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PERFORMANCE IMPROVEMENTS OF 3GPP-LTE-OFDMA USING THE MULTIWAVELET TRANSFORM

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ABSTRACT

Today, the buzzword is high-data rate, wireless connectivity without mobility constraints with minimum bit error rate (BER). Long Term Evolution (LTE) is considered to be the 4th generation (4G) of radio technologies designed to increase the capacity and speed of mobile telephone networks. LTE has adopted Orthogonal Frequency Division Multiple Access (OFDMA) for the downlink transmission. The provision of high rates to users, anytime and everywhere is challenged by the time varying wireless medium and dynamic nature of interference. In this paper a novel method based on the Multiwavelet Transform (MWT) for implementing the OFDMA in LTE is proposed. The proposed scheme is tested in different channels such as Additive White Gaussian Noise (AWGN) and fading channel (flat fading and selective Fading) with other parameters such as second path gain and path delay. The results show that the proposed system overcome the traditional method based on the Fast Fourier transform (FFT) and give lower BER compared with the system based on FFT.

KEYWORDS: 4G, AWGN, BER, Fading Channel, LTE, MWT, OFDMA, SNR

INTRODUCTION

Wireless communication has become increasingly important not only for professional applications but also for many fields in our daily routine and in consumer electronics. In 1990, a mobile telephone was still quite expensive, whereas today most teenagers have one, and they use it not only for calls but also for data transmission [1]. Long Term Evolution is developed by (3GPP) Third Generation Partnership Project and considered to be 4G wireless broadband technologies [2, 3]. It is an important technology transfer from circuit switch network to all-IP network architecture [3]. The LTE technology offers a number of distinct advantages over other wireless technologies. These advantages include increased performance attributes, such as high peak data rates, high spectral efficiency, very low latency, support of variable bandwidth, simple protocol architecture, compatibility and interworking with earlier 3GPP releases, interworking with other systems, e.g., cdma2000, FDD and TDD within a single radio access technology, efficient multicast broadcast and greater efficiencies in using the wireless spectrum [4]. The data rate of 100Mbps in downlink and 50Mbps in uplink are expected for 20MHz channel [5,6,7].

OFDMA

OFDMA offers good flexibility and performance for a reasonable complexity. The users of a same cell are multiplexed in frequency, each user's data being transmitted on a subset of the sub-carriers of an Orthogonal Frequency Division Multiplexing (OFDM) symbol depending on its velocity and the reliability of its channel quality indicator [8].

The OFDMA technology divides the available bandwidth into multiple subcarriers and allocates a group of sub-carriers to a user based on its requirements, current system load and system configuration [9]. The radio resource that is available for a user in the downlink 3GPP LTE system is defined in both frequency and time domains and is called a Resource Block (RB). In the frequency domain, the RB consists of 12 consecutive subcarriers (180 kHz total bandwidth) and in the time domain it is made up of one time slot of 0.5 ms duration. A time slot consists of 7 OFDM symbols [10]. Physical Resource Block (PRB) is the minimum resolution for scheduling in the frequency domain. There are 100 PRBs in a 20MHz system, the sub-carrier bandwidth is 15 kHz [11].

THE MULTIWAVELET TRANSFORM

Multiwavelet is a relatively new addition to the wavelet theory, and has received considerable attention. It is found wide spread application in several fields due to the orthogonally of basis functions and their greater suitability for use in communication systems [12].

Multiwavelet have advantages compared to scalar one, like , feature such as short support, orthogonality, symmetry and vanishing moment which are known to be important in signal processing. A scalar wavelet cannot possess all of these properties at the same time[13]. On the other hand, a Multiwavelet system can simultaneously provide perfect reconstruction while preserving length (orthogonality), good performance at the boundary (via linear-phase symmetry), and high order of approximation (via vanishing moment), this suggests that Multiwavelet may perform better in various application [14].

A very important Multiwavelet filter is the DGHM filter [15, 16]. A Multiwavelet with r scaling functions and r wavelet functions is said to have multiplicity r. When $r = 1$, one scaling function and one wavelet function, the multiwavelet system reduces to the scalar wavelet system. The perfect reconstruction Multiwavelet filter bank employs 2×2 matrix filter that provide extra degrees of freedom in the design [17].

For notational convenience, the set of multiscaling function can be written by using the notation

$$\Phi(t) = [\Phi_1(t)\Phi_2(t) \ \dots \ \Phi_r(t)]^T \tag{1}$$

Where T means transpose of matrix,the Multiwavelet function is defined from the set of wavelet function as:

$$\Psi(t) = [\ \Psi_1(t) \ \ \Psi_2(t) \ \ \cdots \ \Psi_r(t)\ ]^T \tag{2}$$

In principle r can be arbitrary large, the Multiwavelet studied to date are primary for $r = 2$.

The DGHM two scaling and wavelet function satisfy the following two scale dilation equation [18].

$$\begin{bmatrix}\Phi_1(t)\\ \Phi_2(t)\end{bmatrix} = \sqrt{2}\sum_k H_k \begin{bmatrix}\Phi_1(2t-k)\\ \Phi_2(2t-k)\end{bmatrix}, \quad \begin{bmatrix}\Psi_1(t)\\ \Psi_2(t)\end{bmatrix} = \sqrt{2}\sum_k G_k \begin{bmatrix}\Psi_1(2t-k)\\ \Psi_2(2t-k)\end{bmatrix} \tag{3}$$

Where $H(k)$ and $G(k)$ are matrix filters that (r × r) or in this case (2x2) matrices for each integer $k$as [19]:

$$H_k = \begin{bmatrix}h_0(2k) & h_0(2k+1)\\ h_1(2k) & h_1(2k+1)\end{bmatrix}, G_k = \begin{bmatrix}g_0(2k) & g_0(2k+1)\\ g_1(2k) & g_1(2k+1)\end{bmatrix} \tag{4}$$

And$\sum_k h_0(k)^2 = 1, \quad \sum_k h_1(k)^2 = 1, \sum_k g_0(k)^2 = 1 \ , \sum_k g_1(k)^2 = 1$ (5)

Therefore the matrix filters $H(k)$ and $G(k)$can be written as:

$$H_0 = \frac{1}{20\sqrt{2}}\begin{bmatrix}12 & 16\sqrt{2}\\ -\sqrt{2} & -6\end{bmatrix}, H_1 = \frac{1}{20\sqrt{2}}\begin{bmatrix}12 & 0\\ 9\sqrt{2} & 20\end{bmatrix}, \ H_2 = \frac{1}{20\sqrt{2}}\begin{bmatrix}0 & 0\\ 9\sqrt{2} & -6\end{bmatrix}, \ H_3 = \frac{1}{20\sqrt{2}}\begin{bmatrix}0 & 0\\ -\sqrt{2} & 0\end{bmatrix} \tag{6}$$

$$G_0 = \frac{1}{20\sqrt{2}}\begin{bmatrix} -\sqrt{2} & -6 \\ 2 & 6\sqrt{2} \end{bmatrix},\ G_1 = \frac{1}{20\sqrt{2}}\begin{bmatrix} 9\sqrt{2} & -20 \\ -18 & 0 \end{bmatrix},\ G_2 = \frac{1}{20\sqrt{2}}\begin{bmatrix} 9\sqrt{2} & -6 \\ 18 & -6\sqrt{2} \end{bmatrix}, G_3 = \frac{1}{20\sqrt{2}}\begin{bmatrix} -\sqrt{2} & 0 \\ -2 & 0 \end{bmatrix} \quad (7)$$

Calculation of 1D-DMWT

The one-dimensional discrete Multiwavelet Transform 1D-DMWT can be computed by the following steps [14]:

- The input signal should be of length N, where N must be power of 2. For example 4, 8 16, 32 and so on.
- Construct the transformation matrix (W) with dimension of $(2N \times 2N)$ using the DGHM low and high pass filter matrices.
- For DGHM system the preprocessing step can be applied on the input signal by repeating the input stream multiplied by a constant value ($\alpha = 1/\sqrt{2}$) and the input signal become of length 2N.
- the DMWT can be get now by applying the matrix multiplication between (W) which is (2N×2N) and the preprocessing input signal which is (2N×1). Means multiply W of size (2N×2N) by input of size (2N×1).

$$W = \begin{bmatrix} H_0 & H_1 & H_2 & H_3 & 0 & 0 & \cdots & 0 & 0 & 0 & 0 \\ 0 & 0 & H_0 & H_1 & H_2 & H_3 & \cdots & 0 & 0 & 0 & 0 \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ H_2 & H_3 & 0 & 0 & 0 & 0 & \cdots & 0 & 0 & H_0 & H_1 \\ G_0 & G_1 & G_2 & G_3 & 0 & 0 & \cdots & 0 & 0 & 0 & 0 \\ 0 & 0 & G_0 & G_1 & G_2 & G_3 & \cdots & 0 & 0 & 0 & 0 \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \cdots & \vdots & \vdots & \vdots & \vdots \\ 0 & 0 & 0 & 0 & 0 & 0 & \cdots & G_0 & G_1 & G_2 & G_3 \\ G_2 & G_3 & 0 & 0 & 0 & 0 & \cdots & 0 & 0 & G_0 & G_1 \end{bmatrix} \quad (8)$$

Calculation of 1D-IDMWT

The 1D-IDMWT should be used to get the original signal.the reconstruction matrix can be get by transpose the transformation matrix W. To compute a single level 1D Inverse discrete Multiwavelet transform using over-sampled scheme of post processing, the following steps should be done [20]:

- Re-arrange the row pair of the $(2N \times 1)$ vector such that the row pair 1,2 and 3,4 ,…, $N-1, N$ to become 1,2 and 5,6,…,$2N-3, 2N-2$ and the row pair $N+1, N+2$ and $N+3, N+4, \dots, 2N-1, 2N$ to become 3,4 and7,8, …, $2N-1, 2N$ of the resulting matrix. such that the row 1,2,3,4,5,6,7,8 will become 1,2,5,6,3,4,7,8 .
- Multiply the reconstructed matrix W^T(transpose of transformation matrix W) with the re-arrange resulting vector$(2N \times 1)$
- Taking just the odd rows $(1,3,5, \dots, N-1)$ from the resulting matrix and neglect the even rows$(2,4,6, \dots, N)$. The resulting vector $(N \times 1)$ is the original reconstructed vector.

PROPOSED SCHEME OF DMWT-LTE-OFDMA

This section outlines the OFDMA system seen in Fig. 1. Unlike in a point-to-point OFDM system, *K* users are involved in the OFDMA system to share *N* subcarriers. The difference arises in the forming and deforming of MWT block. Each user allocates set of sub-carriers *S*, Optimum solution for a downlink system considers *K* users, *N* subcarriers, and *S* stacks within a subcarrier. Stacks are created with M-QAM symbols. When the channel is in good condition, the transmission is performed with higher data rates (M is high), and when the channel is in poor condition, the transmission rate is lowered (M is low) with small constellation and low-rate codes. The channel side information is feedback to transmitter in order to control transmit power, transmit constellation, and the coding rate. each user get its modulation type and get its time allocation and fixed amount of subcarrier according to channel type that the signal will transfer through it.The power level of the modulation is adjusted to overcome the fading of the channel. The transmission power for AWGN channel can be predicted. The channel may be assumed to be reciprocal. BS is able to estimate the channel of all BS-to-mobile links based on the received uplink transmission as long as the channel variation is slow. As a result, the resource allocation should be done within the coherence time. Therefore, when making the analysis of the new proposed system based on Multiwavelet transform, all the type of the expected modulation types that used should be taken and most of the channel type with the expected cases also will be taken in order to get the all cases of working. After that it can be say if the new system is good or not and this is depending on the parameters that govern the performance of system such as the relation between BER and SNR.

RESULTS AND DISCUSSIONS

In any communication system, it is concerned with an important parameter called the Signal-To-Noise Ratio (SNR), or *S/N*, at the receiver and its relation with the BER (bit error rate). This parameter defines how much received signal power there is as compared to the noise power at the receiver; therefore, it can be considered a figure of merit for the communication system. This criterion is used to compare the activity of the proposed system with the other system based on FFT. This modulation process depends on the channel type and the parameter that is responsible on the channel like path loss, distance, speed, ...etc. the information about the channel is reciprocal between the base station and the mobile user in order to modify and changes the modulation type in order to get the optimum performance. All this process was done by the resource allocation module to manage the process of choosing the correct modulation type and optimum bit rat with minimum BER. Therefore, all the possible type of modulation which is used in LTE and the popular type of channels will be taken and study to get the behavior of the new system.

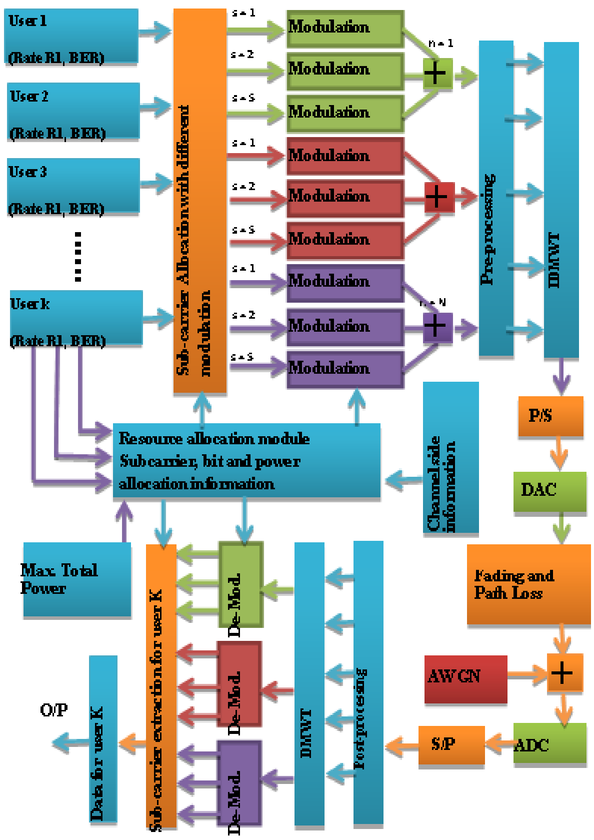

Figure 1: The Block Diagram of DMWT-LTE-OFDMA

The proposed system (LTE-OFDMA) based on DMWT is simulated and run using the MATLAB package version 7.12 (R2011a). The behavior of the proposed system is monitored while changing the parameter that effected on the performance of the system. These parameters are listed in table I. In this simulation the two types of channel will be taken with all details and variable to cover all the cases expected during the simulation.

AWGN Channel with Different Modulation Types

The proposed system was examined in AWGN channel under different types of modulations and then discovers how the response of the system was changed. In AWGN the noise effect will be added to the signal travelling in channel and it will be seen that the proposed system is overcome this noise effect and have performance better than the (FFT-LTE-OFDMA). In all these modulation types it can be noticed that the proposed system performance, which is based on the MWT, is better than the system based on FFT.

Fading Channels

The Doppler frequency and its relation with velocity and frequency are listed in Table I. This table shows some practically speeds from (2.4 km/h) to (192 km/h). The system was examined under the two types of fading channel which are flat fading channel and a frequency-selective fading channel.In flat fading channel it is shown that the performance of the proposed system overcome the system based on FFT in different situation of Doppler frequency that is related to different case of carrier frequency and speed.Now the channel model is selected to be frequency selective fading channel and also will examine the new system of MWT-OFDMA-LTE under the different cases of Doppler frequency and different carrier frequency and velocity.In addition the new parameters are examined which are the second path gain (SPG) and path delay (Pd). These two parameters are tested under different values.

Table I: The Parameters for Simulation

Parameters	Value			
modulation types	QPSK 16QAM 64QAM 256QAM			
Carrier Frequency f_c (MHz)	225 900 2025			
Channel type	AWGN, Flat Fading, Selective Fading			
Second path gain (dB)	-1, -10, -20			
Path delay (T_s)(sample time)	$2 \times T_s$, $6 \times T_s$, $10 \times T_s$			
Target BER	10^{-3}			
Carrier Frequency f_c	**Doppler frequency F_d in various speed**			
	$2.4\ km/h$	$48\ km/h$	$120\ km/h$	$192\ km/h$
400 MHz	0.88 Hz	17.77 Hz	44.44 Hz	71.11 Hz
900 MHz	2.0 Hz	40 Hz	100 Hz	160 Hz
2025 MHz	4.5 Hz	90 Hz	225 Hz	360Hz

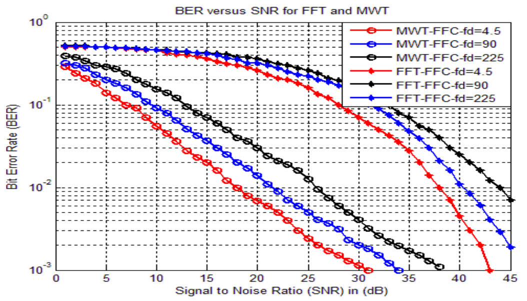

Figure 2: BER versus SNR in AWGN for Different Types of Modulation

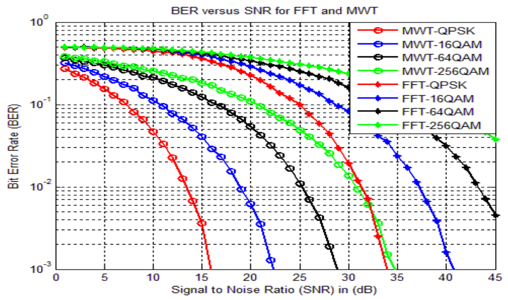

Figure 3: BER versus SNR in Flat Fading Channel with Different (Fd)

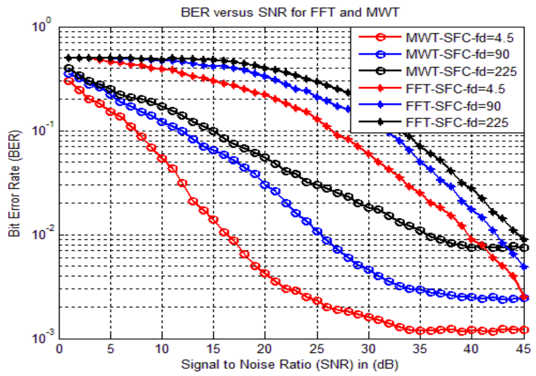

Figure 4:BER versus SNR in (SFC) with Different (Fd)

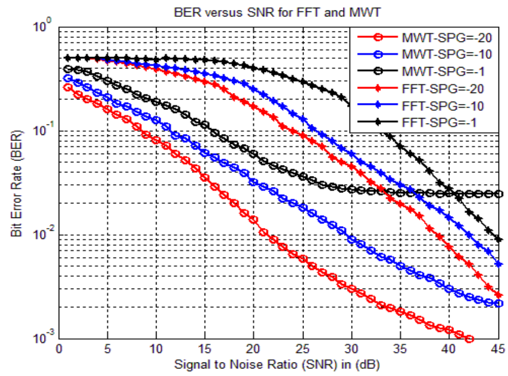

Figure 5: BER versus SNR in (SFC) with Different Second Path Gain (SPG)

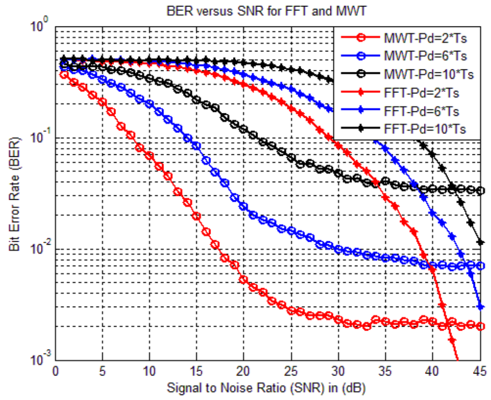

Figure 6: BER versus SNR in (SFC) with Different path delay (Pd) in Sample Time (Ts)

CONCLUSIONS

The LTE uses OFDMA as the downlink technique for sending the information from base station to the mobile user. In this technique each user get its modulation type depends on the channel type that the mobile user work in it. Results shows that in case of the AWGN, the proposed system is much efficient as compared to the system based on FFT, because the new system reach to target BER (10^{-3}) at 16, 23, 29, and 35 dB in QPSK, 16QAM, 64QAM, and 256QAM respectively, while the system based on FFT reach the target BER at 34, 41, ≅50, and ≅60 respectively. Thus it is concluded that the orthogonality of subcarrier in MWT is very strong and robust against the AWGN channel. In flat fading the system behavior show that the performance of the system is degraded with the increasing of the Doppler frequency from 4.5 Hz to 225 Hz and the same thing is occur with the other type which is selective fading channel but the performance of the system in flat fading is better than the in selective fading. In selective fading channel there are two parameters that govern the behavior of the selective fading channel which are (second path gain and path delay). In second path gain the three values are taken to test the system which are -1,-10, and -20 dB. The worst case can be shown with second path gain of -1 dB that means that when the second path gain is high this lead to decrease the activity of the system. The second parameter is path delay and three value are taken which is $2 \times T_s$, $6 \times T_s$, and $10 \times T_s$ where T_s is the time for one sample signal. It can be noticed that when the path delay is increased then the system performance will be decreased. Thus with all these tests for the channels and parameters it is concluded that the proposed system based on MWT works out better than the other system based on the FFT.

From results it is observed that the proposed system (MWT-OFDMA-LTE) is very sensitive to Doppler frequency variations, depending on the channel second path gain and path delay. There is a critical value of Doppler frequency for which increasing the SNR does not affect the BER performance of the system, this is due to the loss in orthogonality between the carriers as a result of the multipath wireless channel. The region between the low SNR to the critical point may be sufficient and adequate to work good in it and most of the equipment work in this period. Therefore broadly it can be say that the proposed system is better than other system based on FFT.

Finally, as there is no cyclic prefix block in sending and receiving, the proposed system is more bandwidth efficient. Thus high data rate transmission is possible without extra bandwidth, that means the quality and quantity of the signal reach to user will be improved.

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