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Performance Evaluation of Ofdm System

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Abstract: ***Orthogonal frequency division multiplexing (OFDM) is a special segment of multi carrier transmission system, which has found its application in numerous wire-less and wired systems. In an OFDM scheme, a large number of orthogonal, overlapping, narrow band sub-channels or subcarriers, transmitted in parallel, divide the available transmission bandwidth. The separation of the subcarriers is theoretically minimal, so that there is a very compact spectral utilization. This paper presents the overview and then the performance evaluation results of an OFDM system, in terms of BER. The results presented in the paper are based on computer simulations performed using MATLAB; a highly efficient tool for different applications.***

Index Terms: OFDM, BER.

I. INTRODUCTION

Orthogonal frequency division multiplexing(OFDM) is a modulation scheme that allows digital data to be efficiently and reliably transmitted over a radio channel, even in multipath environments. the fundamental principle of the OFDM system is to decompose the high rate data stream (bandwidth *w*) into *n parallel* lower rate data streams or channels, one for each subcarrier. Each sub-carrier is modulated with a conventional modulation scheme (such as Quadrature amplitude modulation or Phase-shift keying) at a low symbol rate, maintaining total data rates similar to conventional single-carrier modulation schemes in the same bandwidth. A sufficiently high value of *N* makes the individual bandwidth (*W/N*) of subcarriers narrower than the coherence bandwidth of the channel. The primary advantage of OFDM over single carrier schemes is its ability to cope with severe channel conditions (for example, attenuation of high frequencies in a long copper wire, narrowband interference and frequency-selective fading due to multipath) without use of complex equalization filters. Channel equalization is simplified because OFDM may be viewed as using many slowly-modulated narrowband signals rather than one rapidly- modulated wideband signal. The choice of individual subcarriers is such that they are orthogonal to each other, which allows for the overlapping of subcarriers because the orthogonality ensures the separation of subcarriers at the receiver end. This approach results in a better spectral efficiency than other types of systems like Frequency Division Multiple Access, where no spectral overlap of carriers is allowed. The orthogonality allows for efficient modulator and demodulator implementation using the FFT algorithm on the receiver side, and inverse FFT on the sender side. The major contribution to the OFD Mbecause the orthogonality ensures the separation of subcarriers at the receiver end. This approach results in a better spectral efficiency than other types of systems like Frequency Division Multiple Access, where no spectral overlap of carriers is allowed. The orthogonality allows for efficient modulator and demodulator implementation using the FFT algorithm on the receiver side, and inverse FFT on the sender side. The major contribution to the OFDM implementation was the application of the Fast Fourier Transform (FFT) to the modulation and demodulation processes [11]. Fortunately, the availability of digital signal processing techniques makes it easy to implement it. Recently the Wavelet Transform has also been proposed as a possible transform to generate the sub channels in a multicarrier system [10], with the advantage of flexibility of the transform and the higher suppression of side lobes compared to the side lobes of the rectangular window in the Fourier Transform.

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II. FFT BASED OFDM SYSTEM

Figure 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 that are implemented using the IFFT block After symbol mapping, it is necessary to convert the data stream into parallel form where each parallel data stream represents a sub-channel, so a serial to parallel converter is used. IFFT block is then used to modulate this low data rate stream that also converts the domain of the input. The output of IFFT is the sum of the information signals in the discrete time domain as following:.

$$X_k= \frac{1}{N}\sum_{m=0}^{N-1} x_m\ e^{j2\pi km/N}$$

where $\{xk|0 \le k \le N-1\}$ is a sequence in the discrete time domain, $\{Xm|0 \le m \le N-1\}$ are complex numbers indiscrete frequency domain that are obtained by application of digital modulation methods. After applying IFFT on the symbols in all the channels, cyclic prefix is added. The addition of a cyclic prefix to each symbol solves for both the Inter Symbol Interference and Inter Carrier Interference. If the channel impulse response has a known length L, then the prefix consists simply of copying the last L-1 values from each symbol and appending them in the same order to the front of the symbol [4], [9]. Digital data is then converted to serial form and transmitted over the channel. At the receiver side, the process is reversed to obtain
and decoded the data.

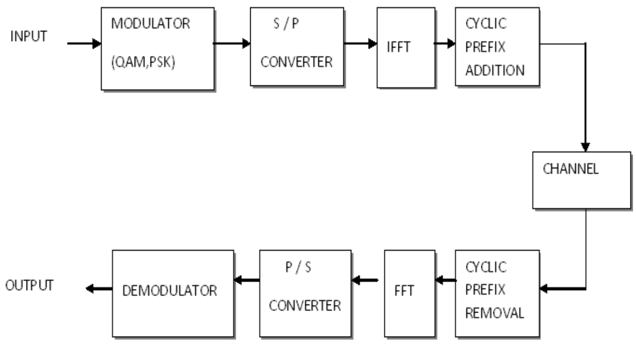

Figure1: FFT OFDM

The output of FFT is the sum of the received signal in discrete frequency domain as follows:

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

After FFT, the signal is converted back to parallel form and demodulated to yield the transmitted signal back. As OFDM requires a cyclic prefix, to remove the ISI, this causes overhead and this overhead may be sometimes much large for the system to be effective.

In wireless applications especially, predicting the channel impulse response length is a tedious task, and moreover, this length can be so big that the performance loss due to insertion of a long cyclic prefix becomes unacceptable. So other techniques have to be introduced. One can try to look for other compensating techniques, making the overall system more and more complex. Another solution is to replace the Fourier Transform by a transform that is less susceptible to all these channel effects, and that can thus more easily compensate for the resulting effects. The Wavelet Transform is proposed by several authors to be such a transform. Its longer basis functions allow more flexibility in the design of the waveforms used, and can offer a higher degree of sidelobe suppression. In DWTOFDM, the modulation and demodulation are implemented by wavelets rather than by Fourier transform. The use of wavelet promises to reduce the ISI and ICI without the usage of cyclic prefix as used in FFT-OFDM. Many researchers have used wavelet transform in OFDM in place of Fourier and found out that the wavelet based OFDM has more advantages than Fourier based OFDM.

III. WAVELET BASED MODULATION

A wavelet is a waveform of effectively limited duration that has an average value of zero. The comparative difference between wavelets and sine waves, which are the basis of Fourier analysis is that sinusoids do not have limited duration, they extend from minus to plus infinity and where sinusoids are smooth and predictable, wavelets tend to be irregular and asymmetric. As the well known technique of signal analysis Fourier analysis consists of breaking up a signal into sine waves of various frequencies, similarly, wavelet analysis is the breaking up of a signal into shifted and scaled versions of the original (or mother) wavelet. The Discrete Wavelet Transform (DWT) is used in a variety of signal processing applications, such as video compression, Internet communications compression, object recognition and numerical analysis . The advantage of wavelet transform over other transforms such as Fourier transform is that it is discrete both in time as well as scale. The transform is implemented using filters. One filter of the analysis (wavelet transform) pair is a low-pass filter (LPF), while the other is a high-pass filter (HPF). Each filter has a down-sampler after it, to make the transform efficient. The DWT of a signal x is calculated by passing it through a series of filters. First the samples are passed through a low pass filter with impulse response "g" resulting in a convolution of the two:

$$y[n]=(x*g)[n]=\sum_{k=-\alpha}^{\alpha} x[k]\,g[n-k]$$

The signal is also decomposed simultaneously using a high-pass filter "h". The output gives the detail coefficients (from the high-pass filter) and approximation coefficients (from the low-pass). It is important that the two filters are related to each other and they are known as a quadrature mirror filters. However, since half the frequencies of the signal have now been removed, half the samples can be discarded according to Nyquist's rule. The filter outputs are then sub sampled by two. The outputs of the low-pass filter and the high-pass filter are shown below and are the convolutions of the input data with the respective filter responses:

$$y_{low}[n]=(x*g)[n]=\sum_{k=-\alpha}^{\alpha} x[k]\,g[2n-k]$$

The decomposition has halved the time resolution since only half of each filter output characterizes the signal. However, each output has half the frequency band of the input so the frequency resolution has been doubled. Figure 2 shows the block diagram for upto one level only and hence only one pair of filters (a high-pass filter and a low-pass filter) is used. Each sub stream of data is sub-sampled by two as shown.

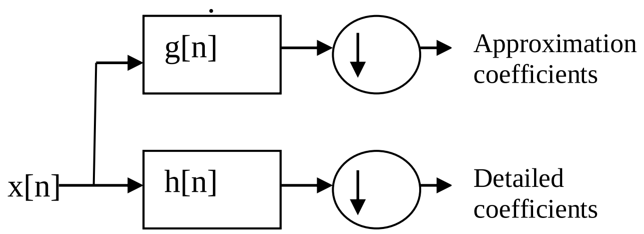

Figure 2:Block diagram of filter analysis

One of the advantages of using wavelet transform is that due to the overlapping nature of wavelet properties, the wavelet based OFDM 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 [6]. The input data is processed as per FFT-OFDM. However, the difference is that the system does not require CP to be added to the OFDM symbol. The output of the inverse discrete wavelet transform (IDWT) can be represented as:

$$d(k)= \sum_{m=0}^{\infty} \sum_{n=0}^{\infty} D^{n}{}_{m} 2^{m/2} \varphi(2^{m}{}_{k} - n)$$

where are the wavelet coefficients and φ(t) is the wavelet function with compressed

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factor *m* times and shifted *n* times for each subcarrier (number *k*, $0 \le k \le N-1$). The wavelet coefficients are the representation of signals in scale and position or time. *Xm* At the receiver side, the process is inversed. The output of discrete wavelet transform (DWT) is

$$D^n_m = \sum_{k=0}^{N-1} d(k) 2^{m/2} \varphi(2^{m}_{k} - n)$$

Multi-resolution analysis of wavelet theory allows to represents wavelet and scaling functions by high and low pass filters (HPF and LPF), respectively with impulse responses *h*[*m*] and *g*[*m*]. Therefore the wavelet transformation can be easily implemented using discrete time filters.

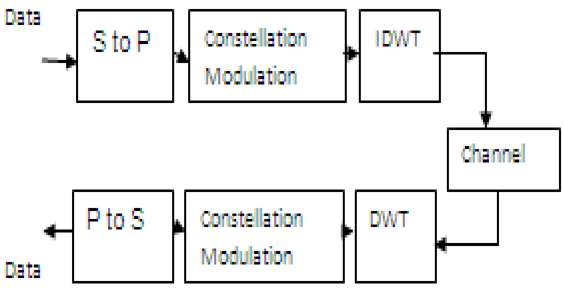

Figure3:DWT OFDM

IV. SIMULATION PARAMETERS AND RESULTS

The performance of FFT-OFDM and DWT-OFDM has been investigated by means of computer simulation. We implemented a communication system viz. WLAN standard IEEE802.11a physical layer with BPSK and DBPSK modulation using Matlab programming. Both the FFT and DWT based systems were implemented using Matlab and the graphical results found show the bit error rate probabilities of both the systems. The systems implemented don't have any error estimation or correction capabilities. Different wavelets are available there for implementation of discrete wavelet transform and we considered Haar wavelet for the system. The results presented show the BER performance as a function of the energy per bit to noise ratio. Following are the parameters that have been considered for system implementation. The results presented show the BER performance as a function of the energy per bit to noise ratio. Following are the parameters that have been considered for system implementation. Three types of channels are considered: AWGN, Rayleigh and Rician fading channel. For DWT based OFDM system, same number of data carriers are used but with no cyclic prefix. For the FFT-OFDM system simulation, the parameters that are loosely based on WLAN standard IEEE 802.11a system are used.

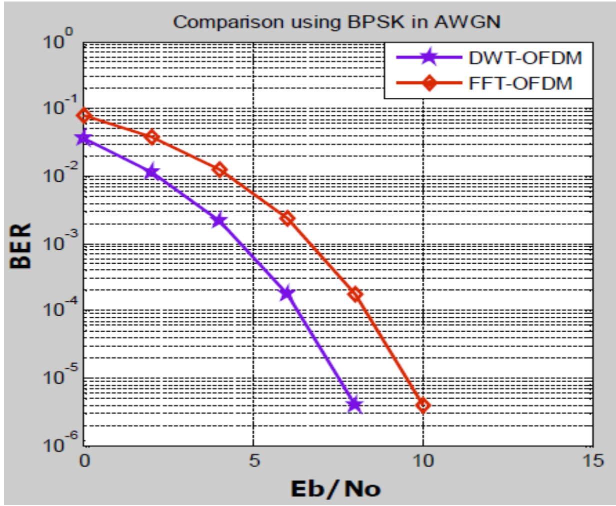

Figure4:BER performance comparison of DWT OFDM and FFT OFDM in AWGN using BPSK

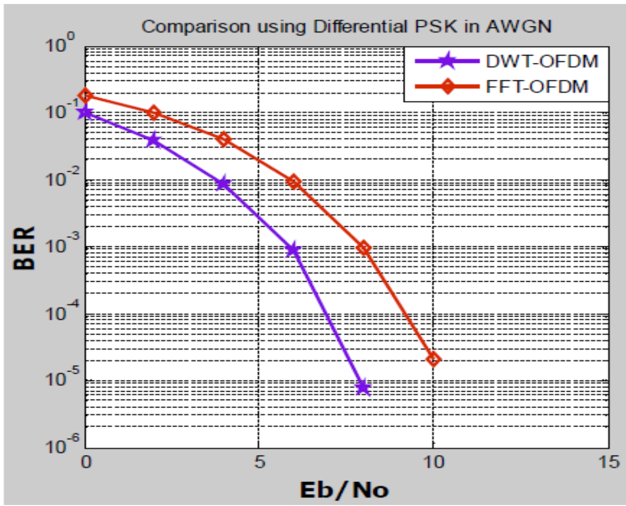

Figure5:BER performance comparision of DWT OFDM and FFT OFDM in AWGN using DPSK

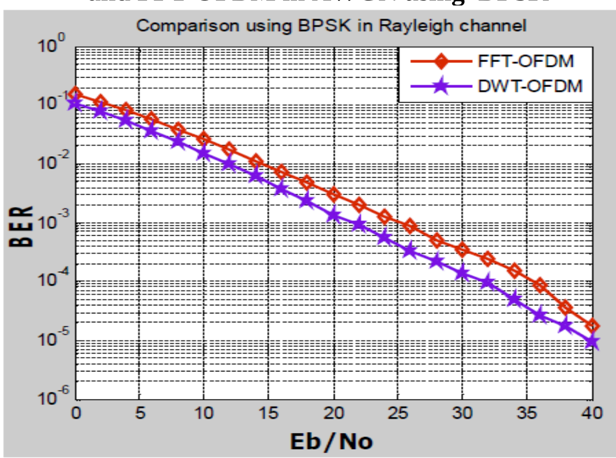

Figure6: BER performance comparision of DWT OFDM and FFT OFDM in Rayleigh using BPSK

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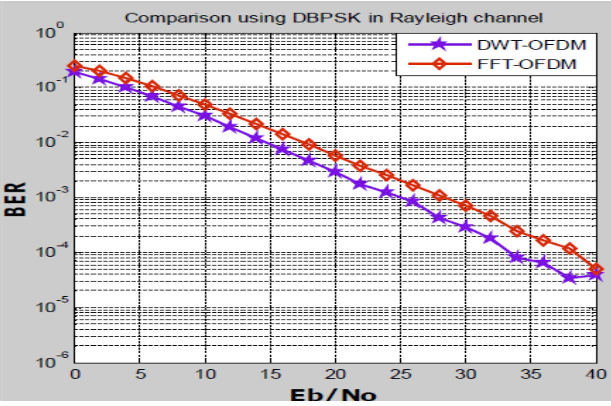

Figure7: BER performance comparision of DWT OFDM and FFT OFDM in Rayleigh using DPSK

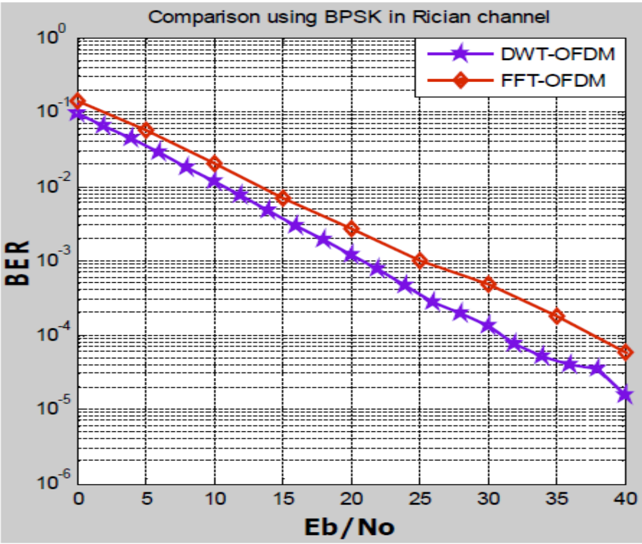

Figure8: BER performance comparision of DWT OFDM and FFT OFDM in Rician using BPSK

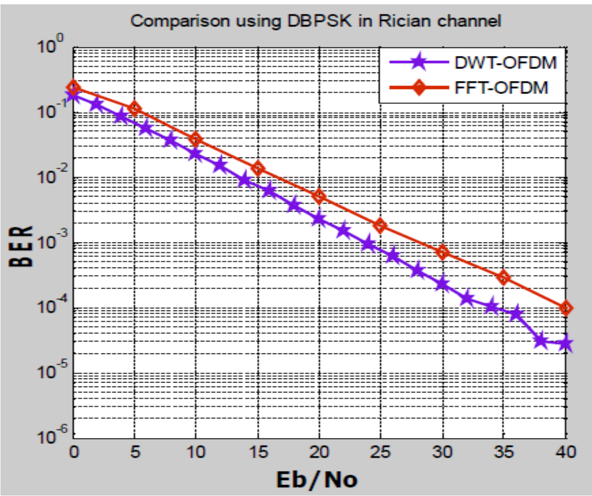

Figure9: BER performance comparision of DWT OFDM and FFT OFDM in Rician using DPSK

As seen in Figures 4, 5,6,7,8 and 9, it is found that as the energy per bit to noise ratio increases in any system, a decrement in bit error rate is encountered. Also, wavelet based system performs better in terms of bit error rate probability by showing less bit error rate as compared to FFT based system for any value of Eb/No in all three channel scenarios.

V. CONCLUSION AND FUTURE WORK

This paper compares the performance of Fourier transform based and Wavelet based OFDM systems, in terms of bit error rate probability, for different channel scenarios. From the performed simulations, in the Additive White Gaussian Noise channel, it was found that the DWT based OFDM system has better performance than that of the FFT-OFDM for both types of the modulations used viz. BPSK and DBPSK. It was also found that DWT-OFDM outperformed FFT-OFDM in other types of channels i.e. Rayleigh and Rician fading channels. Wavelet based system was found having small bit error rate probability, than that of the Fourier transform based system. The purpose of the research was to implement and find the transform that performs better in the wireless channels that are mostly multipath. The paper compares the performance of the systems using binary phase shift keying and differential phase shift keying only whereas the future work may include the implementation of other modulation schemes and different channel scenarios for performance evaluation of any OFDM based system.

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