

BER Analysis of Wavelet Based OFDM and SC-FDMA for 4th Generation LTE Using Various Modulation Techniques

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ABSTRACT: 4th generation long term evolution (LTE) uses orthogonal frequency division multiplexing (OFDM) and single carrier frequency division multiplexing (SC-FDMA). OFDM contains multiple carriers and it provides higher spectral efficiency compared to frequency division multiplexing (FDM). Use of Wavelets provides good orthogonality and there is no need of cyclic prefixing thus the spectrum efficiency increases. Thus Wavelet based OFDM improves the Bit error Rate (BER) performance. Recent research has shown that the Single Carrier Frequency Division Multiple Access (SC-FDMA) is an attractive technology for uplink broadband wireless communications, because it does not have the problems of Orthogonal Frequency Division Multiple Access (OFDMA) such as the large Peak-to-Average Power Ratio (PAPR). In this paper, an efficient transceiver scheme for the SC-FDMA system, using the wavelet transforms is proposed. In the proposed scheme, the Fast Fourier Transform (FFT) and its inverse (IFFT) are replaced by the Discrete Wavelet Transform (DWT) and its inverse (IDWT). Wavelet filter banks at the transmitter and the receiver have the ability to reduce distortion in the reconstructed signals, while retaining all the significant features present in the signals. The performance of the proposed scheme is investigated with different wireless channels. Simulation results show that the proposed scheme provides better performance, when compared to the wavelet based OFDM, while the complexity of the system is slightly increased. In this paper, BER performance of DWT based OFDM and DWT based SC-FDMA are compared using different modulation techniques such as QPSK, 16-QAM, 64-QAM.

KEYWORDS: LTE, OFDM, SC-FDMA, BER, wavelet transform

I. INTRODUCTION

There are specific requirements which are necessary for 4th generation of cellular systems. They are specified by International telecommunication union Radio communication department (ITU-R). The requirement for data rates for mobile communication was specified in International mobile telecommunications advanced project (IMT-Advanced). The 3rd generation partnership project i.e. (3GPP) was established in 1998. They started working on LTE project to define radio access network (RAN) and core network [1]. For 4G system, LTE-Advanced was selected by 3GPP. The main technique which is used in LTE is orthogonal frequency division multiplexing (OFDM).

Today for different wireless networks, spectrum efficiency and flexible utilization of spectrum are highly required for various wireless related applications. In multiple in multiple out (MIMO) or in multicarrier systems, the main idea is to divide data into multiple streams and use them to modulate different carriers also called as sub-carriers. There are two main advantages of such technique. One is there is no requirement of signal enhancement for noise which is required in single carrier system because of the equalizers. And the second is because of long symbol duration effect of multipath fading which is occurred in communication systems. [2] In OFDM, the sub carriers used are orthogonal to each other. Due to this, sometimes may overlap on each other in frequency domain. Thus the bandwidth efficiency is obtained without any inter carrier interference [3]. But OFDM has several inherent disadvantages such as the large PAPR and the sensitivity to Carrier Frequency Offset (CFO) [3]-[5]. Recently, much attention has been focused on Single Carrier systems with Frequency-Domain Equalization (SC-FDE) [3]-[5] and SCFDMA systems [6], [7]. OFDMA and SC-

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FDMA are modified versions of the OFDM and SC-FDE schemes. One disadvantage of OFDMA is the high PAPR, which raises the cost and lowers the power efficiency of the transmitter power amplifier. With a lower PAPR, the power amplifiers at mobile terminals employing SC-FDMA can be simpler and more power-efficient than they would be with OFDMA transmission. On the other hand, with its high signaling rate, the frequency-domain equalizer of an SC-FDMA link is far more complicated than an OFDMA equalizer. With SC-FDMA transmission confined to the Long Term Evolution (LTE) uplink, complicated equalizers are required only at base stations and not at mobile terminals. There are several techniques for equalization such as Zero Forcing (ZF) equalization, Minimum Mean-Square Error (MMSE) equalization, Decision Feedback Equalization (DFE), and turbo equalization [8]-[12]. There are two methods to choose the sub-carriers for SC-FDMA systems; interleaved sub-carriers mapping and localized sub-carriers mapping. Wavelet transform is used to analyze signals in both, time and frequency domain. The basis functions of wavelet transform are localized in both time domain and frequency domain. In these waveforms, the elementary waveforms are not sine waves or cosine waves like in Fourier transform. If orthogonality is lost between the sub carriers, then ISI and ICI are occurred due to multipath propagation of the signal in Discrete Fourier Transform (DFT) based OFDM. Inter symbol interference occurs between successive symbols of the same sub-carrier and inter carrier interference occurs between different signals at different subcarriers. Thus cyclic prefixing is used to avoid both the interferences. But cyclic prefix causes power loss and bandwidth inefficiency in DFT based OFDM. In this paper we have compared the BER performance of DFT based OFD system with the BER performance of Wavelet based OFDM system for various LTE modulation techniques. Also BER performance of Wavelet base SC-FDMA system is analysed using different transmission channels. For wavelet based system we used Haar and Daubechies2 wavelets.

II. CONVENTIONAL OFDM SYSTEM

In DFT based that is conventional OFDM system sinusoids of DFT form an orthogonal basis function set. In Discrete Fourier transform, the transform is correlated with its input signal with each of sinusoidal basis function[9]. Here the orthogonal basis functions are the subcarriers used in OFDM. The signals are combined at the receiver to obtain the information transmitted by the transmitter. In practice, the Fast Fourier transform (FFT) and Inverse Fast Fourier Transform (IFFT) are used to implement the OFDM system because the less number of computations are required in FFT and IFFT. Multiple replicas are received by the receiver due to the time dispersive nature of the transmission channel. This causes frequency selective fading. To reduce this, the guard interval is used and it is called as cyclic prefix [10]. Cyclic prefix is the copy of some part of symbol end. When the channel delay spread remains within the limit of cyclic prefix, there would not be any loss in subcarriers' orthogonality. The downlink of Long Term Evolution (LTE) technique uses orthogonal frequency division multiplexing access (OFDMA). In the uplink data in LTE, single carrier- frequency division multiple access (SC-FDMA) is used.

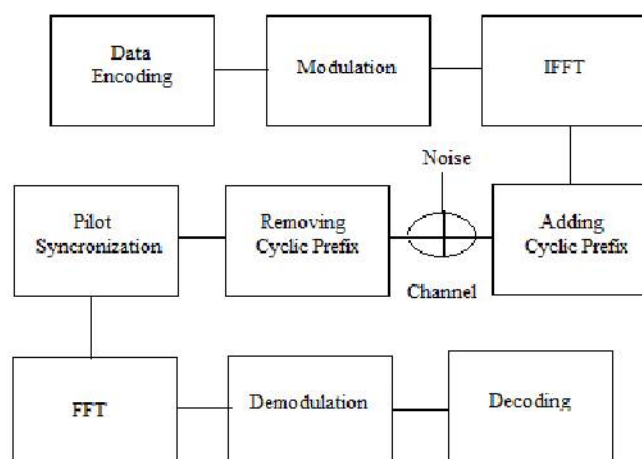


Fig.1 DFT based OFDM transmitter and receiver using AWGN channel model.

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III. WAVELET BASED OFDM SYSTEM

Wavelet transform is a tool to analyze the signal in both times as well as frequency domain. It is a multi-resolution analysis method where input signal is decomposed into different frequency components [8]. The system can be designed according to the need by using any particular type of wavelet filter. By using various wavelet filters, we can design waveforms with scalable time or frequency partitioning for multi user applications [6]. Wavelets have better orthogonally and have localization in both time and frequency domain. Due to this the wavelets have ability to reduce the effect of ISI and ICI. Thus there is no need of cyclic prefixing. And thus the spectrum utilization is good in wavelet based OFDM. Also the complexity of DWT based system is lower than the conventional system.

In DWT the input signal will be passed through different filters and the coefficient are obtained for each level of filtering. The signal is passed through low pass and high pass filters [4]. After filtering, two types of coefficients are obtained, first ones are detailed coefficients obtained through high pass filter and second ones are coarse approximation coefficients obtained from low pass filter and are related with scaling process [4]. After filtering the decimation process is done.

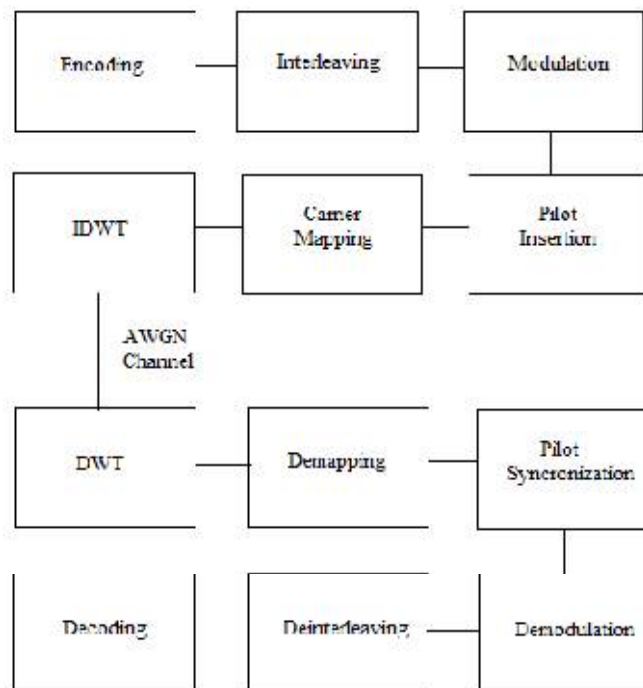


Fig.2 Wavelet based OFDM transmitter and receiver using AWGN channel model

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IV. PROPOSED METHOD USING WAVELET BASED SC- FDMA SYSTEM

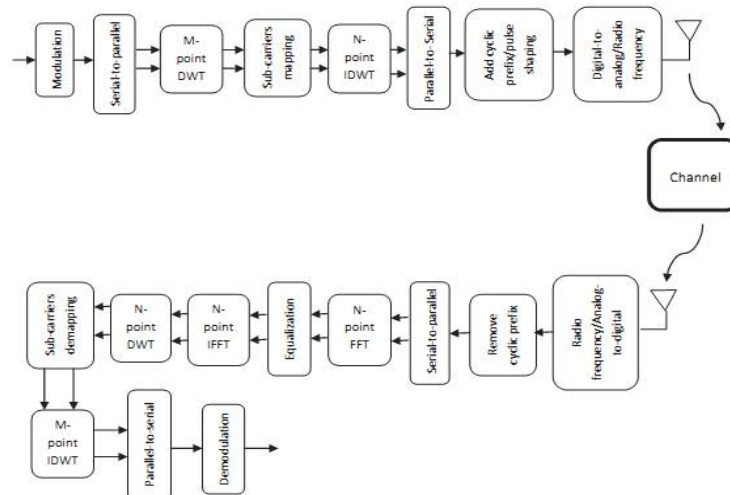


Fig.3. Transmitter and receiver structure of the W-SC-FDMA system

In this section, we describe the proposed Wavelet-based Single Carrier Frequency Division Multiple Access (W-SC-FDMA) scheme. The proposed scheme is shown in Figure.. The steps of the proposed scheme can be summarized as follows:

- 1- The modulation processes are applied on the user data.
- 2- The resulting signal is transformed by the wavelet transform via the DWT. The output of the single-level Haar wavelet transform consists of two signals, which represent the approximation coefficients and the detail coefficients. For two-levels. Haar wavelet transform, the approximation coefficients of the first level is the input to the second level. The output on this case consists of three signals, which represent the approximation coefficients and the detail coefficients signals of the second level and the detail coefficients signal of the first level.
- 3- The resulting signal from the sub-carriers mapping is inserted into the IDWT to produce the signal from the approximation coefficients signal and the detail coefficients signal.
- 4- After that, we add the CP in order to prevent the ISI.
- 5- Finally, the resulting signal is transmitted through the wireless channel

V. BER PERFORMANCE ANALYSIS USING WAVELET BASED SC-FDMA

By using MATLAB tool, the performance characteristics of DFT based OFDM and wavelet based OFDM and SC-FDMA using different channel models are obtained for different modulation techniques such as QPSK, 16-QAM, and 64-QAM that are used for LTE. QPSK does not carry data at very high speed. When signal to noise ratio (SNR) is of good quality then only higher modulation techniques can be used [5].

For simulation purpose, SNR of different values are introduced through the channels. Random data bits are sent in the form of symbols through channel model. Thus the bit error rate (BER) is obtained by averaging all the SNR values for all the symbols.

The BER performance of DFT based OFDM and DWT based OFDM and SC-FDMA using different channel models are obtained. Different wavelet types are used such as db2 and haar. Also different modulation techniques such as QPSK, 16-QAM, 64-QAM are used.

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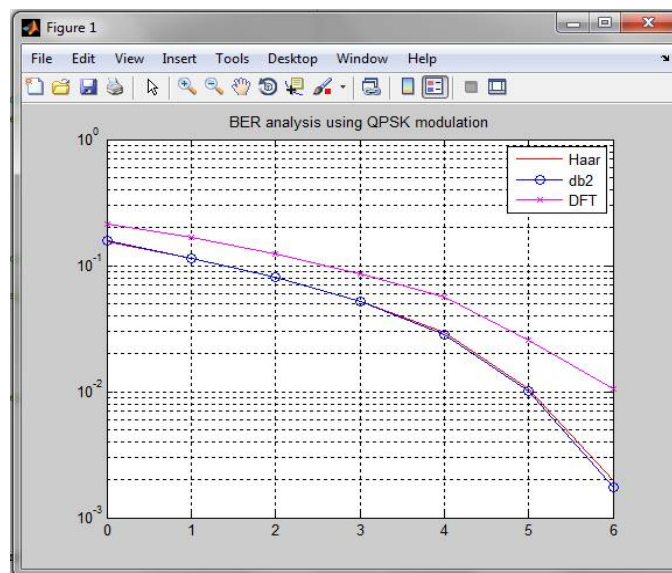


Fig.4. BER performance of wavelets and DFT based OFDM system using QPSK modulation.

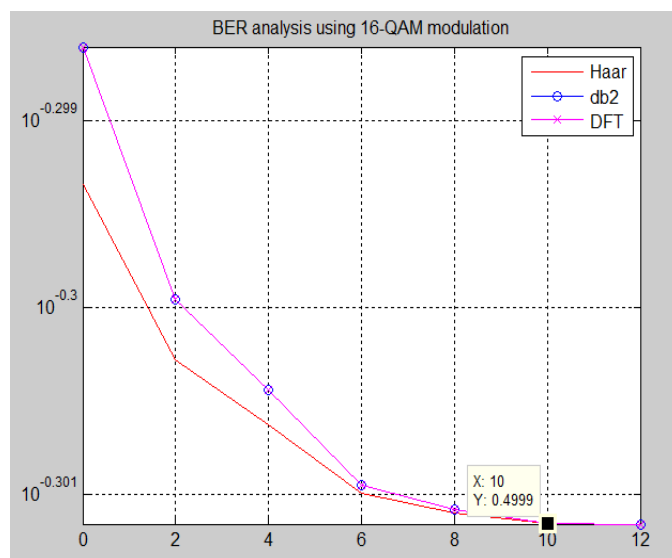


Fig.5 BER performance of wavelets and DFT based OFDM system using 16-QAM modulation

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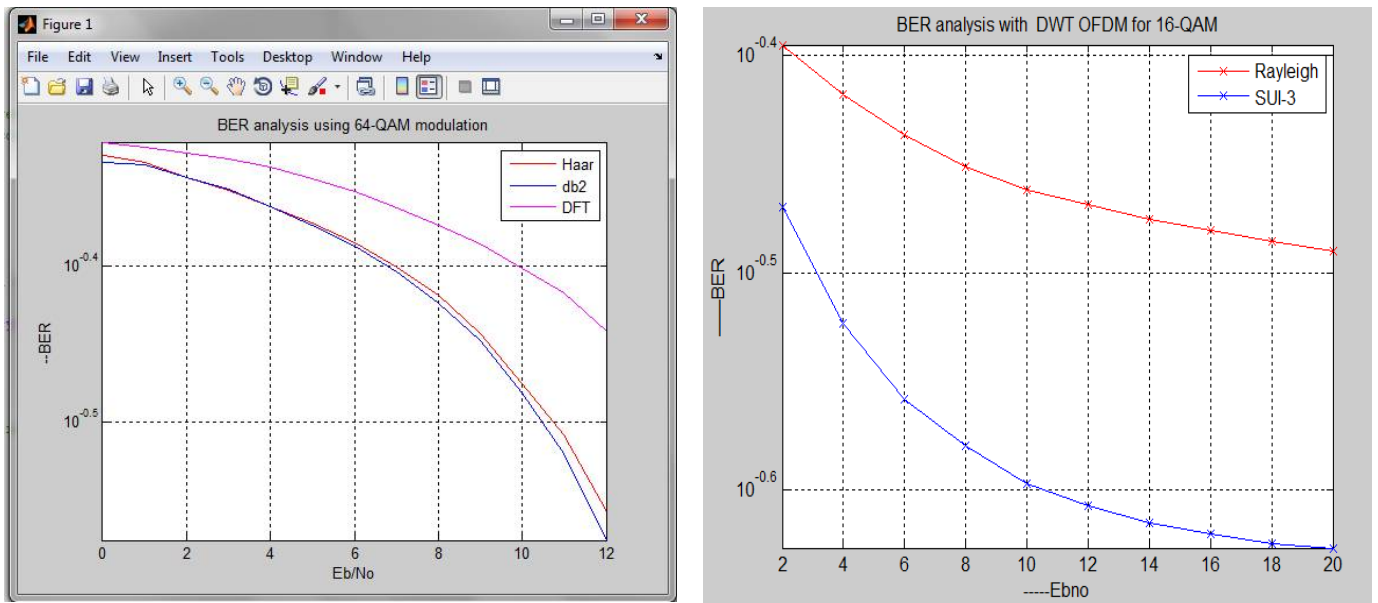


Fig.6 BER performance of wavelets and DFT based OFDM system using 64-QAM modulation

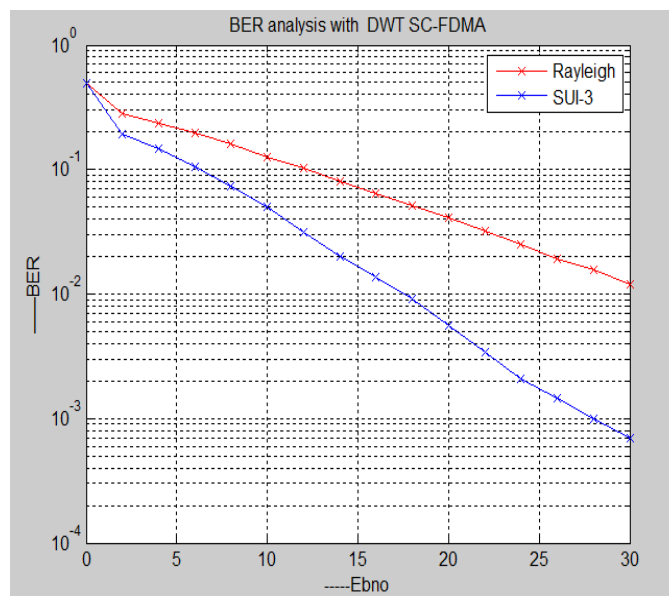


Fig.7. BER performance of wavelet based SC-FDMA system using QPSK modulation

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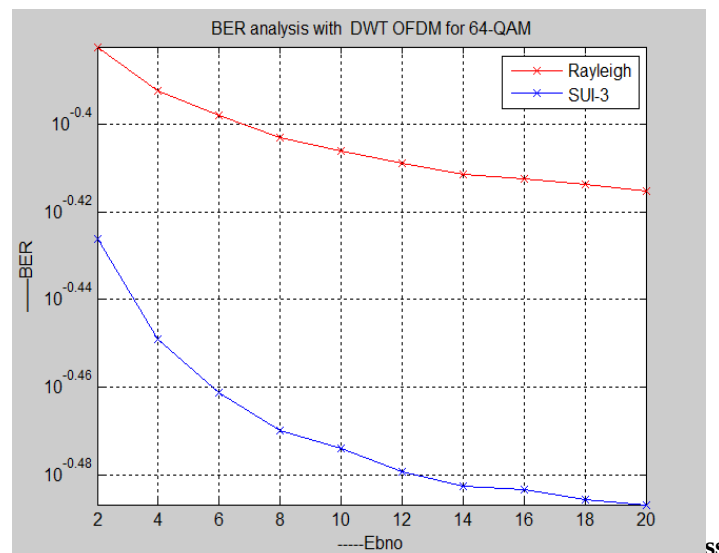


Fig.8 BER performance of wavelet based SC-FDMA system using 64-QAM modulation

VI. CONCLUSION

In this paper we analyzed the Bit Error Rate (BER) performance of wavelet based OFDM and SC-FDMA using different channel models.. From the performance curve it is observed that the BER performance for wavelet based OFDM is better than the DFT based OFDM. Further, BER performance of wavelet based SC-FDMA system is analyzed. Which gives better performance for Bit error rate with slightly higher system complexity than wavelet based OFDM.

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