IJISET - International Journal of Innovative Science, Engineering & Technology, Vol. 2 Issue 3, March 2015.
www.ijiset.com
ISSN 2348 – 7968

A Review - Performance comparison of conventional and wavelet based OFDM system

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Abstract

As the world move in to the future, there is a rising demand for high capacity, high performance and high bit rate wireless communication system to integrate wide variety of communication services. To increase data rate of wireless medium with higher performance, OFDM (orthogonal frequency division multiplexing) is used. OFDM is multicarrier modulation (MCM) technique which provides an efficient means to handle high speed data streams on a multipath fading environment that causes ISI. Normally OFDM is implemented using FFT and IFFT's. To decrease the bandwidth waste brought by adding cyclic prefix, Wavelet based OFDM is employed. Due to use of wavelet transform the transmission power is reduced. In this paper we review the replacement of Fourier transform by Wavelet transform and its effects on the overall system.

Keywords:*FFT,DWT,BER,OFDM, AWGN*

1. Introduction

In the current and future mobile communications systems, data transmission at high bit rates is essential for many services such as high quality audio and video and mobile integrated service digital network.When the data is transmitted at high bit rates, over mobile radio channels, the channel impulse response can extend over many symbol periods, which lead to ISI(Inter-symbol Interference). In OFDM signal the bandwidth is divided into many narrow sub-channels which are transmitted in parallel [1][2].Each sub-channel is typically chosen narrow enough to eliminate the effect of delay spread. OFDM is multi-carrier modulation technique for transmission of signals over wireless channels. It converts a frequency-selective fading channel into a collection of parallel sub channels, which greatly simplifies the structure of the receiver.OFDM is multicarrier modulation (MCM) technique, which provides an efficient means to handle high speed data streams on a multipath fading environment that causes ISI. The spectral containment of the channels is better since it does not use cyclic prefix.One type of wavelet transform is DWT (Discrete Wavelet transforms) have been considered as alternative platforms for replacing IFFT and FFT. It employs Low Pass Filter (LPF) and High Pass Filter (HPF) operating as Quadrature Mirror Filters satisfying perfect reconstruction and orthogonal properties. Wavelet transform [3] is a tool for studying signals in the joint time–frequency domains. Wavelets have compact support (localization) both in time and frequency domain, and possess better orthogonality. Orthogonal wavelets are capable of reducing the power of inter symbol interference (ISI) and inter carrier interference (ICI) which are caused by loss of orthogonality between the carriers as a result of multipath propagation over the wireless fading channels. In OFDM inter symbol interference (ISI) and inter channel interference (ICI) reduced by use of cyclic prefix (CP). In wavelet based OFDM, CP is not required. CP is 20% or more of symbol. Thus wavelet based OFDM gives 20% or more bandwidth efficiency [4]. Wavelet based OFDM is less affected by Doppler shift.In wavelet based OFDM a prototype wavelet filter provides both orthogonality and good time–frequency localization. Wavelet provides phase linearity and significant out of band rejection. Its energy compaction is also high.

Wavelet based OFDM (WOFDM), which is also an MCM technique, possesses almost all advantages and disadvantages of conventional (Fourier based) OFDM. In this technique, the sub bandwidth division is obtained by using the inverse discrete wavelet based transforms, whereas conventional OFDM uses IFFT. Another main difference is that WOFDM symbols overlap in both time and frequency domains, whereas OFDM symbols overlap only in frequency domain. Therefore, adding CP to the WOFDM symbol frame does not have any effect on the bit error rate (BER) performance, as also shown in this work. One major advantage of WOFDM compared to OFDM is that WOFDM is more bandwidth efficient than OFDM.
This paper is organized as: in Section 1, a brief introduction of the previous work demonstrated on COFDM and W-OFDM is discussed. The Section 2 presents the comparison of OFDM & WOFDM and result discussion, followed by the conclusion drawn in Section 3 on the basis of our observations.

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2. Conventional based and Wavelet based OFDM System

2.1 FFT based OFDM System

The block diagram of FFT based OFDM transceivershown in Fig.1. The input digital data is processed by M-aryQAM or PSK modulator to map the data with N subcarriersthat are implemented using the IFFT block [5].

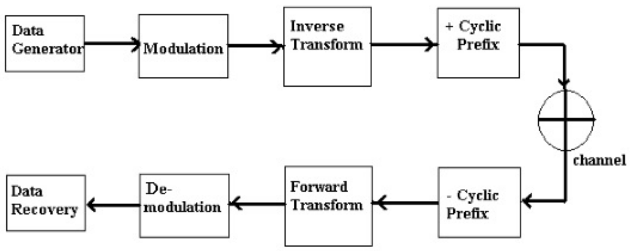

Fig. 1 Basic block diagram of FFT- OFDM[5]

After symbol mapping, it is necessary to convert the datastream into parallel form where each parallel data streamrepresents a sub-channel, so a serial to parallel converter isused. IFFT block is then used to modulate this low data ratestream that also converts the domain of the input. The outputof IFFT is the sum of the information signals in the discrete time domain as follows:

$$x_k = \frac{1}{N}\sum_{m=0}^{N-1} X_m \, e^{j2\pi kn/N} \quad (1)$$

Where$\{x_k|0 \le k \le N-1\}$is a sequence in the discrete time domain,$\{x_m|0 \le m \le N-1\}$are complex numbers in discrete 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. 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. The output of FFT is the sum of the received signal in discrete frequency domain as follows:

$$X_m = \sum_{k=0}^{N-1} x_k \, e^{-\frac{j2\pi km}{N}} \quad (2)$$

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 ISI, this causes overhead and this overhead may be sometimes much large for the system to be effective. The brief introduction of FFT based OFDM shown in Fig.1.

2.2 Wavelet based OFDM System

The use of wavelet promises to reduce the ISI and ICI without the usage of cyclic prefix as used in FFT Based OFDM system. The transceiver of DWT based OFDM is similar to FFT OFDM only inverse discrete wavelet transform (IDWT) and discrete wavelet transform (DWT) replace the IFFT and FFT of conventional FFT BASED OFDM system in modulation and demodulation processes. The output of the inverse discrete wavelet transform (IDWT) can be represented as:

$$d(k) = \sum_{m=0}^{\infty}\sum_{n=0}^{\infty} D_m^n \, 2^{m/2} \, \varphi(2_k^m - n) \quad (3)$$

Where D_m^n are the wavelet coefficients and ψ(t) is thewavelet function with compressed factor m times and shiftedn times for each subcarrier (number k, $0 \le k \le N-1$).Thewavelet coefficients are the representation of signals in scaleand position or time. At the receiver side, the process isinversed. The output of discrete wavelet transform (DWT) is

$$D_m^n = \sum_{k=0}^{N-1} d(k) \, 2^{m/2} \, \varphi(2_k^m - n) \quad (4)$$

In the transmitter part, first data are generated in the random binary form. The BPSK, QPSK and QAM modulation methods are used to map the data. Then these symbols and zeros pads are converted parallel to serial and then apply to vector transpose. The output of this vector transpose is considered as approximated coefficients and detailed coefficients, respectively. This whole part is also known as synthesis filters. Here no need to add cyclic prefix before transmit the signal through channel. Because wavelet transform has stronger ability to suppress the Inter Carrier Interference and Inter Symbol Interferences.

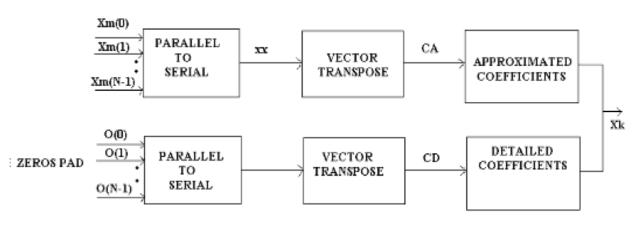

Fig. 2 DWT Transmitter (The synthesis filters)[6]

After passing the signal through the AWGN channel, the process is in reverse at the receiver side to recover the original data and this part is known as analysis filters.

The Discrete Wavelet Transform based OFDM has to satisfy the orthonormal bases and perfect reconstruction

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properties to be considered as wavelet transform. According to this theory, simulation has been work. Proper selection of parameters plays an important role in simulation.

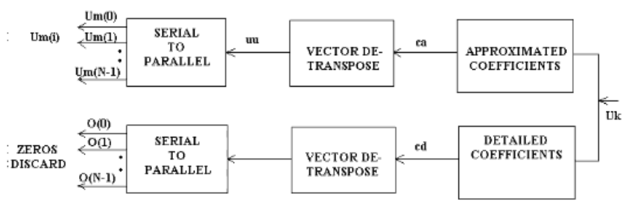

Fig. 3 DWT Receiver (The analysis filters)[6]

At first the results have been compared for the BER performance of Wavelet based OFDM System, and DFT based OFDM system over both Rayleigh fading and AWGN channel. Figs. 4 and 5 Shows the BER performance of DFT based OFDM and wavelet based OFDM under Rayleigh fading channel and AWGN channel respectively.

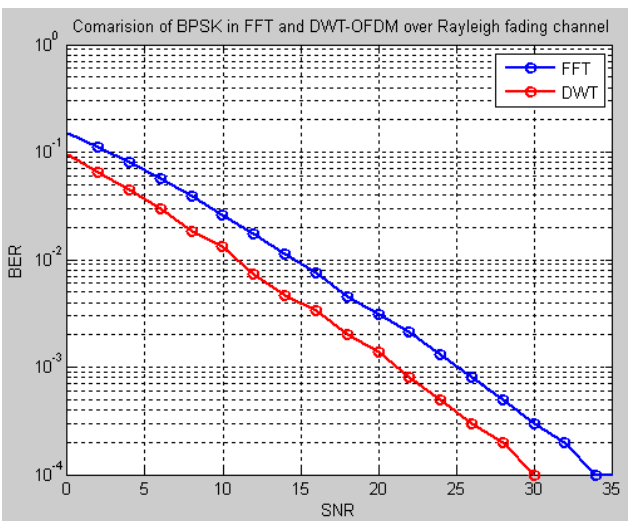

Fig. 4 BER: BPSK over Rayleigh Fading [7]

The BER performance is exactly 10^{-4} in DWT-OFDM atSNR=30dB whereas the same BER performance is given byFFT-OFDM at SNR= 34 dB shown in Fig.4 BPSK over Rayleigh fading.

The following Fig.5 BPSK over AWGN channel indicates that at SNR = 4dB the BER performance is $10^{-2}$and at SNR=8dB the BER performance is nearly equal to 10^{-4} in DWTOFDMsystem which is less than FFT-OFDM system.

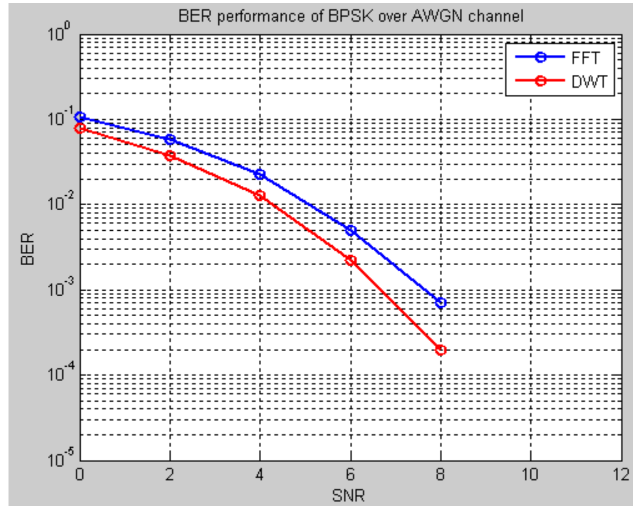

Fig. 5 BER: BPSK over AWGN channel [7]

It is clear from figures that Wavelet based OFDM have better BER performance as compared to DFT based OFDM.

Now the results have been evaluated for the MSE performance of Wavelet and DFT based OFDM system. For MSE performance, LMMSE estimator and LS estimator has been considered.Fig.6 and Fig.7 Shows that LMMSE estimator has 15–20 dB better performance than LS estimator.

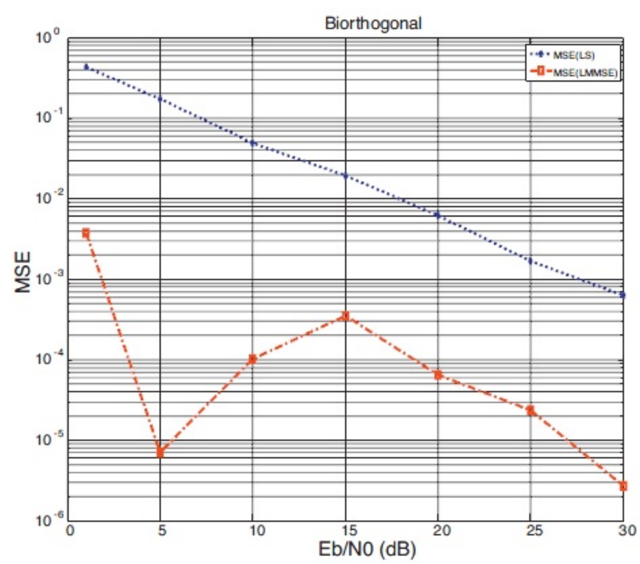

Fig. 6 Performance of Biorthogonal wavelet based OFDM system [8]

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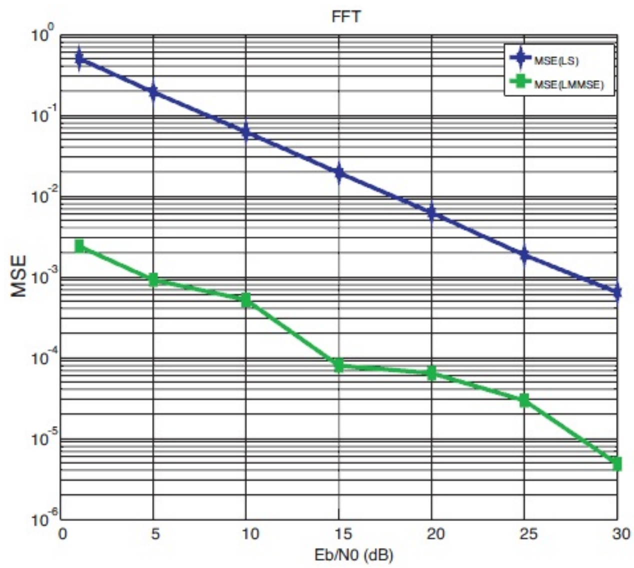

Fig. 7 Performance of FFT based OFDM system[8]

At last performance have been compared for the power spectral density (PSD) of wavelet based OFDM system with DFT based OFDM system. Fig.8 shows that the wavelet based OFDM system is more spectral efficient then DFT based OFDM system. For comparative analysis between wavelet based OFDM system and conventional OFDM system, the Biorthogonal wavelet was considered.

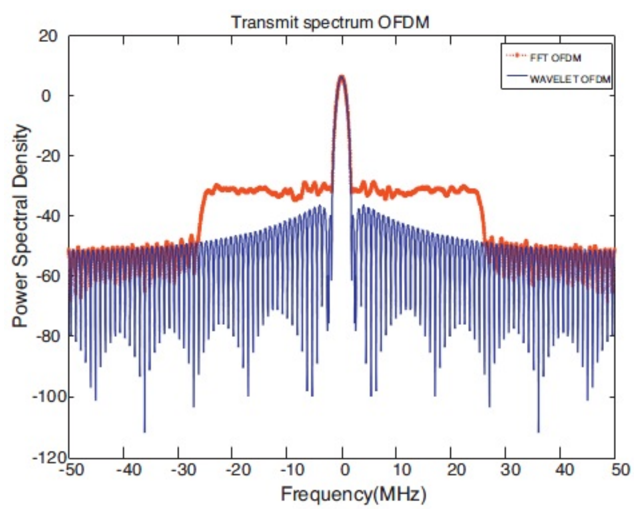

Fig. 8Comparison of power spectral density[8]

3. Conclusions

A comprehensive review of performance of conventional OFDM system and its comparison with wavelet based OFDM is presented in this work. 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 and the filter type can be dynamically chosen depending on the condition of the channel or the data. In the comparison of BERperformance of DFT and wavelet based OFDM system, wavelet based OFDM system have better performance in AWGN channel as well as Rayleigh fading channel. Wavelet based OFDM gives SNR improvement in AWGN channel As well as in Rayleigh fading channel. In the channel estimation of wavelet based OFDM and conventional OFDM the LMMSE estimator gives improvement than LS estimator. Power spectral density of wavelet based OFDM system is much better than conventional OFDM system. The main focus of this work is to put attention towards the realization of future high performance networks by introducing the Wavelet based OFDM in place of conventional OFDM systems.

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