A Proposed Method to Reduce the BER in Wavelet based OFDM

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ABSTRACT
Long term evolution (LTE) selects orthogonal frequency division multiplexing (OFDM) and its single-carrier counterpart SC-FDM as the basic transmission schemes. OFDM is a very interesting approach for high data rate transmission in a Gaussian channel and multipath fading environment that leads to inter symbol interference (ISI). In this paper, a proposed convolutional encoder model is used to improve the error rate performance of OFDM system, by using discrete wavelet transform (DWT) instead of fast Fourier transform (FFT) to reduce ISI. The performance of OFDM based on DWT using M-ary quadrature amplitude modulation (M-QAM) as a modulation scheme to achieve high data rate. The simulation results demonstrate that, the bit error rate (BER) is improved for a proposed convolutional encoder model as compared with the previous work.

General Terms
LTE, MATLAB simulator

Keywords
LTE, OFDM, SC-FDMA, ISI, DWT, FFT, M-QAM, BER

1. INTRODUCTION
LTE is a technology that supports high data rates in mobile communication, which uses the OFDM technology in download as a modulation technique which allocates orthogonal subcarriers and consider as a kind of multi-carrier modulation. OFDM divides the available spectrum into a number of parallel subcarriers and each subcarrier is then modulated by a low rate data stream at different carrier frequency. FFT based OFDM uses the cyclic prefix (CP) to reduce the problems of inter carrier interference (ICI) and ISI that consume 25% from the channel bandwidth. The use of wavelet allows reducing the ISI and ICI without the usage of cyclic prefix and also save 25% of bandwidth. Wavelet transform analyzes the signal in both time and frequency domain. The properties of wavelets make it as a better choice for different applications like biomedical engineering, nuclear engineering, pure mathematics, computer graphics and animation, earthquakes prediction, image processing, data compression, music, optics, human vision, radar etc, the wavelet has many functions such Haar, daubechies, coiflet, biorthogonal, reverse biorthogonal and symlet etc. Haar wavelet transform has some advantages over the other wavelet functions such as simplicity, fast, easy and memory efficient. This paper review the FFT based OFDM, wavelet based OFDM and channel coding, after that the proposed convolutional encoder are studied and last the simulation results. The results in this paper compare the wavelet with FFT based OFDM and the different wavelet functions. The last part compares between the system performances in case of no coding applying and applies the convolutional coding and the proposed model, lastly how to increase the data rates.

2. FFT BASED OFDM SYSTEM
The block diagram of FFT based OFDM system is shown in Fig.1. The input digital data is processed by M-QAM 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, 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 follows [1]:

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

Where, x_k (0<k<N-1) is a sequence data in a discrete time domain, X_m is complex number in a discrete frequency domain and N is the number of subcarriers 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. Digital data is converted to serial form and transmitted over the channel. At the receiver side, the process is reversed to obtain the data. The output of FFT is represented as follow [1]:

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

After FFT, the signal is converted to parallel form by using serial to parallel converter and demodulated by m-ary QAM demodulator to obtain the output binary data.

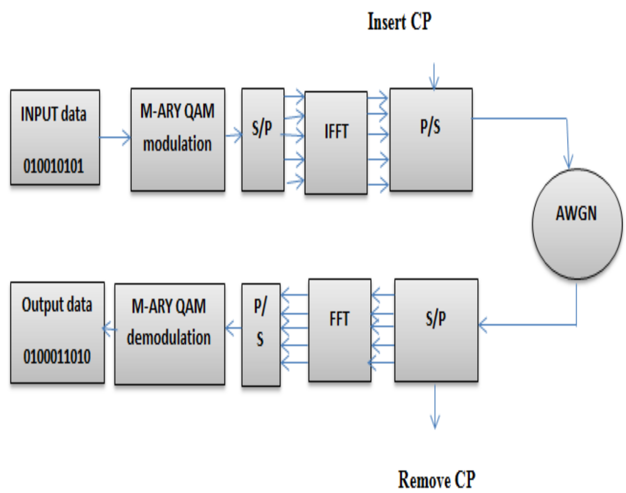

Fig. 1 Block diagram of FFT based OFDM transceiver

3. WAVELET BASED OFDM SYSTEM

The block diagram of wavelet based OFDM is shown in Fig. 2. The inverse discrete wavelet transform (IDWT) used in the transmitter gives the following output:

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

Where D_m^n are the wavelet coefficients and $\varphi(t)$ is the wavelet function with compressed factors m and n for each subcarriers number k ($0 \le k \le N-1$). At the receiver side, the process is inversed. The output of discrete wavelet transform (DWT) is

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

In the transmitter, data are generated in the random binary digital form. The QAM modulation converts the binary data into modulated symbols. These symbols and zeros pads are converted parallel to serial and then apply to vector transpose. The output of the vector transpose is considered as approximated coefficients and detailed coefficients, respectively. This whole part is also known as synthesis.

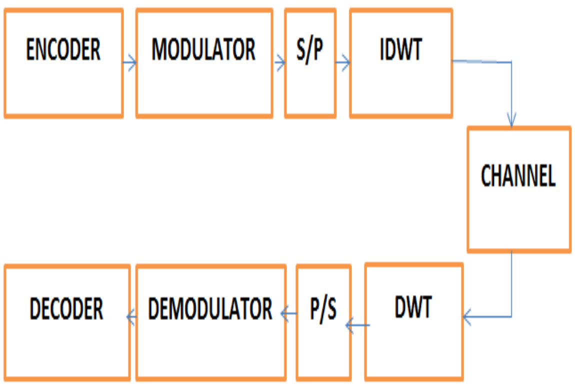

Fig. 2 The block diagram of Wavelet based OFDM transceiver

4. CHANNEL CODING

The main channel coding types are the block coding, convolutional coding and turbo coding [2]. Convolutional encoders are very powerful error correcting codes which finds their applications in digital video, satellite communication and mobile communication. Convolutional encoder is finite state machine which processes the information bits in a serial manner and applied in applications of good performance and low implementation cost. Convolutional encoders are denoted by (n,k,L), where L is code (or encoder) Memory depth (number of memory register stages), k is the input bits and n is output bits as shown in Fig. 3 [3].

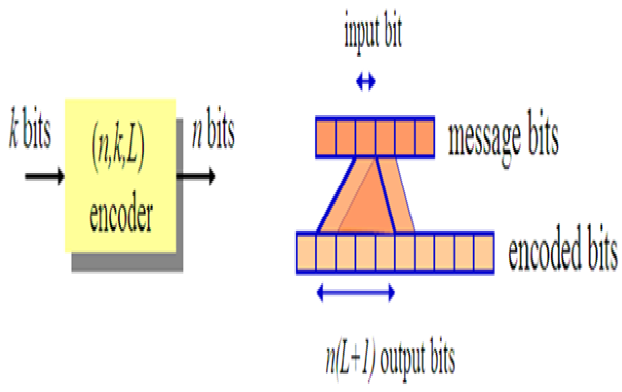

Fig. 3 The convolutional encoder

Constraint length C=n (L+1) is defined as the number of the encoded bits. k/n is the code rate and is a measure of efficiency of the code .

5. PROPOSED CONVOLUTIONAL ENCODER MODEL

The convolutional encoder enhances the OFDM performance by enhancing the system performance. The proposed convolutional encoder model used in this paper generates a random binary data to pass through two convolutional encoder blocks. The encoded data interleaved by a matrix interleaver to be modulated via a QAM modulator block. The proposed model used the IDWT for the transformation in transmitter a shown in Fig.4.

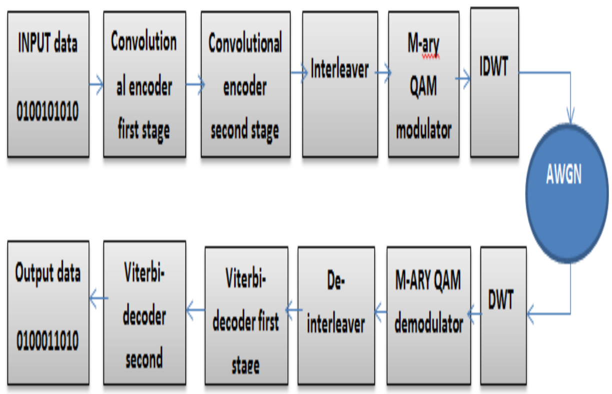

Fig. 4 The proposed convolutional encoder model transceiver

The receiver makes the reverse process after passing the transformed signal through the additive white Gaussian noise (AWGN) channel. The proposed model used a two stage of Viterbi decoder with the convolutional encoder to obtain high performance and simplicity.

6. SIMULATION RESULTS

The simulation of wavelet based OFDM and FFT based OFDM are compared for 16-QAM modulator. The simulation results are implemented using MATLAB (v8.2015a) software. The results plotted for AWGN channel because of its simplicity than the multipath and Rayleigh channel [4]. BER curves are plotted versus the signal to noise ratio (S/N) in dB for different cases of wavelet based OFDM. The system works with 9600 bits for each frames, *N*=512 FFT size, 16-QAM modulation and 10 MHz bandwidth with carrier spacing of 15 kHz.

6.1 Comparing BER in wavelet and FFT based OFDM

Comparing the BER performance for FFT based OFDM with inserting a cyclic prefix and Wavelet based OFDM without any cyclic prefix and using a Haar wavelet function [5 - 6]. BER value equal 0.1454 in FFT based OFDM at 10dB as shown in Fig. 5 whereas equal 0.002604 in wavelet based OFDM at the same signal to noise ratio 10dB as shown in Fig. 6. These results gives a better performance of wavelet based OFDM than FFT based OFDM [7]. The results give an enhancement for wavelet based OFDM than FFT based OFDM by reducing the BER value at the same signal to noise ratio. The reduction in BER value gives low errors and high accuracy and performance in the system.

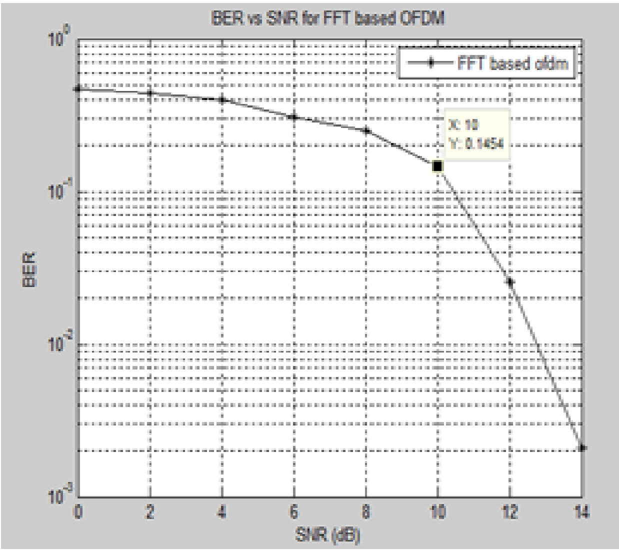

Fig 5 BER in FFT based OFDM

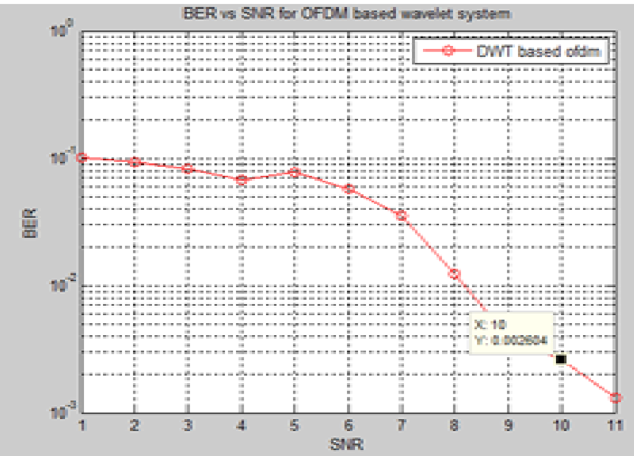

Fig. 6 BER in wavelet based OFDM

6.2 BER in wavelet based OFDM system for different wavelet functions

The simulation of wavelet based OFDM for different wavelet functions are studied in this section. The wavelet has many functions such Haar, daubechies, coiflet, biorthogonal, reverse biorthogonal and symlet etc [8]

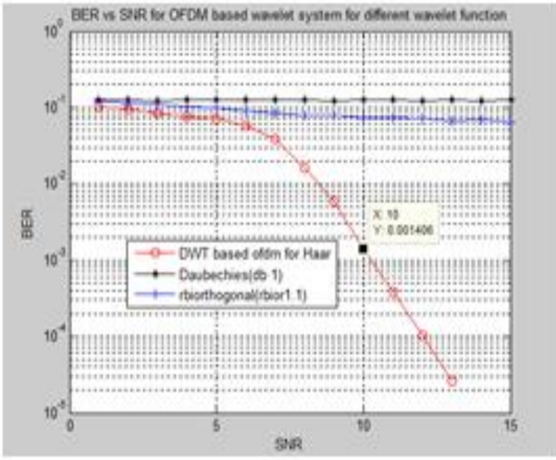

Fig. 7 BER for various wavelet functions

6.3 Effect of Convolutional coding in wavelet based OFDM

This section shows the effect of system before applying the convolutional channel coding and after applying it. The enhancement in the system performance can be obtained by reducing the BER for the same S/N ratio. The system without any coding gives a BER value of 0.08681at 10dB as shown in Fig. 8.

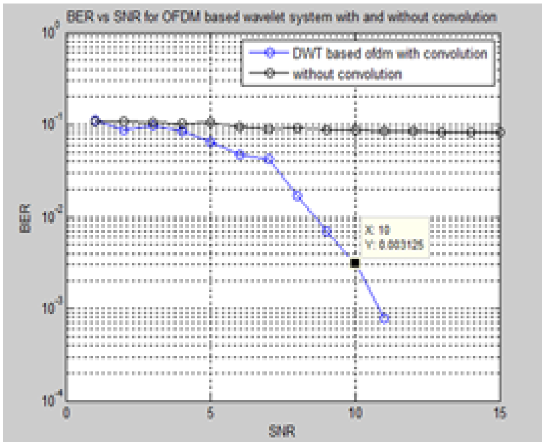

Fig. 8 Wavelet based OFDM with and without coding

When applying a convolutional encoder gives a BER value of 0.003125 at the same value of S/N ratio of 10dB. The BER value in wavelet based OFDM without convolutional encoder can be obtained in wavelet based OFDM with convolutional encoder at S/N ratio of 2 dB. The convolutional encoder saves more than 8 dB which improve the performance than in [9]- [12].

6.4 Proposed Convolutional encoder model

The last results give an enhancement in the wavelet based OFDM system performance than FFT. The BER value can be reduced when using the Haar function and the convolutional encoder. The BER value in the proposed convolutional encoder model is 0.0005208 at S/N ratio of 10 dB as shown in Fig. 9. The proposed model decreases the value of BER for the same S/N ratio used in the above results. When increase the number of stages of the convolutional encoder lead to reducing the BER but increase the complexity and cost. The value of BER with one stage convolutional encoder can be obtained for two stage convolutional encoder at nearly 6.5 dB to save more than 3.5 dB which save the system power.

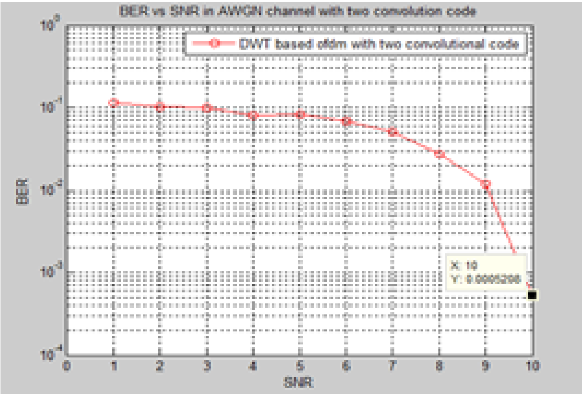

Fig. 9 BER in wavelet based OFDM for two convolutional encoders

6.5 Increase the data rates

The data rates can be increased when using 64-QAM as shown in Fig. 10. The BER has a value of 0.04852 at 10 dB for 64-QAM [13]. The BER performance is decreased for high data rates. M-QAM modulation gives a better performance and data rates than BPSK and QPSK used in [13].

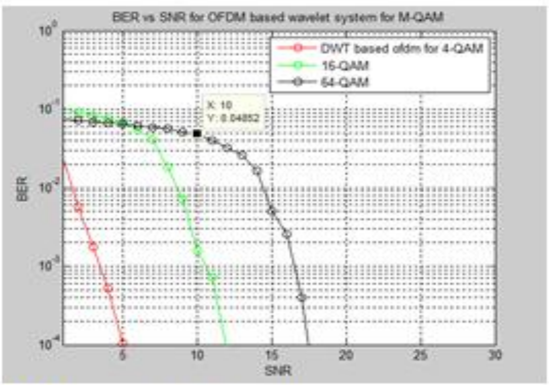

Fig. 10 The wavelet based OFDM for M-QAM

Table 1 will summarize the numerical results with different cases studied

Table 1 Summarized results of the proposed technique

The signal to noise ratio	2dB	5dB	10dB
BER in FFT based OFDM	0.4448	0.3516	0.1506
BER at different wavelet function	Haar 0.00151	DB1 0.12561	Rbior 0.07367
BER Without coding in wavelet	0.1074	0.1049	0.08707
BER with convolution coding in wavelet 16-qam	0.0862	0.06823	0.003125
BER with two successive convolutional code	0.1036	0.07995	0.0005208
BER at 64-QAM for wavelet based OFDM	0.04006	0.03998	0.02526
BER at 256-QAM for wavelet based OFDM	0.06003	0.05716	0.04635

Comparison between the proposed system and previous works is shown in table 2 [14]-[20]

Table 2 Proposed and previous works

Case studied	**BER in Proposed system at S/N of 10dB**	**BER in previous works at 10dB S/N**	**reference**
FFT based OFDM	0.1506	0.636	[14]
Wavelet based OFDM	0.003125	0.1 1 0.001	[15] [16]
HAAR wavelet	0.00151	0.0045 0.0123 0.001	[18] [19] [20]
64-QAM modulation	0.02526	0.1	

7. CONCLUSION

An efficient technique in channel coding is proposed to enhance the performance by decreasing the BER at a certain signal to noise ratio in wavelet based OFDM system. Wavelet based OFDM gives an enhancement in BER performance than FFT based OFDM at the same value of signal to noise ratio

S/N 10 dB. The proposed channel coding technique gives a BER value of 0.0005208 while a convolutional encoder gives a BER value of 0.0035 for S/N ratio of 10 dB. This BER value of the convolutional encoder can be obtained in the proposed technique at 6.5 dB to save more than 3.5dB. The proposed channel coding technique operates in 256-QAM with BER nearly equal the BER at 64-QAM which increase the data rates. The proposed technique can reduce the BER value by increasing the convolutional encoder stages which also increase the cost and complexity. The future work for my work will focus on the different encoders than convolutional encoder to give high reduction in BER. The effect of other channel type will also studied in this system as a future work scope.

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