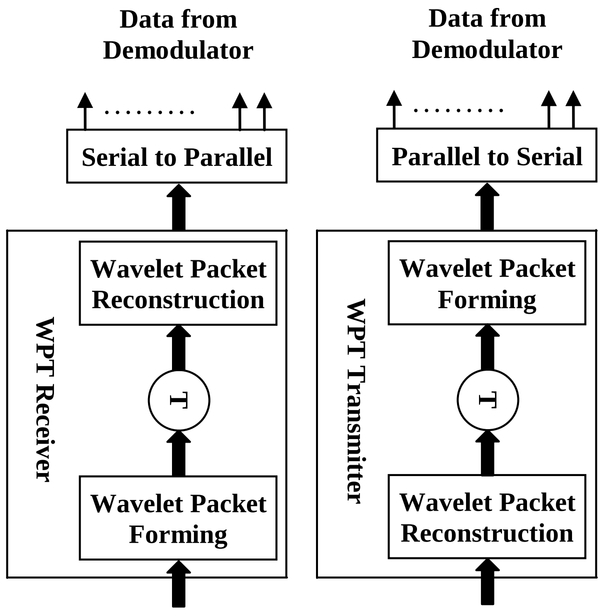

Fig.3. WPM Transceiver

The transmitted signal is given by,

$$s_{WPM}(n) = \sum_{p=0}^{N-1}\sum_{k=0}^{\infty} a_p(l)\phi_{i,p}^{syn}(n-lN) \tag{3}$$

In the above equation, $a_p(l)$ are complex data symbols of different parallel streams p, while $\phi_{k,p}^{syn}$ denotes synthesis wavelet packet function for the p^{th} sub channel.

In the receiver, Wavelet Packet Transformation (WPT) is performed to bring the signals back to their original domain. In an iteration of WPT the input signal is filtered by HPF and LPF, decomposing original signal into two parts. Each of the decomposed parts is then downsampled by two satisfying the Nyquist rule [21].

The process of constructing a wavelet packet function set can be more clearly seen via the wavelet packet construction tree. Fig.4 shows the wavelet packet tree corresponding to the 'T' blocks in the WPT–OFDM transceiver in Fig.3. At each branch of the tree, the wavelet packet forms the wavelet basis function which is split into scaling and wavelet coefficients corresponding to the LPF and HPF coefficients respectively. After wavelet packet reconstruction, the data is converted to parallel form and demodulated.

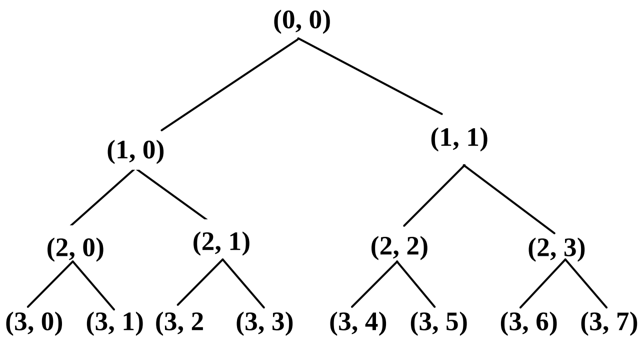

Fig.4. A wavelet packet tree corresponding to 'T' block

The advantage of using WPM is that it is a very flexible system as different wavelets can be used for the transformation. Furthermore, it has been shown that the use of WPM is more robust to narrowband interference and multipath propagation loss than OFDM [22, 23]. Also wavelet OFDM signals are more spectrally efficient than the conventional OFDM signals. The BER performances of FFT–OFDM and WPM systems in presence of carrier offset and phase noise is given in [24].

4. SIMULATION RESULTS

The FFT–OFDM and WPT–OFDM systems are developed, analyzed, and simulated in MATLAB version 7. This paper investigates the impact of the number of constellation points over FFT–OFDM and WPT–OFDM for WLAN in AWGN channel. The analysis is done for various types of modulations as QAM, PSK and DPSK using constellation points (4 to 64), and simulated over AWGN channel. The WLAN IEEE 802.11 parameters are used in simulation.

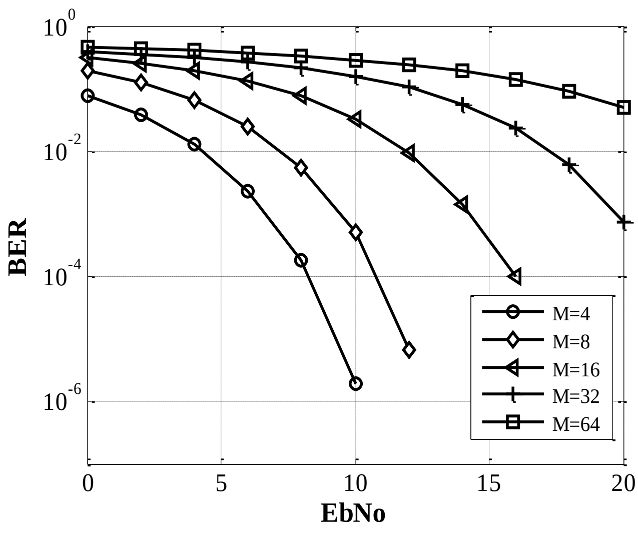

Fig.5. BER for FFT–OFDM (PSK)

We use FFT size of 64, subcarrier are 52 with cyclic prefix of 16 bits. The channel spacing used is 20 MHz. For the simulation of FFT–OFDM, we used cyclic prefix of 25% of the total OFDM symbol period.

The WPT–OFDM families do not require cyclic prefix due to the overlapping nature of their properties. The wavelet used is Haar as it is orthogonal in nature.

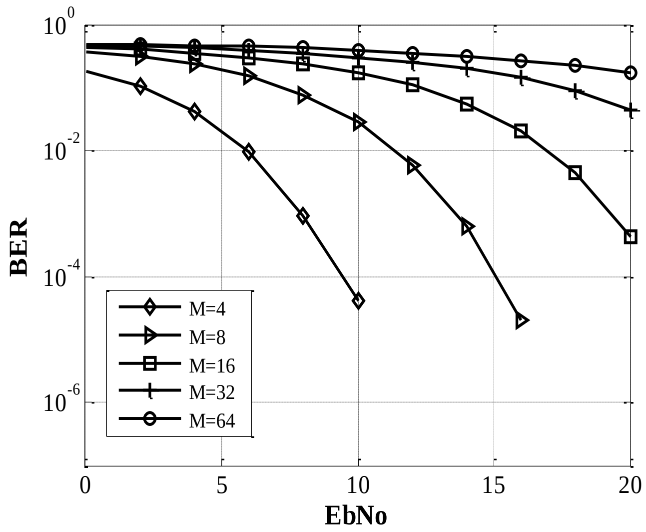

Fig.6. BER for FFT–OFDM (DPSK)

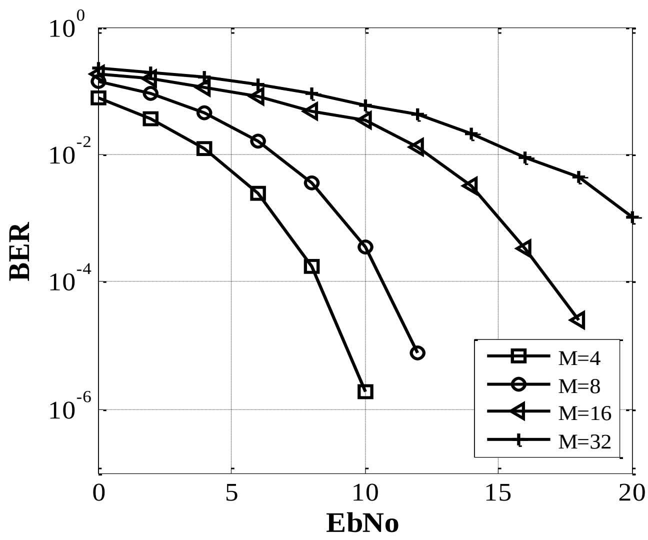

Fig.7. BER of FFT–OFDM (QAM)

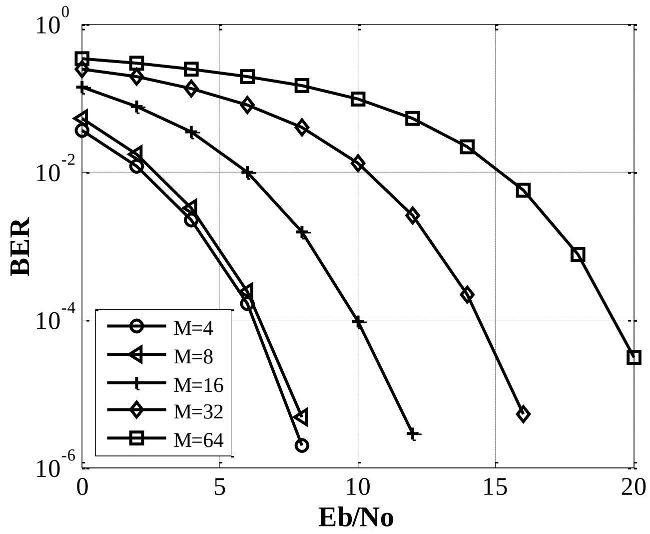

Fig.8. BER of WPT–OFDM (PSK)

The results of all the FFT–OFDM simulations performed are shown in the Fig.5 to Fig.7 whereas Fig.8 to Fig.10 shows the results of all the WPT–OFDM simulations. The results of comparison between FFT and WPT–OFDM are shown in Fig.11 to Fig.13.

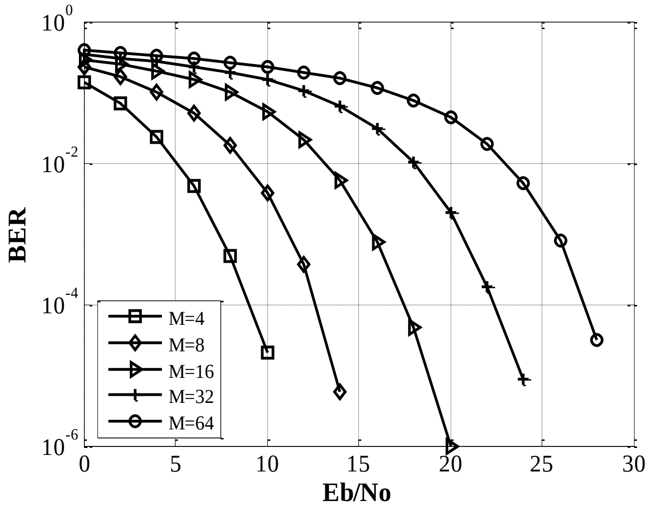

Fig.9. BER of DWPT–OFDM (DPSK)

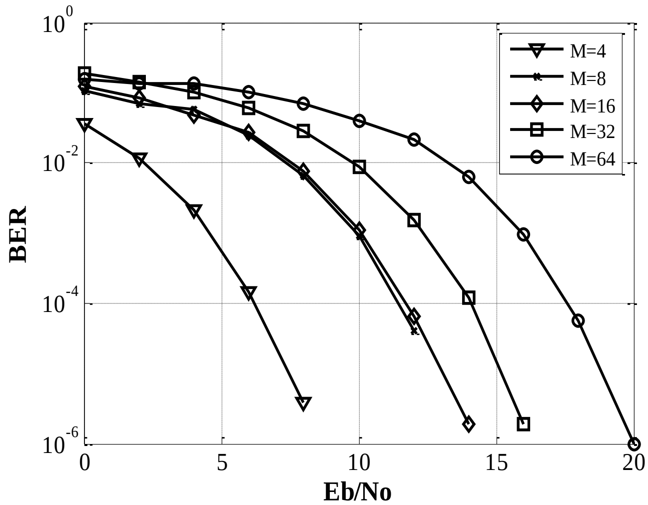

Fig.10. BER of DWPT–OFDM (QAM)

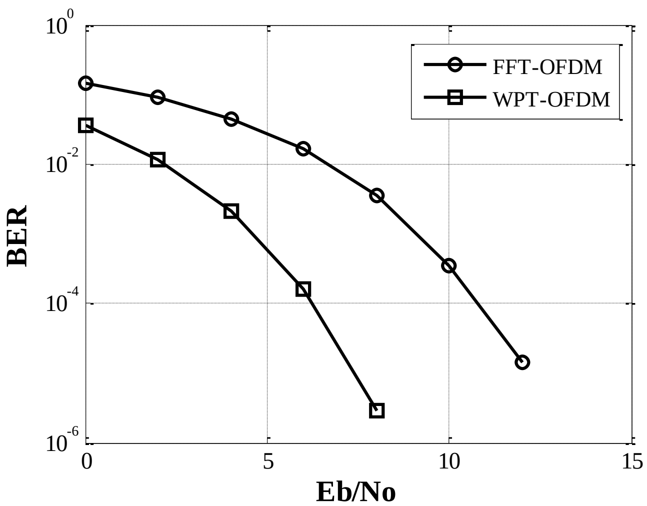

Fig.11. BER Vs Eb/No of QAM (M=4)

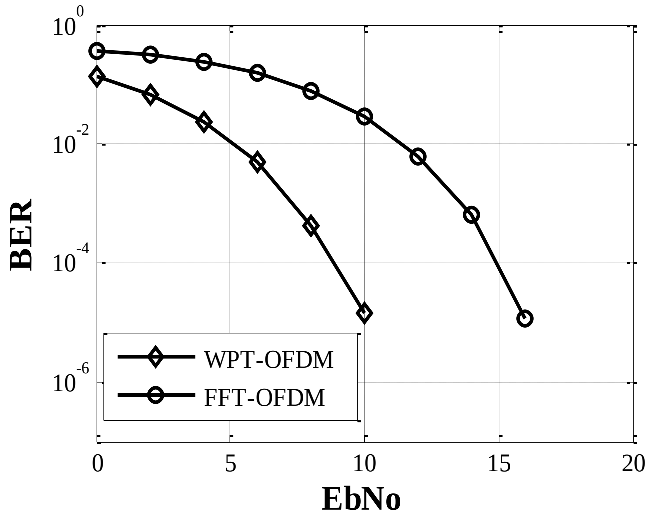

Fig.12. BER Vs Eb/No of DPSK(M=4)

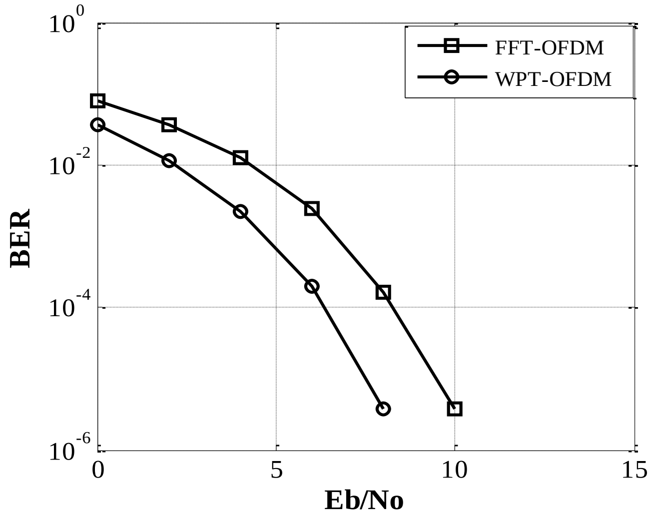

Fig.13. BER of PSK (M=4)

5. CONCLUSION

From the simulation results, it is found that as we increase the value of M in M-ary modulation, the BER performance of the system degrades for both FFT–OFDM and WPT–OFDM. It is also found that the wavelet packet based OFDM (DWPT–OFDM) performs better in terms of Eb/No in WLAN system as compared to Fourier-based OFDM (FFT–OFDM) for all types of M-ary modulation techniques. Also we find that the use of wavelet reduces the overhead as it does not require use of cyclic prefix thus making available a larger bandwidth. DWPT and FFT–OFDM systems have nearly same complexity according to number of subcarriers used. However, DWPT–OFDM systems are more flexible as different wavelets can be used.

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