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PERFORMANCE ANALYSIS OF CONVENTIONAL, INTERLEAVED AND WAVELET BASED OFDM SYSTEMS

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Abstract: The paper provides an overview of Conventional Orthogonal Frequency Division Multiplexing (OFDM), Interleaved OFDM (IOFDM) and Wavelet based systems. Description includes comparison of the tools for studying the signals. In this paper, we have evaluated BER performance for conventional OFDM, IOFDM and WOFDM systems. IOFDM system is proposed to increase the code rate without increasing the number of subcarriers and bandwidth. Later, the work is compared and simulation results in enhancement of performance with a moderate increase in computational complexity and delay.

I. INTRODUCTION

OFDM is multicarrier modulation method (MCM) technique for transmitting data in parallel by using a large number of modulated subcarriers [1]. It is a promising technology in broadband communication due to its spectral efficiency and low complexity. OFDM is bandwidth efficient and eliminates inter channel interference (ICI) with the introduction of cyclic prefix. Nowadays OFDM is considered as standard platform for Asymmetric Digital Subscriber Line (ADSL) and power line communication. Interleaving technique applied on OFDM enhances the code rate without bandwidth expansion and increase in number of subcarriers. It results in good performance with low complexity. OFDM is sensitive to phase noise and carrier frequency offset. Peak to average power ratio (PAPR) problem reduces power efficiency and performance.

Wavelet transform is a tool to study time and frequency representation. It is used to analyze non-stationary signal whose frequency response varies with time [2]. It possesses all advantages and solution for disadvantages of conventional OFDM. In this technique, bandwidth is divided by using inverse discrete wavelet based transform. Wavelet transform is capable of better performance with the elimination of ICI and ISI. Cyclic prefix (CP) is not required so overall system becomes bandwidth efficient. Wavelet filters provides both orthogonality and good frequency time localization. It gives better resolution of signal which is a measure of amount of detail information in signal. Wavelet based OFDM have better BER performance in comparison to FFT based system, but it is computationally more complex. In this work, interleaved based OFDM with CP correction is shown and finally compared to wavelet based system with the help of simulations [5].The paper is organized as follows. In Section 2, system with the help of block diagram is described briefly. Section 3 consists of elaboration of Conventional OFDM and interleaving introduced in OFDM system. Section 4 contains a brief description of wavelet based OFDM system with mathematical representation. Section 5 presents the simulation results and comparison between the three systems with various graphical representations. The paper is concluded in section 6.

II. THE SYSTEM MODEL

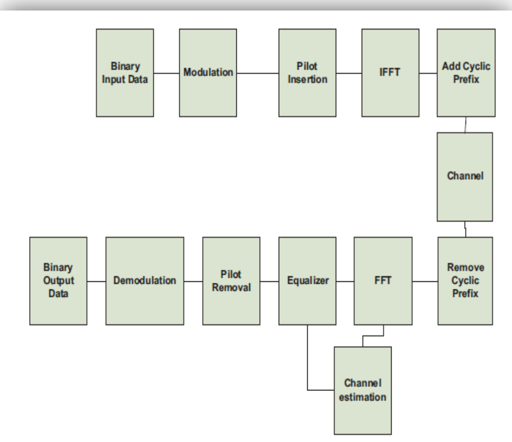

Fig1. OFDM Model

Interleaving and coding for correcting errors of source data is carried out and symbols are modulated on

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orthogonal sub carriers by using IFFT. Orthogonality is maintained during channel transmission with the help of cyclic prefix. In conventional OFDM, IFFT/DFT blocks are used for frequency and time domain conversions [4]. Wavelet based OFDM system replaces these blocks by IDWT/DWT. Addition of cyclic prefix is eliminated which makes wavelet based system bandwidth efficient. The input binary information is first grouped and mapped IFFT generates the required time domain waveform and CP acts like guard interval which makes equalization easy. For wavelet based system, specific period data is send to inverse discrete wavelet transform (IDWT) that converts frequency domain signal into time domain signal, this provides orthogonality to subcarriers.

$$h(n) = \sum \alpha(m)\delta(n - \tau(m))$$

Receiver part of system model consists of Discrete Wavelet Transform (DWT) converts data into frequency domain X(K) from time domain.

$$X_e(k) = \frac{Y(K)}{H_e(k)} \quad k = 0, 1, \ldots, N-1$$

III. CONVENTIONAL OFDM AND INTERLEAVING

OFDM is a parallel transmission scheme, where a high-rate serial data stream is split up into a set of low rate sub streams, each of which is modulated on a separate SC (FDM). Thereby, the bandwidth of the SCs becomes small compared with the coherence bandwidth of the channel; that is, the individual SCs experience flat fading, which allows for simple equalization [4]. implies that the symbol period of the sub streams is made long compared to the delay spread of the time-dispersive radio channel. By selecting a special set of (orthogonal) carrier frequencies, high spectral efficiency is obtained because the spectra of the SCs overlap, while mutual influence among the SCs can be avoided [6]. The derivation of the system model shows that by introducing a cyclic prefix, the orthogonality can be maintained over a dispersive channel. In an OFDM, the cyclic prefix is a repeat of the end of the symbol at the beginning. The purpose is to allow multipath to settle before the main data arrives at receiver. The receiver is normally arranged to decode the signal after it has settled because this is when the frequencies become orthogonal to each other [8]. The length of cyclic prefix is equal to guard interval. Wireless multi-carrier transmission system is based on Orthogonal Frequency-Division Multiplexing (OFDM) including a simple channel coding scheme

IV. WAVELET BASED OFDM SYSTEM

Wavelet filters generate superior multicarrier and multiresolution signals. It provides multiresolution analysis with the application of sub-band coding. Time scale (frequency) representation of signal can be easily obtained by digital filtering technique [10]. The advantage of wavelet based OFDM is its optimal performance over conventional OFDM. CP is not required which gives 20% or more bandwidth efficiency. Pilot insertion is optional that helps in improving additional efficiency by 8%. The wavelet transform blocks, inverse discrete wavelet transform (IDWT) and discrete wavelet transform (DWT) have replaced the IFFT and FFT in modulation and demodulation of FFT-OFDM system [7]. Due to the overlapping nature of wavelet properties, the wavelet based does not need cyclic prefix to deal with delay spreads of the channel. As a result, it has higher spectral containment than that of Fourier-based OFDM. The data $\{d_k\}$ is processed as per FFT-OFDM. However, the difference is that the system does not require CP to be added to the OFDM symbol, and the system uses inverse discrete wavelet transform (IDWT) and discrete wavelet transforms (DWT) to replace IFFT and FFT in transmitter and receiver, respectively. The output of the inverse discrete wavelet transform (IDWT) can be represented as:

$$s(k) = \sum_{m=0}^{\infty} \sum_{n=0}^{\infty} S_m^n 2^{m/2} \psi(2_k^m - n)$$

where $\{S_m^n\}$ are the wavelet coefficients and $\psi(t)$ is the wavelet function with compressed factor m times and shifted n times for each subcarrier (number k, $0 \leq k \leq N-1$). The wavelet coefficients are the representation of signals in scale and position or time. The scale is related to the frequency[9]. Low scale represents compressed wavelet which means that the signal israpidly changing, or the signal is in high frequency. On the other hand, high scale represents stretched wavelet which means that the signal is slowly changing, or the signal is in low frequency. Thus, X_m can be represented to $\{S_m^n\}$ before it is processed to IDWT. At the receiver side, the process is inversed. The output of discrete wavelet transform (DWT) is

$$S_m^n = \sum_{k=0}^{N-1} s(k) 2^{m/2} \psi(2_k^m - n)$$

V.PERFORMANCE EVALUATION

Computer simulations were carried out to evaluate the performance of the system using MATLAB. We have taken total 128sub-carriers and 10 channel coefficients in simulation. 10,000 OFDM symbols are used with the data rate 1Mbps/carrier. A slow fading effect is present so that the channel is time invariant over the symbol interval. Result shows perfect Synchronization between transmitter and receiver with the guard length of 16. We have considered multipath Rayleigh fading channel and after simulation it has been found that IOFDM and Wavelet based systems show better performance than conventional OFDM [11].Fig 2 gives the comparison of the concept applied on symbols for data communication. It is clear

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from the graph thatwavelet gives better performance as BER to SNR value is comparatively better in performance. Fig 3 and 5 explain the two types of wavelet i.e. daubechies and symlets are better than DFT OFDM. Fig 4 gives the performance evaluation between interleaving and

Fig. 2

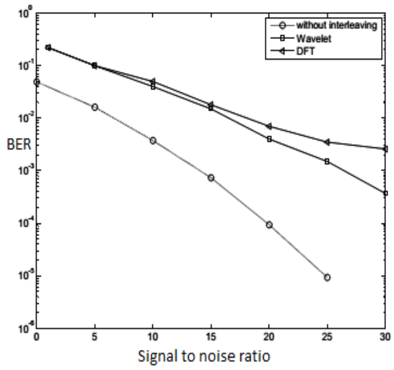


Fig. 3

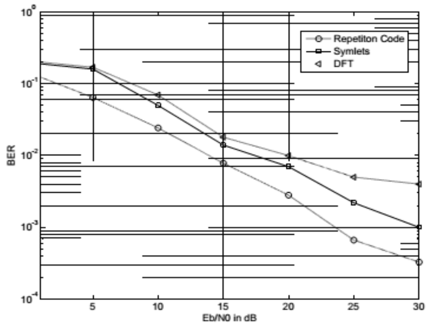
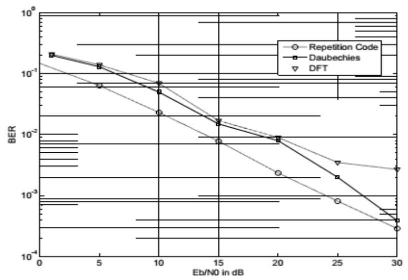
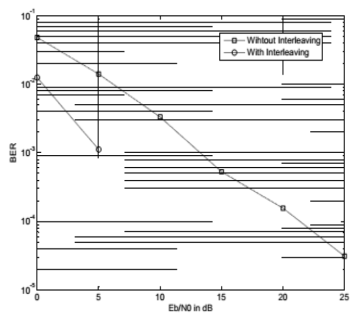


Fig. 4





VI.CONCLUSION

In this paper we have analyzed the performance of conventional OFDM system and its comparison with wavelet based OFDM.Wavelet based OFDM system is a very flexible system which is also simple, and has a low complexity as only low order filters are needed instead of complex FFT processors .From the work, we can easily make it out that IOFDM and Wavelet systems are more bandwidth efficient and have better BER performance than conventional OFDM for Rayleigh fading channels. Graphical representations conclude that interleaving technique applied on symbols is beneficial over conventional OFDM. Wavelet based OFDM system gives 2-8 decibels improvement in Rayleigh fading channel. Hence, analysis on the basis of performance shows that IOFDM and Wavelet based systems are better than conventional OFDM in terms of BER to SNR evaluation.

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