BER Scrutinisation of Conventional and Wavelet Reckoned OFDM in LTE Considering Various Amending Strategies

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***Abstract*—Orthogonal frequency division Multiplexing (OFDM) & MIMO are the important strategies in fourth technology long term development. Compared in accordance, with Frequency Division Multiplexing (FDM) lifetime, more than one carrier is used because it affords greater tribune regarding spectral efficiency. In OFDM systems, due to loss of orthogonality between subcarriers, there is ICI (Inter Carrier Interference) and IS I(Inter Symbol Interference). To solve these problems, cyclic prefixing (CP) is required. But here the disadvantage is that, CP makes use of 20% of the available bandwidth. So a solution to this is wavelet based OFDM. A discrete Wavelet transform (DWT) based OFDM may be suggested to succeed in providing good orthogonality. CP is not required in wavelet based OFDM. In this paper, the performance of wavelet based OFDM system is studied and compared with the performance of DFT based OFDM system. With the aid of wavelet based OFDM better orthogonality is obtained. BER is also boosted. BER versus SNR is plotted for QPSK, 16-QAM and 64-QAM.**

Keywords*— *LTE; OFDM; DFT; Wavelet; BER.

I.INTRODUCTION

Orthogonal Frequency Division Multiplexing or OFDM is a modulation format that is being used for many of the latest wireless and telecommunications standards. OFDM has been adopted in the Wi-Fi arena where the standards like 802.11a, 802.11n, 802.11ac and more. It has also been chosen for the cellular telecommunications standard LTE / LTE-A, and in addition to this it has been adopted by other standards such as WiMAX and many more. Orthogonal frequency division multiplexing has also been adopted for a number of broadcast standards from DAB Digital Radio to the Digital Video Broadcast standards, DVB. It has also been adopted for other broadcast systems as well including Digital Radio Mondiale used for the long medium and short wave bands.

Although OFDM, orthogonal frequency division multiplexing is more complicated than earlier forms of signal format, it provides some distinct advantages in terms of data transmission, especially where high data rates are needed along with relatively wide bandwidths. 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. 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.

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.

The rest of the paper is organized as follows. In section II literature survey is presented. In section III, introduces the conventional OFDM system. In section IV, wavelet based OFDM system is presented. In section V, proposed methodology is explained and section VI concludes the paper.

II. LITERATURE SURVEY

The evolution to 4G cellular systems: LTE-advanced [1], provides an in-depth view on the technologies being considered for Long Term Evolution-Advanced (LTE-Advanced). First, the evolution from third generation (3G) to fourth generation (4G) is described in terms of performance requirements and main characteristics. The new network architecture developed by the Third Generation Partnership Project (3GPP), which supports the integration of current and future radio access technologies, is examined. Then, the main technologies for LTE-Advanced are known, together with possible improvements, their associated challenges, and some approaches that have been considered to tackle those challenges.

Multicarrier modulation for data transmission [2] deals with the general technique of parallel transmission on many carriers, called multicarrier modulation (MCM).The performance that can be achieved on an undistorted channel and algorithms. Ways of dealing with channel impairments and of improving the performance through coding and implementation methods are considered. Duplex operation of MCM and the possible use of this on the general switched telephone network are examined.

The performance of multi-wavelets based OFDM system under different channel conditions [3] deals with the reliability of orthogonal frequency division multiplexing (OFDM) because of the time-varying nature of the channel. This causes inter-carrier interference (ICI) and leads to an increase in inaccuracies in channel tracking. This can effectively be avoided at the cost of power loss and bandwidth expansion by inserting a cyclic prefix guard interval before each block of parallel data symbols. However, this guard interval decreases the spectral efficiency of the OFDM system as the corresponding amount. Recently, it was found that based on Haar-orthonormal wavelets, discrete wavelet-based OFDM (DWT-OFDM) is capable of reducing the inter symbol interference (ISI) and ICI, which are caused by the loss in orthogonality between the carriers. DWT-OFDM can also support much higher spectrum efficiency than discrete Fourier-based OFDM (DFT-OFDM). DFT-OFDM is replaced by Multiwavelets OFDM (DMWT-OFDM) in order to further reduce the level of interference and increase spectral efficiency. It is found that proposed Multiwavelet design achieves much lower bit error rates, increases signal to noise power ratio (SNR), and can be used as an alternative to the conventional OFDM. The proposed OFDM system was modeled tested, and its performance was found under different channel conditions.

In Alamouti coded wavelet based OFDM for multipath fading channels [4], the performance of conventional DFT based OFDM and wavelet based OFDM (WOFDM) with and without Alamouti coding over multipath Rayleigh fading channels with exponential power delay profile has been examined. Results show that WOFDM has slightly better bit error rate performance than the conventional OFDM with and without Alamouti code. Besides the performance improvement of WOFDM as compared to conventional OFDM, increases by the use of Alamouti coding. In addition to having better performance, WOFDM might be an alternative to conventional OFDM since it has better bandwidth efficiency.

To performance evaluation of conventional and wavelet based OFDM system [5], the bit error rate (BER) performance and power spectral density of Discrete Fourier Transform (DFT) based OFDM system with wavelet based OFDM system are being compared. Also the performance of Least Square (LS) and Linear Minimum Mean Square Error (LMMSE) channel estimation technique for wavelet based OFDM system as well as DFT based OFDM system are compared.

III.CONVENTIONAL DFT BASED 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, 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. Power linearization techniques and compression point amplifier need to overcome time dispersive nature of the channel. These methods can be implemented at base station (BS), but are expensive to implement at user equipment (UE).

IV. WAVELET BASED OFDM SYSTEM

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.

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. Wavelets possess better orthogonality and have localization both in time and frequency domain. 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 log2 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,

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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

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

$$y_{low}[k]=\sum_n x[n]h[2k-n]$$

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.

V.PROPOSED METHODOLOGY

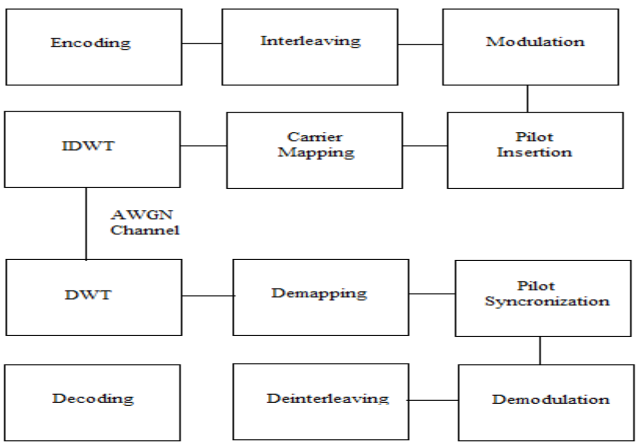

Figure 1:block diagram of wavelet based OFDM system.

To overcome the implementations limitations of the conventional DFT based OFDM, a Discrete Wavelet Transform (DWT) based OFDM is proposed. 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.

Wavelets possess better orthogonality and have localization both in time and frequency domain. 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 log2 N].

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.

VI. RESULTS AND PERFORMANCE EVALUATION

BER performance evaluation and Shannon channel capacity

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 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.

An application of the channel capacity concept to an additive white Gaussian noise (AWGN) channel with B Hz bandwidth and signal-to-noise ratio S/N is the Shannon–Hartley theorem:

$$C = B\ log2(1 + \frac{S}{N})$$

C is measured in bits per second if the logarithm is taken in base 2, or nats per second if the natural logarithm is used, assuming B is in hertz; the signal and noise powers S and N are measured in watts or volts2, so the signal-to-noise ratio here is expressed as a power ratio, not in decibels (dB); since figures are often cited in dB, a conversion may be needed. For example, 30 dB is a power ratio of $10^{\frac{30}{10}} = 10^3 = 1000$

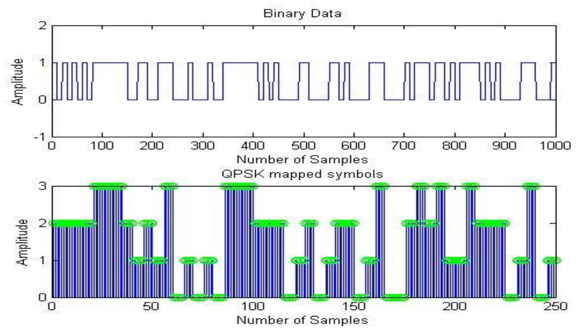

Figure 2: Binary Input Data to QPSK symbol Mapping.

Figure 2 shows the random binary input data which is converted to QPSK symbol mapping.

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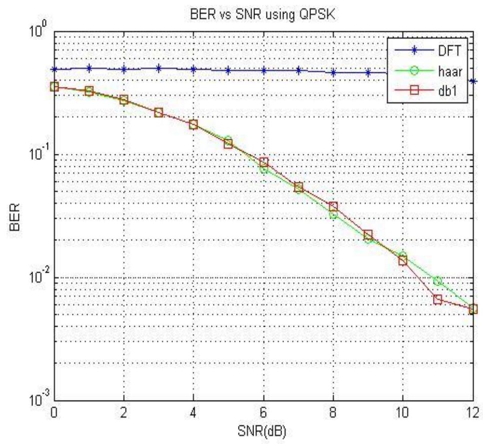

Figure 3: BER versus SNR using QPSK

Figure 3 indicates that Daubechies performs better when QPSK is used.

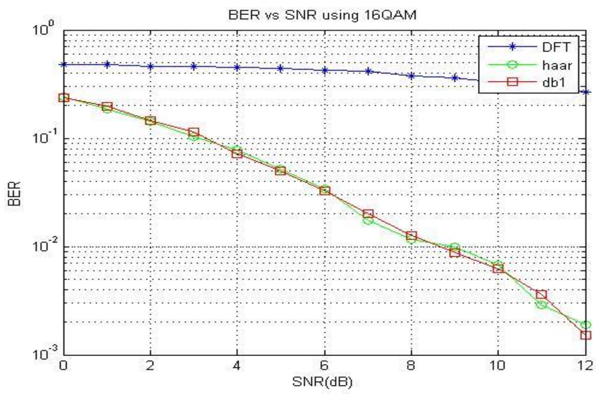

Figure 4:BER versus SNR using 16 QAM

Figure 4 shows that when 16-QAM is used Daubechies and haar have similar performance but far better than DFT.

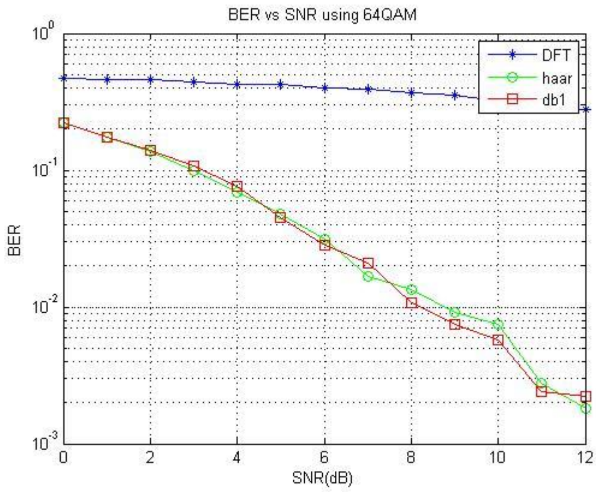

figure 5:BER versus SNR using 64 QAM

In figure 5, where 64-QAM is used, haar and Daubechies performs better than DFT. With the help of BER versus SNR plot, the comparison of how the two wavelets (Daubecies and haar) perform can be done in the 3 methodologies (QPSK, 16-QAM & 64-QAM) and is tabulated as shown below:

Table 1:comparison of BER values for DFT, Haar and Daubechies using QPSK

	BER values using QPSK						
SNR	0	2	4	6	8	10	12
BER for DFT	$10^{0.5}$	$10^{0.5}$	$10^{0.5}$	$10^{0.5}$	$10^{0.5}$	$10^{0.5}$	$10^{0.5}$
BER for Haar	$10^{0.65}$	$10^{0.71}$	$10^{0.82}$	$10^{-1.25}$	$10^{-1.69}$	$10^{-1.9}$	$10^{-2.4}$
BER for Daubechies	$10^{0.65}$	$10^{0.71}$	$10^{0.82}$	$10^{-1.2}$	$10^{-1.6}$	$10^{-1.95}$	$10^{-2.4}$

Table 2: comparison of BER values for DFT, haar and daubechies wavelets using 16 QAM.

	BER values using 16 QAM						
SNR	0	2	4	6	8	10	12
BER for DFT	$10^{0.5}$	$10^{0.52}$	$10^{0.54}$	$10^{0.6}$	$10^{0.62}$	$10^{0.7}$	$10^{0.72}$
BER for Haar	$10^{0.75}$	$10^{0.95}$	$10^{-1.2}$	$10^{-1.67}$	$10^{-1.98}$	$10^{-2.3}$	$10^{-2.8}$
BER for Daubechies	$10^{0.75}$	$10^{0.95}$	$10^{-1.3}$	$10^{-1.69}$	$10^{-1.9}$	$10^{-2.4}$	$10^{-2.85}$

Table 3: comparison of DFT , Haar and Daubechies using 64 QAM

	BER values using 64 QAM						
SNR	0	2	4	6	8	10	12
BER using DFT	$10^{0.5}$	$10^{0.55}$	$10^{0.59}$	$10^{0.6}$	$10^{0.63}$	$10^{0.7}$	$10^{0.72}$
BER using Haar	$10^{0.88}$	$10^{0.95}$	$10^{-1.3}$	$10^{-1.8}$	$10^{-1.97}$	$10^{-2.25}$	$10^{-2.91}$
BER using Daubechies	$10^{0.88}$	$10^{0.95}$	$10^{-1.2}$	$10^{-1.81}$	$10^{-1.99}$	$10^{-2.45}$	$10^{-2.99}$

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REFERENCES

[1] A. Ian F., G. David M., R. Elias Chavarria, “The evolution to 4G cellular systems: LTE-advanced”, Physical communication, Elsevier, vol. 3, no. 4, pp. 217-244, Dec. 2010.

[2] B. John A. C., “Multicarrier modulation for data transmission: an idea whose time has come”, IEEE Communications magazine, vol. 28, no. 5, pp. 5-14, May 1990.

[3] L. Jun, T. Tjeng Thiang, F. Adachi, H. Cheng Li, “BER performance of OFDM-MDPSK system in frequency selective rician fading and diversity reception” IEEE Transactions on Vehicular Technology, vol. 49, no. 4, pp. 1216-1225, July 2000.

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Vol. 6 Issue 09, September - 2017

[4] K. Abbas Hasan, M. Waleed A., N. Saad, "The performance of multiwavelets based OFDM system under different channel conditions", Digital signal processing, Elsevier, vol. 20, no. 2, pp. 472- 482, March 2010.
[5] K. Volkan, K. Oguz, "Alamouti coded wavelet based OFDM for multipath fading channels", IEEE Wireless telecommunications symposium, pp.1-5, April 2009.
[6] G. Mahesh Kumar, S. Tiwari, "Performance evaluation of conventional and wavelet based OFDM system", International journal of electronics and communications, Elsevier, vol. 67, no. 4, pp. 348-354, April 2013.