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A Novel approach for efficient bandwidth utilization by employing different multicarrier modulation and MIMO

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Abstract—The main 4th generation long term evolution (LTE) techniques employed are Multicarrier Modulation method and Multiple Input Multiple Output (MIMO). Multiple carriers is able to deliver elevated level of spectral efficiency as compared to other multiplexing techniques by using Orthogonal frequency division multiplexing (OFDM) . In OFDM if the timing offset is outrageous then intercarrier interference (ICI) and intersymbol interference (ISI) are evident which results in fragmentary loss of orthogonality. To solve this limitation cyclic prefixing (CP) is used, which requires an extra 20% of available bandwidth. Using various modulation techniques like 16-QAM and 64-QAM we can improve the bandwidth utilization but the best technique employed is wavelet based OFDM where we get good orthogonality and also improves Bit Error Rate (BER). In Wavelet based system cyclic prefix is not required, thus the bandwidth utilization is increased. In this paper we propose to use wavelet based OFDM inspite of OFDM based on the Discrete Fourier Transform (DFT) in LTE. Thus with the use of MIMO the performance of the system improves drastically. We have collated the BER performance of DFT and wavelets based on the OFDM in Single Input and Single Output (SISO) and MIMO systems by which efficient bandwidth utilization can be incurred.

Keywords— LTE; Bandwidth utilization; OFDM; MIMO; DFT; Wavelet; BER; multicarrier modulation.

INTRODUCTION

A set of requirements are to be specified in the 4th generation of wireless cellular systems by International Telecommunication Union Radio communication Sector (ITU-R). To define the Radio Access Network (RAN) and core network, the LTE project was introduced by 3GPP [1]. The data rate required was specified in International Mobile Telecommunications Advanced project (IMT-Advanced). The, 3rd Generation Partnership Project (3GPP) was established in 1998. MIMO (Multiple-Input Multiple-Output) techniques boost the data rates [1]. 3GPP then introduced LTE-Advanced for 4G. One of the most important techniques employed in LTE to enhance the data rate is OFDM where, adaptable utilization of bandwidth and bandwidth efficiency is highly recommended for different wireless communication related applications. The concept used in multicarrier communication is to divide the information into multiple streams and by using them we modulate different carriers. The two prime positives of multicarrier communication are, first one is because of long symbol duration reduced effect of fading and second is there is no requirement of signal enhancement for noise which is required in single carrier because of the equalizers [2]. In OFDM subcarriers used are having the phase difference of 90 degree to each other which is known as orthogonal property. This orthogonality causes overlapping of the subcarriers in frequency domain, thus the bandwidth efficiency is obtained without any ICI [3]. By the use wavelet coefficients wavelet transform is used to analyze the signals in both frequency and time domain. Here elementary waveforms are not cosine and sine waveforms like in Fourier transform. Basis functions of transform are localized in both frequency and time domain. The main reason for ICI and ISI in OFDM based on Discrete Fourier Transform (DFT) is theloss of orthogonality between the carriers caused by multipath propagation of the signal is. Among different signals at different subcarriers is ICI and between successive symbols of same sub-carrier is ISI. Both are negligibaly eliminated by the use of cyclic prefixing which causes the bandwidth inefficiency and power loss in OFDM based on Discrete Fourier Transform (DFT) [3]. There are few recent works on wavelet based OFDM systems. Wavelet transform shows the potential to replace DFT in OFDM. Wavelet transform is the tool to analyse 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 the particular resolution matching to scale [8]. The channel estimation is to process the characterizing, effect of the transmission channel on the input signal. Channel estimation attempts to track the channel response. A dynamic estimation of channel is required before the demodulation of OFDM signals since the radio channel is frequency selective and time-variant for wideband mobile communication systems [18]. Given a wireless system employingNt TX (transmit) antennas and Nr RX (receive) antennas, the maximum data rate at which error-free transmission over a fading channel is theoretically possible which is proportional to the minimum of Nt and Nr (provided that the NtNr transmission paths between the TX and RX antennas are statistically in-dependent). Thus the huge throughput gains can be achieved by applying Nt× Nr MIMO systems compared to conventional 1 × 1 systems that uses single antenna at both the ends of the link with the same power requirment and bandwidth [19].

DFT OFDM SYSTEM

Sinusoids of DFT form an orthogonal basis function set for this OFDM system. In DFT the transform compares with each of sinusoidal basis function with the input signal [13], subcarriers of the OFDM are here the orthogonal basis functions. At receiver, the signals are combined to obtain the information transmitted. To implement the DFT based OFDM, in practice we use Fast Fourier transform (FFT) and Inverse Fast Fourier Transform (IFFT) because very less number of computations are required in FFT and IFFT. Due to the time dispersive nature of the channel, multiple replicas of the signal are received at the receiver end and hence frequency selective fading results and to reduce this kind of interference guard interval is used, which is known as cyclic prefix [14]. Cyclic prefix is usually the last 25% of the original symbol. The LTE has different downlink and uplink access technologies (OFDMA, SC-FDMA), along which it options and exceptions for each mode and access technology.The amplitude of OFDM signal has a very large dynamic range. Therefore, RF power amplifiers are required which possess high peak to average power ratio (PAPR). OFDM systems are more sensitive to the carrier frequency offset and drift as compared to the single carrier systems [14].

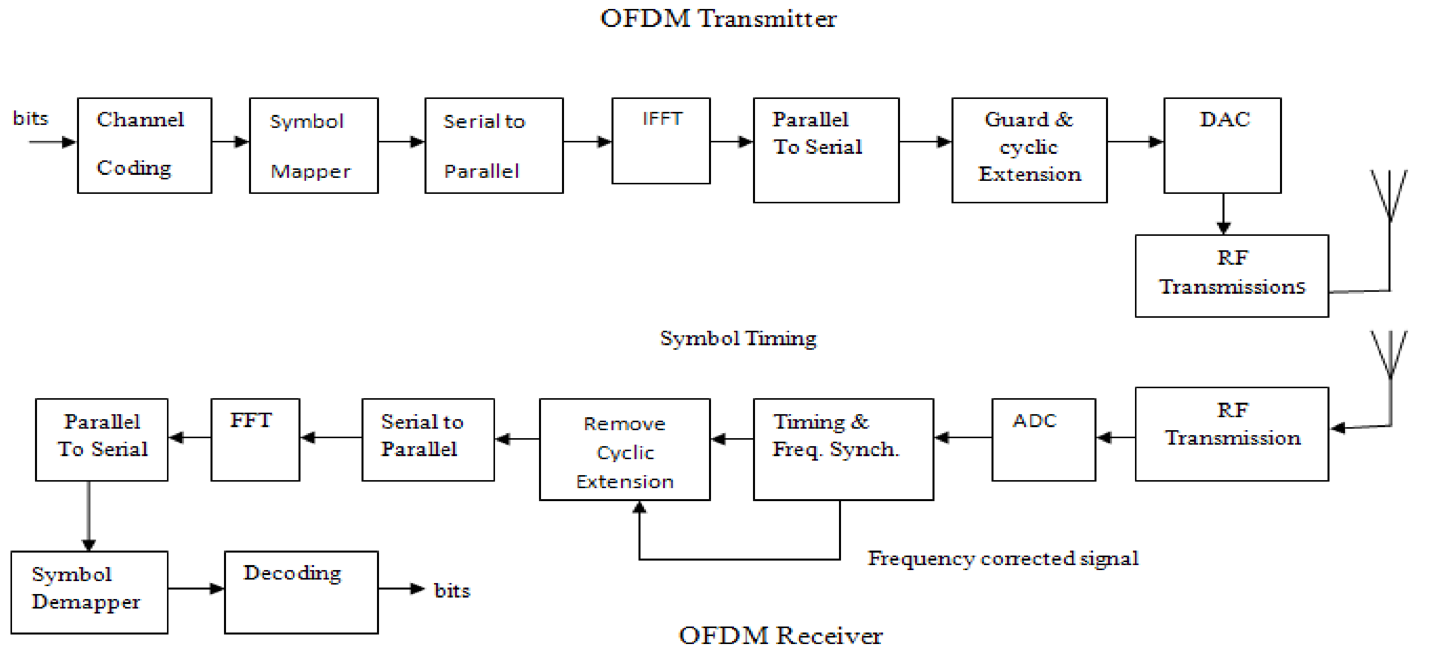

Fig. 1.DFT based OFDM transmitter and receiver.

WAVELET BASED OFDM SYSTEM

Wavelet transform shows the potential to replace DFT in OFDM. Wavelet transform is the tool for analysis of signal in time and frequency domain jointly. It is known as a multi resolution analysis mechanism where input signal is decomposed into different frequency components for the analysis with particular resolution matching with the scale [8]. By varying the wavelet filter, one can design waveforms with selectable time/frequency partitioning for the multi user application. The multi resolution signal can be generated by using the wavelets and also by using any particular type of wavelet filter thus the system can be designed according to the need and requirment. [6]. Wavelets possess better orthogonality and have localization both in the time and frequency domain [16]. Cyclic prefix is not required in wavelet based OFDM system so that it results in bandwidth inefficiency. Complexity can be reduced by the use of 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]. There is no need of any cyclic prefixing in wavelet based OFDM, which is required in DFT based OFDM to maintain theorthogonality so wavelet based system has more bandwidth efficient when compared with the DFT based OFDM. In discrete wavelet transform (DWT), input signal presented can pass through several different filters and will be decomposed into low pass and high pass bands through the filters. 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 the 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.

The two filtering and sub-sampling operations can be expressed by the expressions given [8]:

$$Z_{high}[k] = \Sigma_n u[n]\, g\, [2k-n]$$
$$Z_{low}[k] = \Sigma_n u[n]\, h\, [2k-n] \qquad (1)$$

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. Zhigh[k] and Zlow[k] can obtained after filtering and decimation by the factor of 2. In inverse discrete wavelet transform (IDWT), the reverse process of decomposition can be performed.

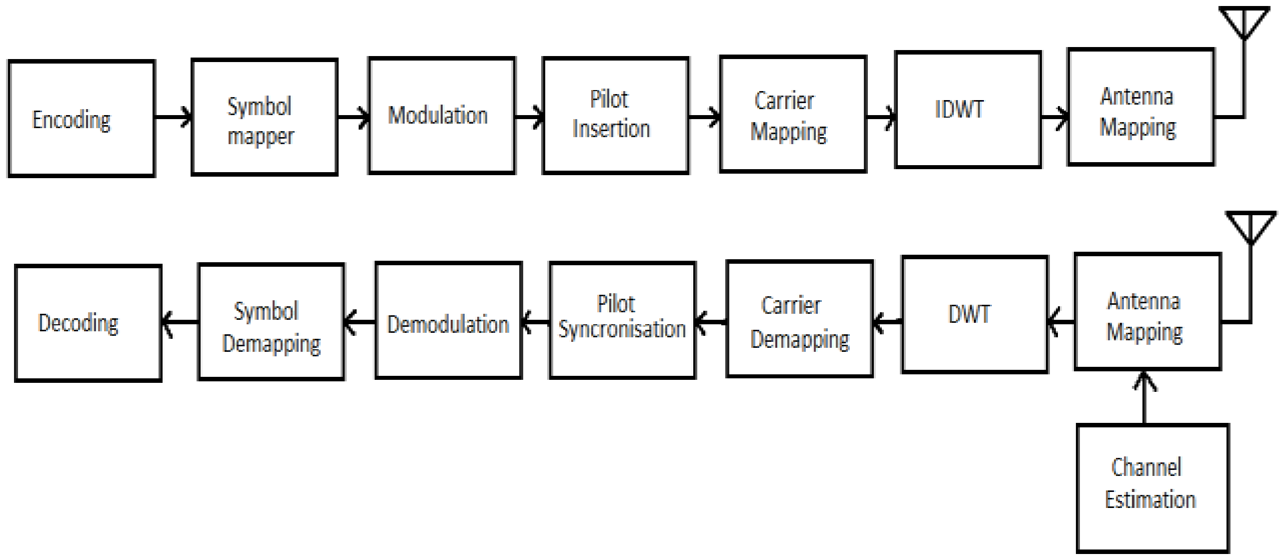

Fig. 2. Wavelet based proposed OFDM system design.

PROPOSED WAVELET BASED OFDM with MIMO DESIGN

As shown in the above figure 2, in the proposed model instead of IDFT and DFT we have applied IDWT and DWT. Without using cyclic prefixing and AWGN channel is used for transmission. Here initially the conventional encoding is done which is followed by symbol mapping then the data is converted into decimal form and modulation is done next. After modulation the pilot insertion for error detection and sub carrier mapping is done after that is the IDWT of the data, which provides better bandwidth utilization mainly because cyclic prefixing is not needed. IDWT will convert time domain signal to the frequency domain. We use MIMO system to transmit and receive data into and from the channel respectively. Hence huge throughput gains may be achieved by adopting Nt × Nr MIMO systems compared to conventional 1 × 1 systems that use single antenna at both ends of the link with the same requirement of power and bandwidth. After passing through the channel, channel estimation for coherent detection of information symbols and channel synchronization. Here we use zero forcing and mean square error equalizers. On the received signal DWT will be performed and then pilot synchronization where the pilots inserted 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.

BER PERFORMANCE EVALUATION

By using MATLAB, performance characteristic of the DFT based OFDM and the wavelet based OFDM can be obtained for differet modulations that are used for LTE and also characteristic after using MIMO, as shown in figures 3-5. Modulations that are used for LTE in the paper are QPSK, 16 QAM and 64 QAM (Uplink and downlink). When signal to noise ratio is of good quality, QPSK does not carry data at very high speed then, only higher modulation techniques can be used. Lower forms of modulation (QPSK) does not require high signal to the noise ratio. Signal to noise ratio (SNR) of different values are introduced through AWGN channel for the purpose of simulation. Averaging for a particular value of SNR for all the symbols is done and BER is obtained and same processes are 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 modulationtechniques. Different wavelet types daubechies1 and haar is used in wavelet based OFDM for QPSK, 16-QAM, 64-QAM. It is very clear from the fig. 3.1, fig. 3.2 and fig. 3.4 that the BER performance of wavelet based OFDM is better than the DFT based OFDM. Fig. 3.1 indicates that db1 performs better when QPSK is applyed. Fig. 3.2 shows that when 16-QAM is used db1 and haar have similar performance but far better than that of the DFT. Fig. 3.4, where 64-QAM is used haar and db1 performs better than DFT. Fig 3.3 shows MIMO system performs better than 1×1 system.

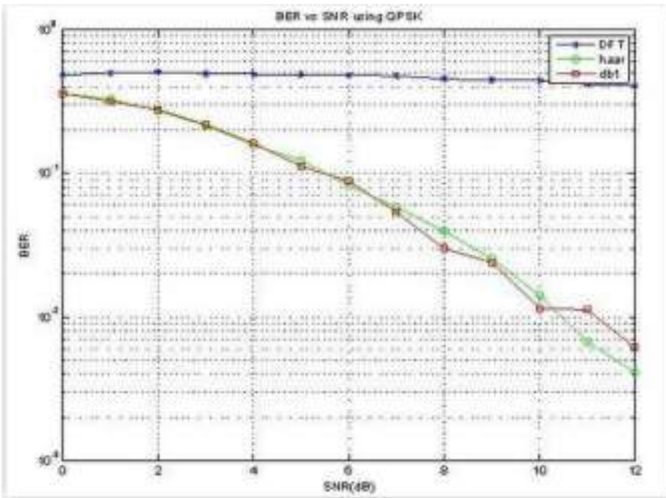

Fig 3.1: BER performance of wavelets and DFT based OFDM system using QPSK modulation.

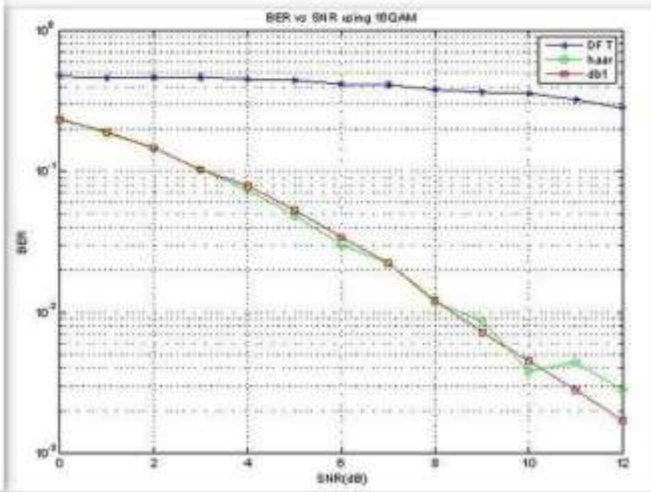

Fig. 3.2. BER performance of wavelets and DFT OFDM using 16-QAM

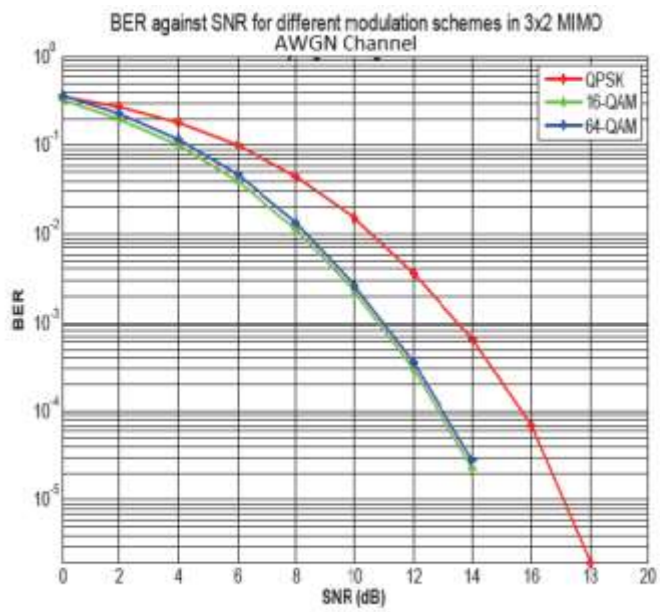

Fig. 3.3.BER against SNR using 3x2 MIMO in AWGN channel

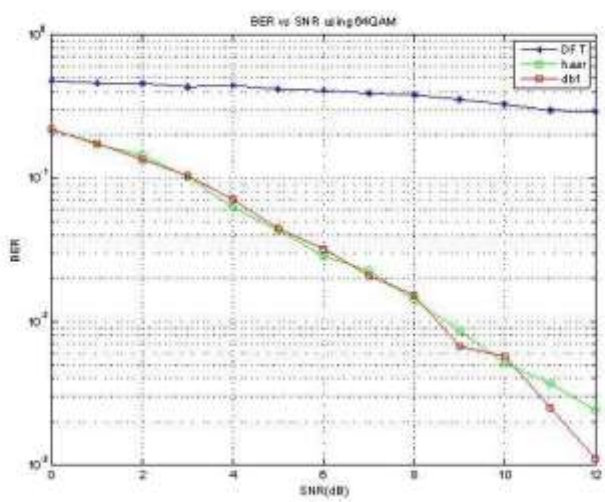

Fig. 3.4.BER performance of wavelets and DFT based OFDM system using 64-QAM

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CONCLUSION

In this paper we have analyzed the performance of the wavelet based OFDM system and then compared it with the performance of the DFT based OFDM system. Also we have collated the different modulation schemes in MIMO system. From the performance curve we can observe the BER curves obtained from wavelet based OFDM are better than that of the DFT based OFDM and BER curves obtained in MIMO system is better than 1×1 system that uses single antenna on both the ends of the link. We have used three modulation techniques for implementation i.e., 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 daubechies1 and haar wavelets, where both provide their best performances at different intervals of SNR.

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. TjengThiang, 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.

[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.

[7] J. Antony, M. Petri, "Wavelet packet modulation for wireless communication", Wireless communication & mobile computing journal, vol. 5, no. 2, pp. 1-18, March 2005.

[8] L. Madan Kumar, N. Homayoun, "A review of wavelets for digital wireless communication", Wireless personal communications, Kluwer academic publishers- Plenum publishers, vol. 37, no. 3-4, pp. 387-420, May 2006.

[9] L. Alan, "Wavelet packet modulation for orthogonally multiplexed communication", IEEE transaction on signal processing, vol. 45, no. 5, pp. 1336-1339, May 1997.

[10] K. Werner, P. Gotz, U. Jorn, Z Georg, "A comparison of various MCM schemes", 5th International OFDM-workshop, Hamburg, Germany, pp. 20-1 – 20-5, July 2000.

[11] IEEE std., IEEE proposal for 802.16.3, RM wavelet based (WOFDM), PHY proposal for 802.16.3, Rainmaker technologies, 2001.

[12] O. Eiji, I Yasunori, I Tetsushi, "Multimode transmission using wavelet packet modulation and OFDM", IEEE vehicular technology conference, vol. 3, pp. 1458-1462, Oct. 2003.

[13] L. Louis, P. Michael, "The principle of OFDM" RF signal processing, http://www.rfdesign.com, pp. 30-48, Jan 2001.

[14] "LTE in a nutshell: The physical layer", white paper, 2010, http://www.tsiwireless.com.

[15] R. Mika, T. Olav, "LTE, the radio technology path toward 4G", Computer communications, Elsevier, vol. 33, no. 16, pp. 1894-1906, Oct. 2010.

[16] Broughton SA, Bryan K. Discrete Fourier analysis and wavelets. New Jersey, John Wiley, 2009.

[17] C. See Jung, L. Moon Ho, P. Ju Yong, "A high speed VLSI architecture of discrete wavelet transform for MPEG-4", IEEE transaction consumer electron, vol. 43, no. 3, pp. 623-627, June 1997

[18] Ozdemir MK, Arslan H. Channel estimation for wireless OFDM systems. IEEE CommunSurv 2007; 9(2).

[19] "MIMO-OFDM communication systems: channel estimation and wireless location", Zhongshan Wu B.S., Northeastern University, China, 1996 M.S., Louisiana State University, US, 2001 May 2006