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BER Analysis of a Novel LTE Technique Adopting SUI Modeling for Conventional and Wavelet Based OFDM

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Abstract: Orthogonal Frequency Division Multiplexing (OFDM) and Multiple Input and Multiple Output (MIMO) are two main techniques employed in 4th Generation Long Term Evolution (LTE). In OFDM multiple carriers are used and it provides higher level of spectral efficiency as compared to Frequency Division Multiplexing (FDM). In OFDM because of loss of orthogonality between the subcarriers there is inter carrier interference (ICI) and intersymbol interference (ISI) and to overcome this problem use of cyclic prefixing (CP) is required, which uses 20% of available bandwidth. Wavelet based OFDM provides good orthogonality and with its use Bit Error Rate (BER) is improved. Wavelet based system does not require cyclic prefix, so spectrum efficiency is increased. It is proposed to use wavelet based OFDM at the place of Discrete Fourier Transform (DFT) based OFDM in LTE. We have compared the BER performance of wavelets and DFT based OFDM which uses Stanford University Interim (SUI) channel is replace in place of AWGN channel.

KEYWORDS: *LTE; OFDM; DFT; Wavelet; BER.*

1. INTRODUCTION

A set of requirements are specified for 4th generation of cellular systems by International Telecommunication Union Radio communication Sector (ITU-R). The requirement of data rate was specified in International Mobile Telecommunications Advanced project (IMT-Advanced). 3rd Generation Partnership Project (3GPP) was established in 1998 [1].3GPP started working on the LTE project to define the Radio Access Network (RAN) and core network [1]. 3GPP's candidate for 4G was LTE- Advanced. OFDM is one of the main techniques employed in LTE to enhance the data rate. Spectrum efficiency and flexible utilization of spectrum is highly required today for different wireless communication related applications. In multicarrier communication the main idea is to divide the data into several streams and using them to modulate different carriers. The two main advantages of multicarrier communication are, first one is there is no requirement of signal enhancement for noise which is required in single carrier because of the equalizers and second is because of long symbol duration reduced effect of fading [2]. In OFDM subcarriers used are orthogonal to each other. Orthogonality causes the subcarriers to overlap in frequency domain, so the bandwidth efficiency is obtained without any ICI [3]. Wavelet transform is used to analyze signals by the coefficients of wavelets in both time and frequency domain. Basis functions of transform are localized in both time and frequency domain. Here elementary waveforms are not sine and cosine waveforms like in Fourier transform. ISI and ICI are generally caused by loss of orthogonality between the carriers caused by multipath propagation of the signal in Discrete Fourier Transform (DFT) based OFDM. ISI is between successive symbols of same sub-carrier and ICI is among different signals at different subcarriers. Both are avoided by use of cyclic prefixing which causes power loss and bandwidth inefficiency in DFT based OFDM [3]. There are some recent works on wavelet based OFDM systems. In [4], author compares performance of wavelet based OFDM system in different channel condition using haar wavelets with DFT based OFDM system. In [5], author have compared performance of DFT based OFDM and wavelet based OFDM by using BER as performance parameter and Rayleigh fading channel. In [6], author have compared BER performance and mean square error (MSE) performance of conventional DFT based OFDM system with wavelet based OFDM system using different types of wavelets in Rayleigh fading channel. In [7], author described wavelet packet modulation for wireless communication, and concluded it as an alternative to conventional OFDM system. In [8], author gives a review on wavelet for digital wireless communication and described wavelet for single carrier modulation and multicarrier modulation as well. In [9], author presented wavelet packet modulation for OFDM and presented the performance comparison of both the techniques. In [10], author have presented a comparison on different multicarrier modulations and used ISI/ICI for performance measurement. In [11], wavelet modulation has been proposed for multicarrier communication. In [12], author proposed multimode transmission using wavelet modulation and OFDM. In this paper we have compared the performance of wavelets based OFDM system with performance of conventional OFDM system for different LTE modulation techniques. For wavelet based system we have used daubechies2 and haar wavelets. Stanford University Interim (SUI) channel is used for transmission in place of Additive White Gaussian Noise (AWGN) channel. The paper is organized as first of all the conventional OFDM system is discussed in section 2 and wavelet based OFDM system in section 3 and wavelet based OFDM design used Additive White Gaussian Noise (AWGN) channel is presented in section 4 and then the performance evaluation and the results obtained from the simulation are discussed in section 5. The proposed wavelet based OFDM design used Stanford University Interim (SUI) channel is presented in section 6 Conclusion is summarized in section 7.

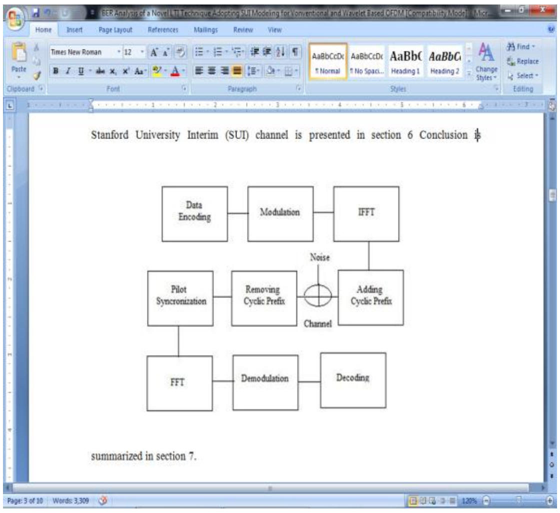

Fig-1: DFT based OFDM transmitter and receiver.

II.CONVENTIONAL OFDM SYSTEM

For conventional OFDM system sinusoids of DFT form an orthogonal basis function set. In DFT the transform correlates its input signal with each of sinusoidal basis function [13], here orthogonal basis functions are the subcarriers used in OFDM. At the receiver the signals are combined to obtain the information transmitted. Practically, Fast Fourier Transform (FFT) and Inverse Fast Fourier Transform (IFFT) are used for the implementation of the OFDM system because less number of computations required in FFT and IFFT. Multiple replicas of the signal are received at the receiver end because of the time dispersive nature of the channel, so frequency selective fading results and to reduce this interference guard interval is used, which is called cyclic prefix [14]. Cyclic prefix is copy of the some fraction of symbol end. As long as the channel delay spread remains within the limit of the cyclic prefix there would not be any loss in orthogonality. For LTE, in the downlink data of different users is multiplexed in frequency domain and access technique is called Orthogonal Frequency Division Multiple Access (OFDMA) [15]. In the uplink of the LTE access technique used is Single Carrier-Frequency Division Multiple Access (SC-FDMA). High Peak

Average Power Ratio (PAPR) occurs due to random constructive addition of subcarriers and results in spectrum spreading of signal leading to adjacent channel interference. So power linearization techniques and compression point amplifier need to be used to overcome this problem. These methods can be implemented at base station (BS), but are expensive to implement at user equipment (UE). Hence LTE uses SC-FDMA with cyclic prefix on uplink, which will result in reduction of PAPR because of the presence of single carrier. Due to single carrier modulation effect of ISI will be high in uplink and to overcome from its effect low complexity equalizer will be required but SC-FDMA is not sensitive to frequency offset and Doppler shift [14].

III.WAVELET BASED OFDM SYSTEM

In previous works use of Discrete Fourier Transform was proposed for the implementation of OFDM [2]. Wavelet transform show the potential to replace the DFT in OFDM. Wavelet transform is a tool for analysis of the signal in time and frequency domain jointly. It is a multi resolution analysis mechanism where input signal is decomposed into different frequency components for the analysis with particular resolution matching to scale [8]. Using any particular type of wavelet filter the system can be designed according to the need and also the multi resolution signal can be generated by the use of wavelets. By the use of varying wavelet filter, one can design waveforms with selectable time/frequency partitioning for multi user application [6]. Wavelets possess better orthogonality and have localization both in time and frequency domain [16]. Because of good orthogonality wavelets are capable of reducing the power of the ISI and ICI, which results from loss of orthogonality. To reduce ISI and ICI in conventional OFDM system use of cyclic prefix is there, which uses 20% of available bandwidth, so results in bandwidth inefficiency but this cyclic prefix is not required in wavelet based OFDM system. Complexity can also be reduced by using wavelet transform as compared with the Fourier transform because in wavelet complexity is O[N] as compared with complexity of Fourier transform of $O[N \log_2 N]$ [17]. Wavelet based OFDM is simple and the DFT based OFDM is complex. Wavelet based OFDM is flexible as well and because better orthogonality is provided by it, there is no any need of cyclic prefixing in wavelet based OFDM, which is required in DFT based OFDM to maintain orthogonality so wavelet based system is more bandwidth efficient as compared with the DFT based OFDM. In discrete wavelet transform (DWT), input signal presented will pass through several different filters and will be decomposed into low pass and high pass bands through the filters. During decomposition the high pass filter will remove the frequencies below half of the highest frequency and low pass filter will remove frequencies that are above half of the highest frequency. The decomposition halves the time resolution because half of the samples are used to characterize the signal similarly frequency resolution will be doubled and this decomposition process will be repeated again for obtaining the wavelet coefficients of required level. Two types of coefficients are obtained through processing, first ones are called detailed coefficients obtained through high pass filter and second ones are called coarse approximations obtained through low pass filter related with scaling process. After passing the data through filters the decimation process will be performed. The whole procedure will continue until the required level is obtained.

This decomposition can be given as [8]:

$$y_{high}[k]=\sum_n x[n]\, g[2k-n]$$

$$y_{low}[k]=\sum_n x[n]\, h[2k-n] \qquad (1)$$

Where x[n] is the original signal, g[n] is impulse response of half-band high pass filter and h[n] is impulse response of half-band low pass filter. $y_{high}[k]$ and $y_{low}[k]$ are obtained after filtering and decimation by a factor of 2. In inverse discrete wavelet transform (IDWT), the reverse process of decomposition is performed, so here firstly up-sampling is done then the signal is passed through the filters. The data obtained after filtering is combined to obtain reconstructed data. Number of levels during reconstruction will be same as that of the decomposition.

IV .WAVELET BASED OFDM DESIGN USING (AWGN) CHANNEL.

As shown in figure 2, in this model we are using IDWT and DWT at the place of IDFT and DFT. AWGN channel is used for transmission and cyclic prefixing is not used. Here first of all conventional encoding is done followed by interleaving then data is converted to decimal form and modulation is done next. After modulation the pilot insertion and sub carrier mapping is done then comes the IDWT of the data, which provides the orthogonality to the subcarriers. IDWT will convert time domain signal to the frequency domain. After passing through the channel on the signal DWT will be performed and then pilot synchronization where the inserted pilots at the transmitter are removed then the demodulation is done. Demodulated data is converted to binary form and the de-interleaved and decoded to obtain the original data transmitted.

V.BER PERFORMANCE VALUATION

By using MATLAB performance characteristic of DFT based OFDM and wavelet based OFDM are obtained for

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different modulations that are used for the LTE, as shown in figures 3-5. Modulations that could be used for LTE are QPSK, 16 QAM and 64 QAM (Uplink and downlink). QPSK does not carry data at very high speed. When signal to noise ratio is of good quality then only higher modulation techniques can be used. Lower forms of modulation (QPSK) does not require high signal to noise ratio.

For the purpose of simulation, signal to noise ratio (SNR) of different values are introduced through AWGN channel. Data of 9600 bits is sent in the form of 100 symbols, so one symbol is of 96 bits. Averaging for a particular value of SNR for all the symbols is done and BER is obtained and same process is repeated for all the values of SNR and final BERs are obtained.

Firstly the performance of DFT based OFDM and wavelet based OFDM are obtained for different modulation techniques. Different wavelet types daubechies2 and haar is used in wavelet based OFDM for QPSK, 16-QAM, 64-QAM. It is clear from the fig. 3, fig. 4 and fig. 5 that the BER performance of wavelet based OFDM is better than the DFT based OFDM. Fig. 3 indicates that db2 performs better when QPSK is used. Fig. 4 shows that when 16-QAM is used db2 and haar have similar performance but far better than DFT. Fig. 5, where 64-QAM is used haar and db2 performs better than DFT.

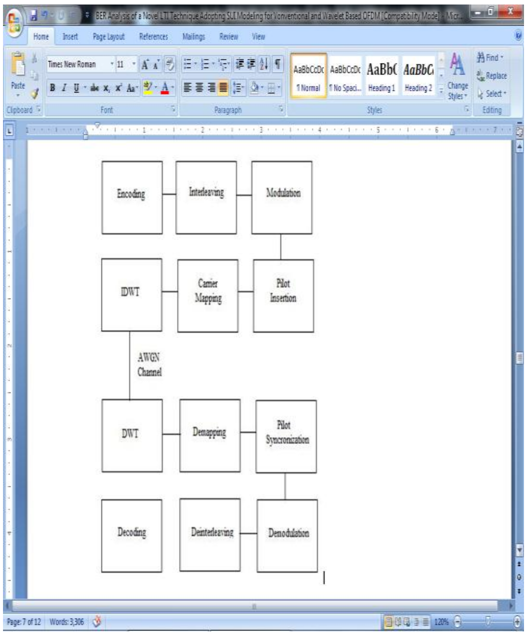

Fig-2:Wavelet based proposed OFDM system design.Using AWGN channel

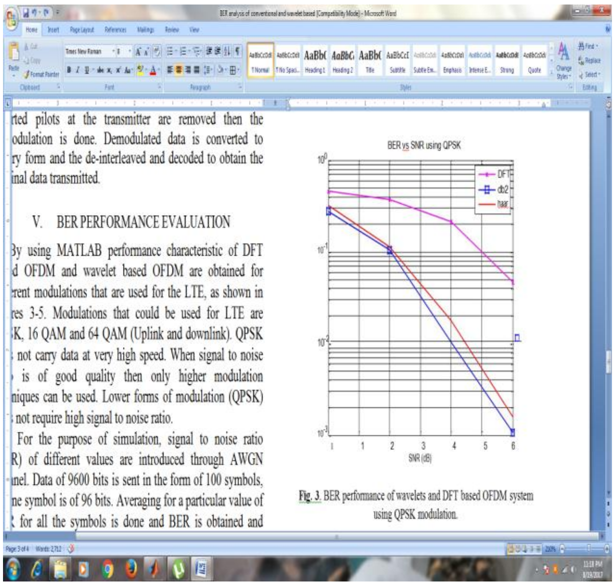

Fig3:BER performance of wavelets and DFT based OFDM system using Qpsk modulation

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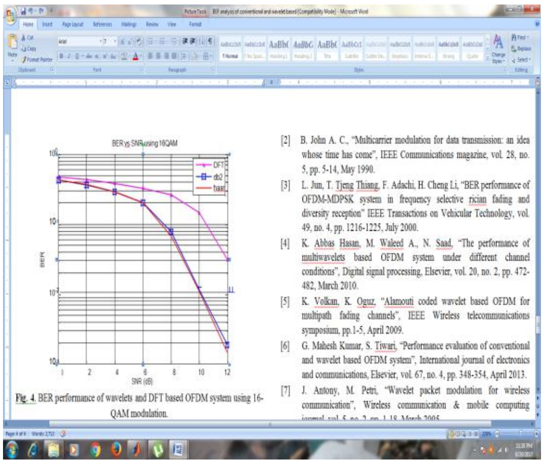

Fig4:BER performance of wavelets and DFT based OFDM system using 16-QAM modulation

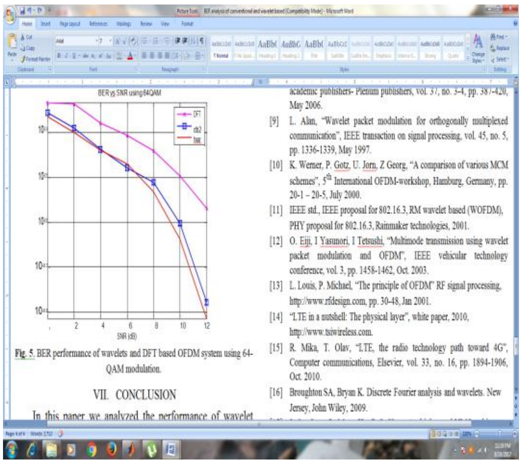

Fig5:BER performance of wavelets and DFT based OFDM system using 64-QAM modulation

IV. PROPOSED WAVELET BASED OFDM DESIGN USING SUI CHANNEL

SUI channel is used for transmission and cyclic prefixing is not used. This Stanford University Interim (SUI) Channel Models is a set of 6 channel models representing three terrain types and a variety of Doppler spreads, delay spread and line-of-sight/non-line-of-site conditions that are typical of the continental US as follows[Erceg2001]. The terrain type A, B, C is same as those defined earlier for Erceg model. The multipath fading is modeled as a tapped delay line with 3 taps with non-uniform delays. The gain associated with each tap is characterized by a Rician Distribution and the maximum Doppler frequency. The figure 6 shows the Generic structure of SUI Channel models, in that Input Mixing Matrix part models correlation between input signals if multiple transmitting antennas are used. The Tapped Delay Line Matrix models the multipath fading of the channel. The multipath fading is modeled as a tapped delay line with 3 taps with non-uniform delays. The gain associated with each tap is characterized by a distribution (Rician with a K-factor > 0, or Raleigh with K-factor = 0) and the maximum Doppler frequency and the Output Mixing Matrix models the correlation between output signals if multiple receiving antennas are used. Using the above general structure of the SUI Channel and assuming the following scenario, six SUI channels are constructed which are representative of the real channels.As shown in figure 7, in this proposed model we are using IDWT and DWT at the place of IDFT and DFT. Here first of all conventional encoding is done followed by interleaving then data is converted to decimal form and modulation is done next. After modulation the pilot insertion and sub carrier mapping is done

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then comes the IDWT of the data, which provides the orthogonality to the subcarriers. IDWT will convert time domain signal to the frequency domain. After passing through the channel on the signal DWT will be performed and then pilot synchronization where the inserted pilots at the transmitter are removed then the demodulation is done. Demodulated data is converted to binary form and the de-interleaved and decoded to obtain the original data transmitted.

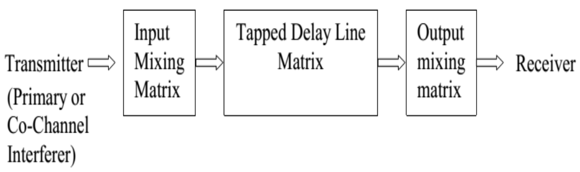

Figure 6: Generic structure of SUI Channel models

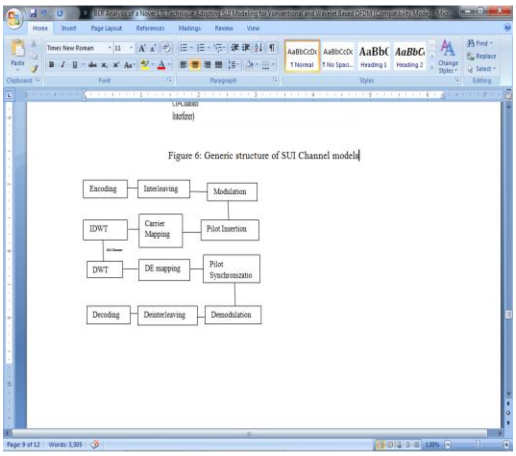

Figure 7: Wavelet based proposed OFDM system design Using SUI channel

V.BER PERFORMANCE EVALUATION

By using MATLAB performance characteristic of DFT based OFDM and wavelet based OFDM are obtained for different modulations that are used for the LTE, as shown in figures 8-10. Modulations that could be used for LTE are QPSK, 16 QAM and 64 QAM (Uplink and downlink). QPSK does not carry data at very high speed. When signal to noise ratio is of good quality then only higher modulation techniques can be used. Lower forms of modulation (QPSK) does not require high signal to noise ratio. For the purpose of simulation, signal to noise ratio (SNR) of different values are introduced through AWGN channel. Data of 9600 bits is sent in the form of 100 symbols, so one symbol is of 96 bits. Averaging for a particular value of SNR for all the symbols is done and BER is obtained and same process is repeated for all the values of SNR and final BERs are obtained. Firstly the performance of DFT based OFDM and wavelet based OFDM are obtained for different modulation techniques. Different wavelet types daubechies2 and haar is used in wavelet based OFDM for QPSK, 16-QAM, 64-QAM. It is clear from the fig. 8, fig. 9 and fig. 10 that the BER performance of wavelet based OFDM is better than the DFT based OFDM. Fig. 8 indicates that db2 performs better when QPSK is used. Fig. 9 shows that when 16-QAM is used db2 and haar have similar performance but far better than DFT. Fig. 10, where 64-QAM is used haar and db2 performs better than DFT.

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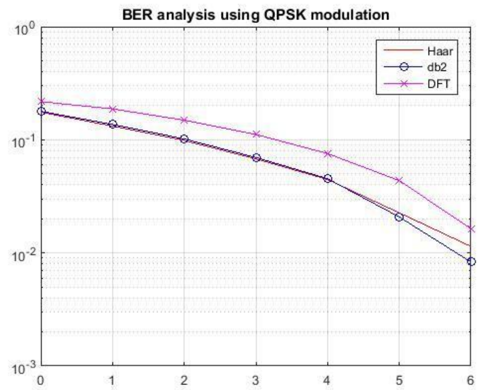

Figure 8 BER analysis using qpsk

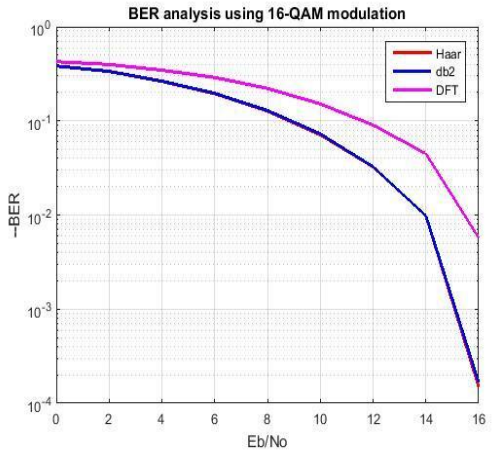

Figure 9:BER analysis using 16-QAM

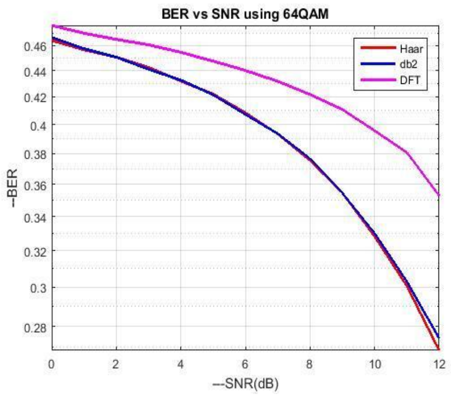

Figure 10: BER analysis using 64-QAM

VI.CONCLUSION

In this paper we analyzed the performance of wavelet based OFDM system and compared it with the performance of DFT based OFDM system. From the performance curve we have observed that the BER curves obtained from wavelet based OFDM are better than that of DFT based OFDM. We used three modulation techniques for implementation that are QPSK, 16 QAM and 64 QAM, which are used in LTE. In wavelet based OFDM different types of filters can be used with the help of different wavelets available. We have used daubechies2 and haar wavelets, both provide their best performances at different intervals of SNR.

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