



A Novel Bit Error Rate Reduction Method for 3GPP-LTE-SCFDMA Using the Multiwavelet Transform

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Abstract: The rapid development of wireless communication technology has brought great convenience to people's lives and work. The goal of next generation of mobile wireless communication system is to achieve ubiquitous, high quality, high-speed mobile multimedia transmission with minimum bit error rate BER. To achieve this goal, the third generation partnership project 3GPP has developed the Long Term Evolution LTE. So, LTE has been considered as one of the core technologies of 4th generation 4G wireless communication system. The LTE uses the Single Carrier Frequency Division Multiple Access SC-FDMA for uplink because of its ability to reduce BER and peak to average power ratio PAPR as compare to Orthogonal Frequency Division Multiple Access OFDMA that is used in downlink. In this paper a novel approach for implementing the SC-FDMA was proposed using the Multiwavelet Transform MWT instead of Fast Fourier Transform FFT in order to reduce the BER and more robustness against fading channels. The new system was tested under six types of different channels cases. The results show that the proposed system gives lower BER as compare with the old system based on FFT.

Keywords: 4G, LTE, SC-FDMA, BER, MWT, FFT

I. INTRODUCTION

Nowadays, mobile radio system is immersed by more and more services with data rate from few Kbit/s up to several Mbit/s by an explosive growing demand for a wide variety of high quality of services in voice, video, and data. Wireless communications is moving rapidly towards small, low cost devices. However, the mobility and value of these devices is often limited by battery life since device miniaturization is progressing at a faster rate than battery technology optimization. Thus, the issue of battery life represents a key concern in the next generation of wireless communication systems [1]. In the next generation mobile communication systems, broadband data services are demanded. However, since the data rate increases, the transmit power should be increased to satisfy the required transmission quality, an unacceptably high transmit power is required. In addition to this, much higher transmit power is required in wireless communication systems due to the propagation path loss and the shadowing loss to guarantee the required quality of communication [2]. As the proliferation of smaller and faster devices increases, efficient use of limited battery resources becomes ever more paramount [3].

In the Orthogonal Frequency Division Multiplexing (OFDM), a lot of modulated sub-carriers are multiplexed in time domain, which causes high Peak-to-Average Power Ratio (PAPR). High PAPR may be major drawback of OFDM. Especially, it is more problematic in uplink than downlink because it incurs expensive mobile terminal or reduced uplink coverage [4]. Third generation partnership project long term evolution (3GPP LTE) represents a key advance in cellular mobile technology. The overall target of 3GPP LTE is to provide improved services, increase data rates, and higher spectral efficiency as well as lower latency [5]. SC-FDMA, which combines the features of the Single Carrier Frequency Domain Equalization (SC-FDE) and Frequency Division Multiple Access (FDMA) techniques, has been adopted as the standard for the uplink wireless access scheme in 3GPP-LTE for its lower peak-to-average power ratio than that of orthogonal frequency division multiple access [6]. SC-FDMA can allocate different sub-carriers to different users to achieve multiple access interference free transmission. The simple single-tap equalizer can be used in the frequency domain for channel equalization, with Zero Forcing (ZF) or Minimum Mean Square Error (MMSE) criterion [5]. The scalable bandwidth of LTE-SC-FDMA is 1.5MHz to 20MHz while the number of subcarriers change from the 72 (for 1.5MHz) to 1200 (for 20MHz) [7].

II. SCFDMA

As shown in figure 1, the transmitter of an SC-FDMA system converts a binary input signal to a sequence of modulated subcarriers. At the input to the transmitter, a baseband modulator transforms the binary input to a multilevel sequence of complex numbers x_n in one of several possible modulation formats. The transmitter next groups the modulation symbols $\{x_n\}$ into blocks each containing N symbols. The first step in modulating the SC-FDMA subcarriers is to perform an N -point DFT to produce a frequency domain representation X_k of the input symbols. It then maps each of the N DFT outputs to one of the M ($> N$) orthogonal subcarriers that can be

transmitted. If $N = M/Q$ and all terminals transmit N symbols per block, the system can handle Q simultaneous transmissions without co-channel interference. Q is the bandwidth expansion factor of the symbol sequence. The result of the subcarrier mapping is the set $\tilde{x}_l$ ($l = 0, 1, 2, \dots, M-1$) of complex subcarrier amplitudes, where N of the amplitudes are non-zero. As in OFDMA, an M -point IDFT transforms the subcarrier amplitudes to a complex time domain signal $\tilde{x}_l$. Each $\tilde{x}_l$ then are transmitted sequentially [8].

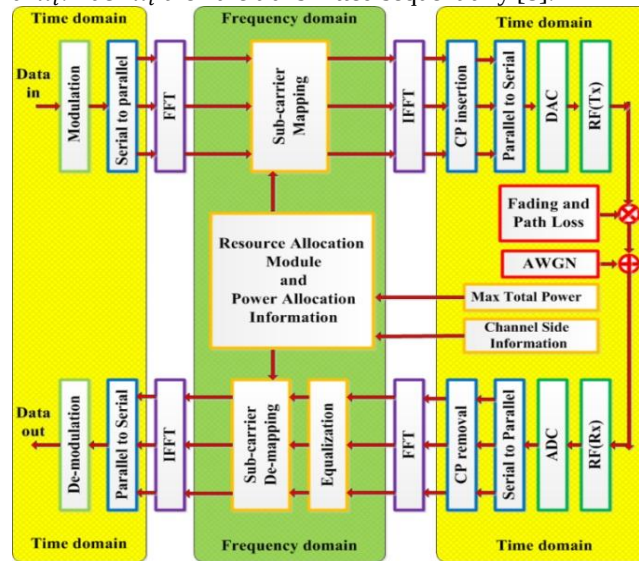


Figure 1: The block diagram of the SCFDMA system

There are M subcarriers, among which N ($N < M$) subcarriers are occupied by the input data. In the time domain, the input data symbol has symbol duration of T seconds and the symbol duration is compressed to $\tilde{T} = T \frac{N}{M}$ seconds after going through SC-FDMA modulation. There are two types of sub-carrier mapping which are Localized and Distributed mapping as shown in figure 2.

In Localized Mapping the output from the DFT is mapped to a subset of consecutive subcarrier, confining only to a fraction of system bandwidth and the zero padding process is done either at the first or last, but the outputs of the DFT will be placed in the sequence order without any interchanging. In distributed Mapping the output of the DFT is assigned, non-continuously to the sub-carrier, over the entire bandwidth and the zero padding is done equally over the entire bandwidth [7]. The data block consists of N complex modulation symbols generated at a rate R_{source} (symbols/sec). The N -point FFT produces N frequency-domain symbols that modulate N out of M orthogonal sub-carriers spread over a bandwidth W . The sub-carriers mapping process can be shown in figure 3. Where W can be defined as [9]:

$$W = M \cdot F_0 \text{ Hz} \quad (1)$$

Where F_0 (Hz) is the sub-carriers frequency spacing. The channel transmission rate is:

$$R_{channel} = [M/N] \cdot R_{source} \text{ (Symbol/sec)} \quad (2)$$

The bandwidth spreading factor Q is given by:

$$Q = R_{channel}/R_{source} = M/N \quad (3)$$

The SC-FDMA system can handle up to Q orthogonal source signals with each source occupying a different set of N orthogonal sub-carriers.

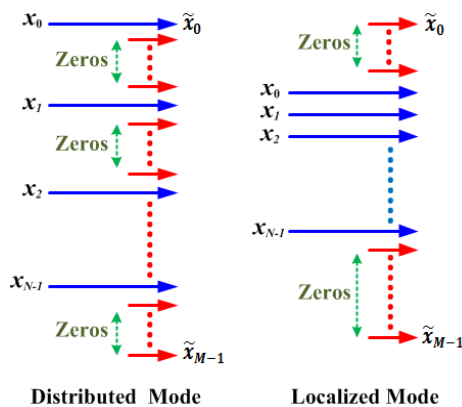


Figure 2: The two types of sub-carrier mapping

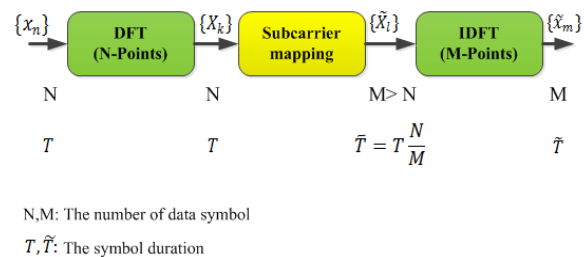


Figure 3: The process of sub-carriers mapping

For LFDMA, the frequency samples after subcarrier mapping $\{\tilde{x}_l\}$ can be described as follows [8]:

$$\tilde{x}_l = \begin{cases} x_l, & 0 \leq l \leq N-1 \\ 0, & 0 \leq l \leq M-1 \end{cases} \quad (4)$$

Let $m = Q.n + q$, where $0 \leq n \leq N-1$
and $0 \leq q \leq Q-1$ Then

$$\tilde{x}_m = \tilde{x}_{Qn+q} = \frac{1}{M} \sum_{l=0}^{M-1} x_l e^{j2\pi l \frac{m}{M}} = \frac{1}{Q} \sum_{l=0}^{N-1} x_l e^{j2\pi l \frac{Qn+q}{QN}} \quad (5)$$

If $q=0$ then

$$\tilde{x}_m = \tilde{x}_{Qn} = \frac{1}{Q} \sum_{l=0}^{N-1} x_l e^{j2\pi l \frac{Qn}{QN}} = \frac{1}{Q} \sum_{l=0}^{N-1} x_l e^{j2\pi l \frac{n}{N}} = \frac{1}{Q} x_n = \frac{1}{Q} x_{(m) \bmod N} \quad (6)$$

If $q \neq 0$, since $x_l = \sum_{p=0}^{N-1} x_p e^{-j2\pi l \frac{p}{N}}$

Then eqn. 5 can be expressed as follows:

$$\tilde{x}_m = x_{Qn+q} = \frac{1}{Q} \sum_{l=0}^{N-1} x_l e^{j2\pi l \frac{Qn+q}{QN}} = \frac{1}{Q} \sum_{l=0}^{N-1} \left(\sum_{p=0}^{N-1} x_p e^{-j2\pi l \frac{p}{N}} \right) e^{j2\pi l \frac{Qn+q}{QN}} \quad (7)$$

$$= \frac{1}{Q} \sum_{l=0}^{N-1} \sum_{p=0}^{N-1} x_p e^{j2\pi l \left\{ \frac{(n-p)}{N} + \frac{q}{QN} \right\}} = \frac{1}{Q} \sum_{p=0}^{N-1} x_p \left(\sum_{l=0}^{N-1} e^{j2\pi l \left\{ \frac{(n-p)}{N} + \frac{q}{QN} \right\}} \right) \quad (8)$$

$$= \frac{1}{Q} \sum_{p=0}^{N-1} x_p \frac{1 - e^{j2\pi \frac{q}{Q}}}{1 - e^{j2\pi \left\{ \frac{(n-p)}{N} + \frac{q}{QN} \right\}}} = \frac{1}{Q} \sum_{p=0}^{N-1} x_p \frac{1 - e^{j2\pi \frac{q}{Q}}}{1 - e^{j2\pi \left\{ \frac{(n-p)}{N} + \frac{q}{QN} \right\}}} = \frac{1}{Q} \left(1 - e^{j2\pi \frac{q}{Q}} \right) \frac{1}{N} \sum_{p=0}^{N-1} \frac{x_p}{1 - e^{j2\pi \left\{ \frac{(n-p)}{N} + \frac{q}{QN} \right\}}} \quad (9)$$

As can be seen from above equations, LFDMA signal in the time domain has exact copies of input time symbols with a scaling factor of $1/Q$ in the N -multiple sample positions and in between values are sum of all the time input symbols in the input block with different complex-weighting.

Now, For DFDMA, the frequency samples after subcarrier mapping $\tilde{x}_l$ can be described as follows.

$$\tilde{x}_l = \begin{cases} x_{l/\tilde{Q}}, & l = \tilde{Q}.k \quad (0 \leq k \leq N-1) \\ 0, & \text{otherwise} \end{cases} \quad (10)$$

Where $0 \leq l \leq M-1$, $M = Q.N$, and $1 \leq \tilde{Q} \leq Q$

Let $m = Q.n + q$ ($0 \leq n \leq N-1$, $0 \leq q \leq Q-1$)

Then

$$\tilde{x}_m (= \tilde{x}_{Q.n+q}) = \frac{1}{M} \sum_{l=0}^{M-1} \tilde{x}_l e^{j2\pi l \frac{m}{M}} = \frac{1}{Q} \sum_{k=0}^{N-1} x_k e^{j2\pi \tilde{Q}k \frac{Qn+q}{QN}} \quad (11)$$

If $q=0$ then

$$\tilde{x}_m = \tilde{x}_{Q.n} = \frac{1}{Q} \sum_{k=0}^{N-1} x_k e^{j2\pi \tilde{Q}k \frac{Qn}{QN}} = \frac{1}{Q} \sum_{k=0}^{N-1} x_k e^{j2\pi \tilde{Q}k \frac{n}{N}} = \frac{1}{Q} \sum_{k=0}^{N-1} x_k e^{j2\pi k \frac{\tilde{Q}n}{N}} \quad (12)$$

$$= \frac{1}{Q} \left(\sum_{k=0}^{N-1} x_k e^{j2\pi k \frac{(\tilde{Q}.n) \bmod N}{N}} \right) = \frac{1}{Q} x_{(\tilde{Q}.n) \bmod N} = \frac{1}{Q} x_{(Q(m) \bmod N) \bmod n} \quad (13)$$

If $q \neq 0$, since $x_k = \sum_{p=0}^{N-1} x_p e^{-j2\pi k \frac{p}{N}}$ Eqn. 19 can be expressed as follows after derivation

$$\tilde{x}_m = \tilde{x}_{Q.n+q} = \frac{1}{Q} \left(1 - e^{j2\pi q \frac{\tilde{Q}}{Q}} \right) \frac{1}{N} \sum_{p=0}^{N-1} \frac{x_p}{1 - e^{j2\pi \left\{ \frac{(Qn-p)}{N} + \frac{\tilde{Q}q}{QN} \right\}}} \quad (14)$$

From a resource allocation point of view, subcarrier mapping methods are further divided into static and Channel-Dependent Scheduling (CDS) methods. CDS assigns subcarriers to users according to the channel frequency response of each user. CDS is of great benefit with localized subcarrier mapping because it provides significant multi-user diversity which leads to improved system capacity and performance [6],[10]. This improvement can be shown in figure 6. For these reasons only LFDMA concept is proposed to use in the 3GPP-LTE specifications. Therefore, we will focus and use this approach exclusively further in this paper.

III. MULTIWAVELET TRANSFORM

Multiwavelet Transform (MWT) was introduced previously and found wide spread application in several fields due to the orthogonality of basis functions and their greater suitability for use in communication systems. Multiwavelet are capable of reducing the Inter-Symbol Interference (ISI) and Inter-Carrier Interference (ICI), which are caused by the loss in orthogonality between the carriers [11]. Multiwavelet offer simultaneous orthogonality, symmetry, and short support that are not possible with the wavelet transform systems [12].

A very important Multiwavelet filter is the filter proposed by Geronimo, Hardian, and Massopust (GHM). For notational convenience, the set of scaling function $\Phi(t)$ and Multiwavelet function $\Psi(t)$ can be written by using the notation.

$$\Phi(t) = [\Phi_1(t) \quad \Phi_2(t) \quad \dots \quad \Phi_r(t)]^T, \Psi(t) = [\Psi_1(t) \quad \Psi_2(t) \quad \dots \quad \Psi_r(t)]^T \quad (15)$$

The Multiwavelet studied to date are primary for $r = 2$. The GHM two scaling and wavelet function satisfy the following two scale dilation equation [13].

$$\begin{bmatrix} \Phi_1(t) \\ \Phi_2(t) \end{bmatrix} = \sqrt{2} \sum_k H_k \begin{bmatrix} \Phi_1(2t-k) \\ \Phi_2(2t-k) \end{bmatrix}, \begin{bmatrix} \Psi_1(t) \\ \Psi_2(t) \end{bmatrix} = \sqrt{2} \sum_k G_k \begin{bmatrix} \Psi_1(2t-k) \\ \Psi_2(2t-k) \end{bmatrix} \quad (16)$$

Where $H(k)$ and $G(k)$ are matrix filter as

$$H_k = \begin{bmatrix} h_0(2k) & h_0(2k+1) \\ h_1(2k) & h_1(2k+1) \end{bmatrix}, G_k = \begin{bmatrix} g_0(2k) & g_0(2k+1) \\ g_1(2k) & g_1(2k+1) \end{bmatrix} \quad (17)$$

$$\sum_k h_0(k)^2 = 1, \sum_k h_1(k)^2 = 1, \sum_k g_0(k)^2 = 1, \sum_k g_1(k)^2 = 1 \quad (18)$$

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

$$H_0 = \frac{1}{20\sqrt{2}} \begin{bmatrix} 12 & 16\sqrt{2} \\ -\sqrt{2} & -6 \end{bmatrix}, H_1 = \frac{1}{20\sqrt{2}} \begin{bmatrix} 12 & 0 \\ 9\sqrt{2} & 20 \end{bmatrix}, H_2 = \frac{1}{20\sqrt{2}} \begin{bmatrix} 0 & 0 \\ 9\sqrt{2} & -6 \end{bmatrix}, H_3 = \frac{1}{20\sqrt{2}} \begin{bmatrix} 0 & 0 \\ -\sqrt{2} & 0 \end{bmatrix} \quad (19)$$

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

III.1 Calculation of 1D-DMWT

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

1. The input signal should be of length N , where N must be power of 2. For example 4, 8 16 and so on.
2. Construct the transformation matrix (W) with dimension of $(2N \times 2N)$ using the GHM low and high pass filter matrices as in equation 42.
3. For GHM system the preprocessing step can be applied on the input signal by repeating the input stream multiplied by a constant value ($\alpha = 1/\sqrt{2}$).

The DMWT can be get now by applying the matrix multiplication between (W) which is $(2N \times 2N)$ and the preprocessing input signal which is $(2N \times 1)$

$$W = \begin{bmatrix} H_0 & H_1 & H_2 & H_3 & 0 & 0 & \dots & 0 & 0 & 0 & 0 \\ 0 & 0 & H_0 & H_1 & H_2 & H_3 & \dots & 0 & 0 & 0 & 0 \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ H_2 & H_3 & 0 & 0 & 0 & 0 & \dots & 0 & 0 & H_0 & H_1 \\ G_0 & G_1 & G_2 & G_3 & 0 & 0 & \dots & 0 & 0 & 0 & 0 \\ 0 & 0 & G_0 & G_1 & G_2 & G_3 & \dots & 0 & 0 & 0 & 0 \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ 0 & 0 & 0 & 0 & 0 & 0 & \dots & G_0 & G_1 & G_2 & G_3 \\ G_2 & G_3 & 0 & 0 & 0 & 0 & \dots & 0 & 0 & G_0 & G_1 \end{bmatrix} \quad (21)$$

III.2 Calculation of 1D-IDMWT

The one Dimensional Inverse Discrete Multiwavelet Transform (1D-IDMWT) should be used to reconstruct the original signal from the transformed signal. The reconstruction matrix can be getting by transpose or inverse 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 [15]:

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

The goal of preprocessing is to relate the given scalar input signal of length N to a sequence of length-2 vectors to start the analysis algorithm and reduce noise effects. In the one-dimensional signals, the computational method for DMWT and IDMWT by an oversampled scheme of preprocessing is convenient and influential and further performance gains were made by looking into alternative orthogonal bases functions and finding a better transform than FFT [16].

IV. PROPOSED MWT-SC-FDMA

A block diagram of proposed LTE-SC-FDMA system is shown in figure 4 which illustrates the transmitter and receiver structure of MWT-LTE-SC-FDMA.

At the input to the transmitter, a baseband modulator transforms the binary input to a multilevel sequence of complex numbers in one of several possible modulation formats. Commonly used baseband modulation schemes in upcoming LTE standard include QPSK, 16-QAM and 64-QAM. In general, transmitter adopts the modulation scheme to match the particular channel conditions and characteristics for the certain time instance. The process of modulation scheme is controlled by the resource allocation module. In this module the information is taken from the condition of the channel. If the channel in bad condition then the decision is to apply the low speed type of modulation such as QPSK, while if the channel in good condition then this module apply the high speed modulation types such as 16QAM or 64QAM. After choosing the suitable type of modulation, the transmitter concatenates the modulation symbols into blocks through Serial to parallel converter (S/P) block. After that the coded streams enter to new and important block which is the preprocessing block.

The goal of preprocessing is to relate the given input signal of length N to a sequence of length-2 vectors to start the analysis algorithm and reduce noise effects.

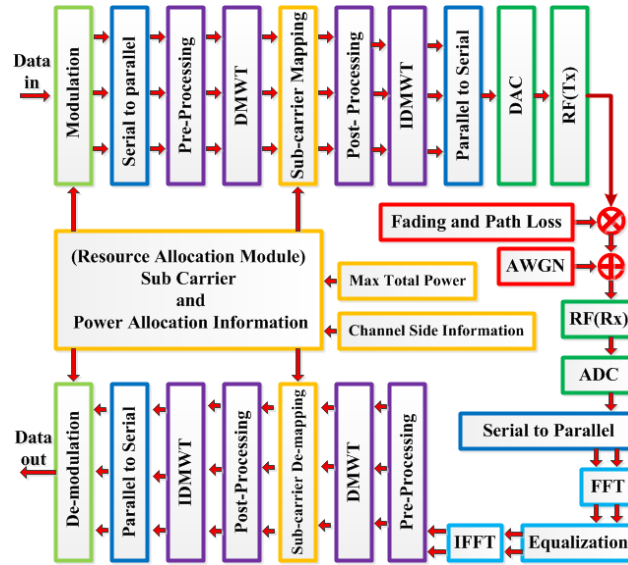


Figure 4: Proposed MWT-LTE-SC-FDMA system

In the one-dimensional signals, the computational method for DMWT and IDMWT by an oversampled scheme of preprocessing (repeated row) is convenient, influential and further performance gains were made by looking into alternative orthogonal bases functions and finding a better transform than Fast Fourier Transforms FFT. The signal after that is input to the DMWT block. The main motivation for using Multiwavelet is the superior spectral containment properties of Multiwavelet filters over Fourier filters. This high degree of suitability is related to the finite support and self-similarity of the basis functions. The replacement of the Fast Fourier transform by the Multiwavelet transforms leads to overcoming several limitations and improves performance efficiency.

The data stream after that inputs to the sub carrier allocation block in which each user will get its sub carrier's amount and type of sub-carrier mapping according to the information that feedback from the receiver side. In this feedback all the information about the channel will be feed in order to select the right type of mapping that suitable for specific type of channel in order to reduce the Bit Error Rate (BER). After that the data input to the blocks of post processing and IDMWT. In this block all the data will be returned to the time domain. Then the data will be changed to serial mode by the parallel to serial module (P/S) then to Digital to Analog module (DAC). After that this analog signal will be input to radio frequency module to travel through the channel. The signal suffers from more than one types of degradation which are AWGN and fading which are flat fading and selective fading.



Figure 5: The process of channel equalization

All the process in the transmitter will be inverted in the receiver in order to get the original signal with minimum BER and distortion. The first step in the receiver is RF stage then analog to digital block A/D. After that, the signal enter to serial to parallel block (S/P) then to the part of system that try to equalize the effect of degradation which is known as channel equalization as shown in figure. 5. The received signal is equalized in the frequency domain using the FFT block. After the equalization block the equalized signal is then transformed back to the time domain using the IFFT by the following steps:

Let $E(m)$ where $(m=0, 1, 2 \dots N_{FFT} - 1)$ denote the equalizer coefficient for the m^{th} sub carrier, the time domain equalized signal $K(n)$ can be expressed as:

$$k(n) = \frac{1}{N_{FFT}} \sum_{m=0}^{N_{FFT}-1} E(m)G(m) e^{\frac{j2\pi mn}{N_{FFT}}} \quad (22)$$

Where $n = 0, 1, 2, \dots, N_{FFT} - 1$

The equalizer coefficients $E(m)$ are determined to minimize the mean square error between the equalized signal and the original signal. The equalizer coefficients are computed according to the types of the frequency domain equalization (FDE) in two methods as follows [9]:

A. The zero forcing (ZF) Equalizer is

$$E(m) = 1/H(m) \quad m = 0, 1, 2, \dots, N_{FFT} - 1 \quad (23)$$

B. The Minimum Mean Square Error (MMSE) Equalizer is

$$E(m) = H^*(m)/[|H(m)|^2 + (E_b/N_0)^{-1}] \quad (24)$$

Where $*$ denotes the complex conjugate, $H(m)$ is the transfer function of the channel and E_b/N_0 is average energy-per-bit to noise power spectral density. Equalization will be used to eliminate the effect of ISI. From figure 7 it can be noticed that the MMSE method is better than the ZF method and give lower BER compared with other method. Therefore, in all tests and simulations for channel models, the MMSE method will be use. The signal after output from the IFFT Block become in the time domain. Then, in order to complete processing, the signal input to the block of preprocessing then to the discrete Multiwavelet transform (DMWT) to make the system work in the Multiwavelet domain instead of the Fourier domain in order to get the better performance with minimum BER. Now all the subcarrier will be input to the subcarrier de-mapping which arrange the subcarrier for each user according to the information comes from the resource allocation module. After the rearrange of the subcarrier the new configuration will be input to the block of the post processing following by the block of IDMWT in order to return the subcarrier to time domain. After all this process the signal will be back to serial form then to the demodulation block that depends on the resource allocation module which takes the information from the channel to select suitable type of modulation.

V. Results and Discussion

The proposed system (3GPP-MWT-LTE-SC-FDMA) was simulated and run using MATLAB package version 7.12. The behavior of the proposed system was monitored while change the parameters that effect on the performance of the system. These parameters are listed in table I.

The characteristics of wireless signal changes as it travels from the transmitter antenna to the receiver antenna. These characteristics depend upon the distance between the two antennas, the path or paths taken by the signal, and the environment around the path. The term channel refers to the medium between the transmitting antenna and the receiving antenna [17]. The profile of received signal can be obtained from that of the transmitted signal if we have a model of the medium between the two. This model of the medium is called Propagation channel model. Propagation channel models are essential tools for simulation and testing of wireless transmission systems. The literature is extensive on this topic, and many standards have recommended channel models for specific propagation environments [18]. Some of these channels will be study and apply on the proposed system and calculate the BER and comparing with other system based on FFT. These channels are:

Table I: The parameters for simulation

Parameters	Value
System bandwidth	5 MHz
Modulation types	QPSK
Carrier Frequency	2025 MHz
Sub-carriers spacing	15 KHz
Sub-carriers mapping	Localized
No. of DMWT points	64
Channel equalization	MMSE
Bit rate	5 Mbps
Target BER	10^{-4}
Channel estimation	Perfect
Channel Types	SUI, COST 259, Cost 207, 3GPP TDL, ITU,WCDMA

V.1 SUI channel models

Stanford University Interim (SUI) model is developed for IEEE 802.16 by Stanford University. It is used for frequencies above 1900 MHz in this propagation model, three different types of terrains or areas are considered. These are called as terrain A, B and C. Terrain A represents an area with highest path loss, it can be a very dense populated region while terrain B represents an area with moderate path loss, a suburban environment. Terrain C has the least path loss which describes a rural or flat area.

It is obvious that there are many possible combinations of parameters to obtain such channel descriptions. A set of six typical channels (SUI1, SUI2...SUI6) was selected for the three terrain types [19]. The performance of the system can be shown in figure 8.

V.2 COST 259 channel models

The European Co-Operation in the field of Scientific and Technical research (COST 259) was developed by the European COST 259 project. The COST 259 is wideband and capable of providing channel impulse responses in both spatial and temporal domains. It can also provide these in vertical and horizontal polarization components. It operates at the frequency range from 0.45 to 5 GHz. One of the work items identified in COST 259 is to propose a new set of channel models which overcome the limitations in the GSM channel models, while aiming at the same general acceptance. The main difference between the COST 259 model and previous models is that it tries to describe the complex range of conditions found in the real world by distributions of channels rather than a few typical cases.

There are three types of channel models which are the Rural Area channel model (RAx), the Hilly Terrain channel model (HTx) and the Typical Urban channel model (TUx) [20]. The performance of the system can be shown in figure 9.

V.3 COST 207 channel models

The COST 207 model gives normalized scattering functions, as well as amplitude statistics for four typical environments which are rural area (RA), typical urban area (TU), bad urban area (BU), and hilly terrain (HT). The COST 207 model was presented as an outdoor wireless channel model. This model specifies power gains and time delays for four typical environments [21]. The performance of the system can be shown in figure 10.

V.4 3GPP-TDL channel models

The LTE standard adopts models based on the ITU-R M.1225 [18] recommendation and the 3GPP TS 05.05 [19] specification for GSM, widely used in the context of third generation mobile systems. The 3GPP models are defined by Tapped-Delay Line (TDL) models, where each tap corresponds to a multipath signal characterized by a fixed delay, relative average power and Doppler spectrum. They were designed for a 5 MHz operating bandwidth, and an apparent periodicity appears in their frequency correlation properties for higher bandwidths. The three models are the Extended Pedestrian-A (EPA), Extended Vehicular-A (EVA) and Extended Typical Urban (ETU) channel models [22]. The performance of the system can be shown in figure 11.

V.5 ITU channel models

For the selection of the air interface of third-generation cellular systems, the International Telecommunications Union (ITU) developed set of models that is available only as a tapped-delay-line implementation. The ITU models have been widely used, because they were accepted by international standards organizations. It specifies three environments: indoor, pedestrian (including outdoor to indoor), and vehicular (with high BS antennas). For each of these environments, two channels are defined: channel A (low-delay-spread case) and channel B (high-delay-spread case) [23]. ITU pedestrian profile B used for a mobile speed of 3km/h while ITU vehicular profile A used for a mobile speed of 60km/h [24]. The performance of the system can be shown in figures 12, 13 and 14.

V.6 3G-WCDMA channels

3GPP UMTS (the Universal Mobile Telecommunications System) is the third generation (3G) uses Wideband CDMA (WCDMA or W-CDMA) to carry the radio transmissions. The scope of 3GPP was to produce globally applicable Technical Specifications and Technical Reports for a 3rd Generation Mobile Telecommunications System [25]. Since it was originally formed, 3GPP has also taken over responsibility for the GSM standards as well as looking at future developments including LTE and LTE Advanced. It contains three types of channels which are Indoor, Pedestrian and Vehicular. The performance of the system can be shown in figure 15.

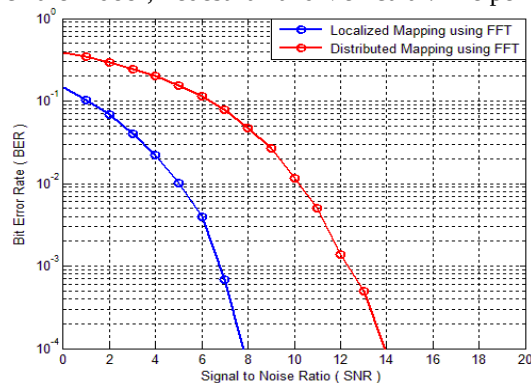


Figure 6: performance under two types of mapping

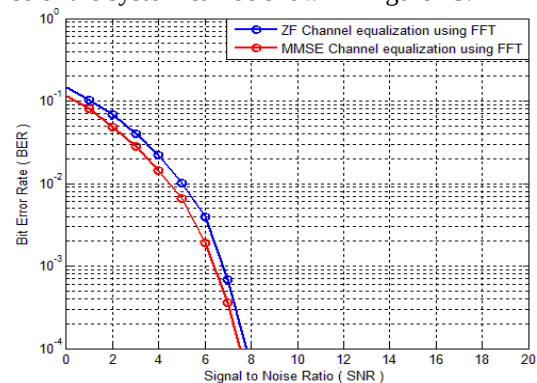


Figure 7: performance under two types of equalization

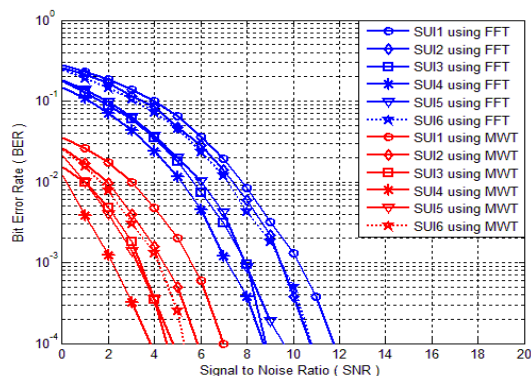


Figure 8: system performance under SUI channel models

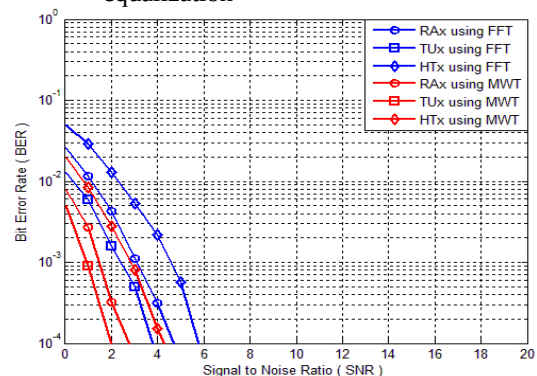


Figure 9: performance under COST 259 channels

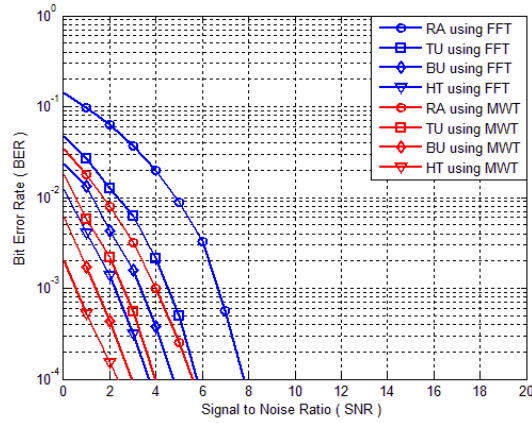


Figure 10: performance under COST 207 channels

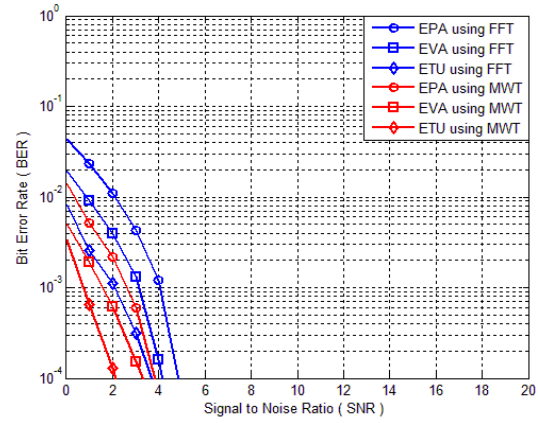


Figure 11: performance under 3GPP-TDL channels

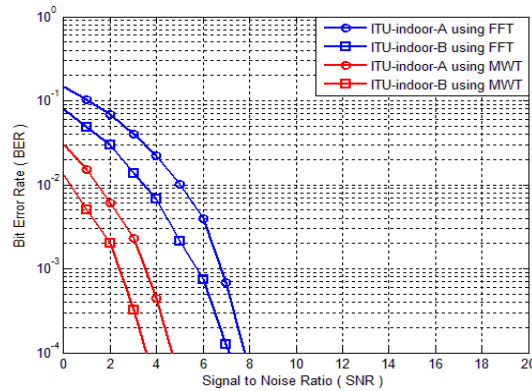


Figure 12: performance under ITU-indoor channels

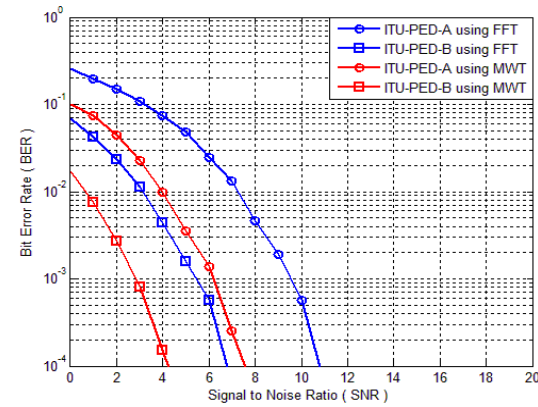


Figure 13: performance under ITU- Ped. channels

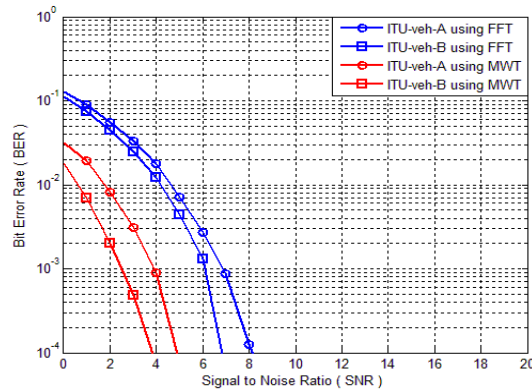


Figure 14: performance under ITU- Veh. Channels

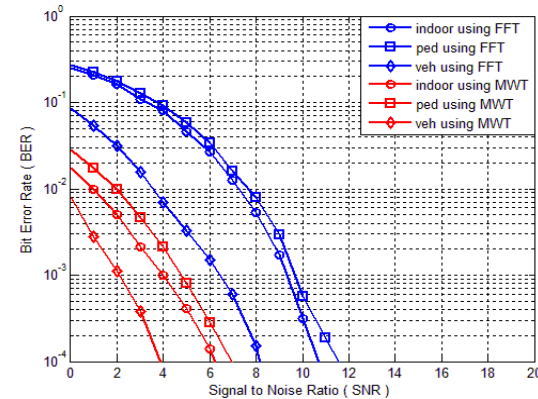


Figure 15: performance under WCDMA channels

VI. CONCLUSION

In this paper two types of subcarrier mapping was tested and found that the localized subcarrier mapping was better than the distributed mode. Also two types of quantization was tested and found that the MMSE equalization is better than the ZF method also a new method of implementing the SC-FDMA was proposed based on the Multiwavelet Transform (MWT) instead of the Fast Fourier Transform (FFT). The proposed system gives the lower BER and high performance than the other system based on FFT. In all the channel types, which are six cases, it can be noticed that the reduction obtained in BER was different for each case according to channel types but still better than system based on FFT in all cases. This is a reflection to the fact that the orthogonal bases of the MWT are much significant than the orthogonal bases used in FFT. Thus, with all these tests for the channels and parameters it is conclude that the proposed system based on MWT works out better than the other system based on the FFT. Finally, as there is no cyclic prefix block in sending and receiving block, that means 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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