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A New Long Term Evolution LTE 3GPP Transceiver Based OFDM Multiwavelet Signals

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Abstract

In this paper an overview of the Long Term Evolution (LTE) is presented. LTE is the development of the Universal Mobile Telecommunications System (UMTS). It allows mobile users to access Internet through their devices (mobile telephones, laptop…). LTE intends to deliver high speed data and multimedia services to next generation. The main contribution of this paper work is to propose a new LTE 3GPP Long Term Evolution Physical Layer Transceiver scheme based **Orthogonal Frequency-Division Multiplexing OFDM،** *Discrete Multiwavelet Transform (DMWT). The proposed Transceiver scheme has been designed and tested to investigate whether it achieves its goal. 6 SUI-channel types have been used. The simulation by matlab approved the proposed design which achieved much lower bit error rates (BER), increased signal-to-noise power ratio (SNR), robustness for multipath channels and does not require cyclically prefixed guard interval and have higher spectral efficiency than transceiver based OFDM on Discrete Wavelet Transform (DWT) and Fast Fourier transform (FFT) also can be used as an alternative conventional transceiver used in present time.*

Keywords: LTE, 3GPP, OFDM, FFT, DWT, DMWT, SUI.

جهاز الإرسال والاستقبال التطور على المدى الطويل (LTE 3GPP) الجديد المبني على تقسيم مضاعفة التردد (OFDM) للاشارات المتعددة المويجات

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الخلاصة

في هذا البحث تم تقديم نبذة عن تطور طويل الأمد (LTE) . LTE هو تطوير للنظام العالمي للاتصالات المتنقلة (UMTS). لأنها تتيح لمستخدمي الهواتف المتحركة للوصول إلى الإنترنت من خلال أجهزتهم (الهواتف المحمولة ، وكمبيوتر محمول ...) . تعتزم LTE لتوفير البيانات عالية السرعة و خدمات الوسائط المتعددة إلى الجيل القادم. المساهمة الرئيسية لهذا البحث هو اقتراح جديد لتصميم واداء الطبقة الفيزيائية لجهاز الارسال والاستقبال التطور على المدى الطويل (LTE 3GPP) والمبني على تقسيم مضاعفة التردد (OFDM) لاشارات متعددة المويجات (DMWT) وقد تم تصميم وفحص واختبار اداء جهاز الارسال والاستقبال المقترح في قنوات جامعة ستانفورد

المؤقتة (SUI) للتحقق في ما اذا كان حقق الهدف وقد استخدمت 6 انواع من هذه القنوات .اثبتت المحاكاة بواسطة الماتلاب ان التصميم المقترح حقق اقل نسبة في معدلات الخطا (BER) وزيادة في نسبة الاشارة الى الضوضاء (SNR) ومقاومة لقنوات التلاشي المتعددة ولا يتطلب فترة الحراسة المسبوقة دوريا (cyclically prefixed guard interval) ولها كفاءة اعلى من الجهاز المبني على تقسيم مضاعفة التردد (OFDM) المبني على اشارات المويجات (DWT) وتحويل فورييه السريع (FFT) و ويمكن استخدام التصميم المقترح عوضا عن جهاز الارسال والاستقبال التقليدي المستخدم في الوقت الحالي.

I. Introduction

The 3rd Generation Partnership Project (3GPP) is ready to present a latest cellular network standard; Long Term Evolution (LTE). LTE amends communication for public safety users' similar police, medical, and rescue workers in cellular networks. This creates a need to examine whether LTE can satisfy public safety users requirements. In the recent years, the world was introduced to mobile broadband. Multimedia applications across the Internet have gathered more attention. Applications such as live streaming, online gaming, mobile TV require higher data rate. The Third-generation Partnership Project (3GPP) started to work on solutions to these challenges and came up with the *High Speed Packet Access* (HSPA). The HSPA is currently used in 3G phones for such applications. Later, the 3GPP has worked on the Long Term Evolution (LTE) and intends to surpass the performance of HSPA. Thus LTE will enhance applications. It is expected that in this year, 80% of broadband users will be mobile broadband subscribers and they will be served by HSPA and LTE networks [1]. The 3GPP is the standards-developing body that specifies the 3G Universal Terrestrial Radio Access (UTRA) and *Global System for Mobile* Communications (GSM) systems. LTE as defined by the 3GPP [2] is the evolution of the Third-generation of mobile communications, Universal Mobile Telecommunications System (UMTS). LTE intends to create a new radio-access technology which will provide high data rates, a low latency and a greater spectral efficiency. The 3GPP has started with the *Rainforest Action Network* (RAN) Evolution workshop in November 2004 [3]. In order to stay competitive in the long run, 3GPP (Third generation partnership project) has initiated activity on the long term evolution of Universal Terrestrial Radio Access Network (UTRAN), which is eyeing clearly beyond to what the Wideband Code Division Multiple Access (WCDMA) can do with High-Speed Downlink Packet Access (HSDPA) or High Speed Uplink Packet Access (HSUPA). 3GPP's answer to this demanding situation is 3G LTE (Long term evolution) or Super 3G, which could dramatically boost the capabilities of 3G networks and make it par with the other technologies [4]. A lot of research has been carried out and proposals have been presented on the evolution of the Universal Terrestrial Radio access Network (UTRAN). The specifications related to LTE are formally known as the evolved UMTS terrestrial radio access (E-UTRA) and evolved UMTS terrestrial radio access network (E-UTRAN), but are in general referred as project LTE. In December 2008, the LTE specification was published as part of Release 8. The initial deployment of LTE was expected in 2009. The first release of LTE namely release-8 [2] supports peak rates of 300Mb/s, a radio-network delay of less than 5ms. Furthermore LTE operates both Frequency Division Duplexing (FDD) and Time Division Duplexing (TDD) and can be deployed in different bandwidths [5].

II. Proposed of Modified LTE Transceiver Structure:

The block diagram in (**Figure 1**) represents the whole system model for the proposed modified LTE transceiver design based multiwavelet signals and the reference model specifies a number of parameters that can be found in **Table (1).** The LTE transceiver structure is divided into three main sections: transmitter, channel, and receiver:

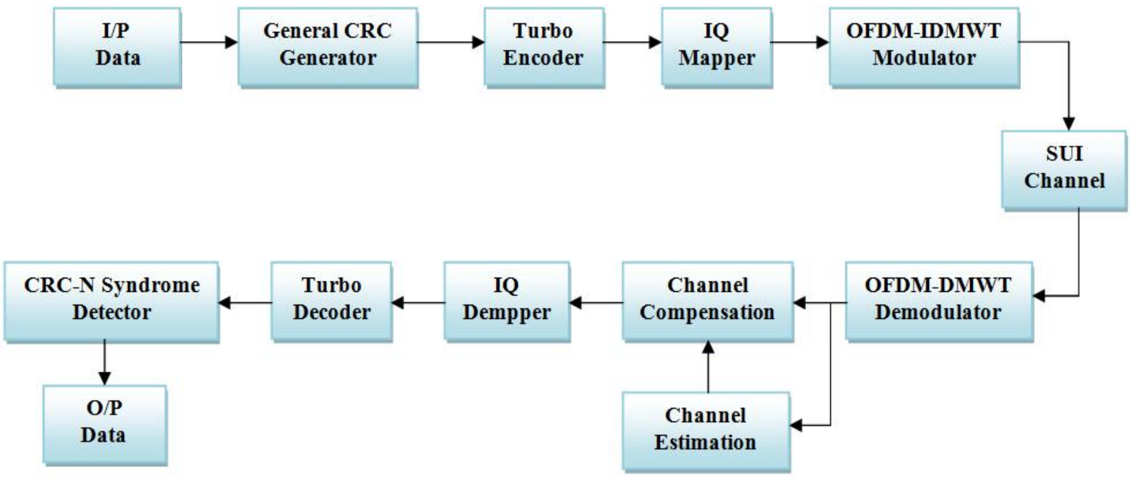

Fig .(1) Block Diagram of Proposed Modified LTE Transceiver Structure

Table .(1) LTE Physical Parameters

Transmission Bandwidth	**2.5 MHz**
Sub-frame duration	**0.5ms**
Sub-carrier spacing	**15KHz**
Sampling Frequency	**3.84MHz**
DMWT Size	**256**
Modulation type	**16QAM**
Channel coding	**Turbo**
Channel type	**SUI Channel**
Channel estimation	**Perfect**
Receiver decoder type	**Soft sphere detection (SSD)**
Number of iterations	**1000**

In transmitter the transport channel is the interface between the physical layer and the MAC layer. As the LTE simulator focuses on the physical layer, the initial data is generated in the form of transport blocks. The transmitter in the physical layer starts with the resource data which are in the form of transport blocks as shown in figure. In each, one transport block will be transferred first to the channel coding part which consists of two Cyclic Redundancy Check (CRC) encoders and one Turbo encoder. According to proposed design in [6], an encoder of CRC is utilized at the beginning of channel coding. There are two CRC schemes for Physical Downlink Shared Channel (PDSCH): '*gCRC24A*' and '*gCRC24B*'. Both of them possess a 24 parity bits length, but work with different cyclic generator polynomials. The '*gCRC24A*' focuses on a transport block, while the '*gCRC24B*' focuses on the code block. The channel coding scheme for PDSCH adopts Turbo coding, which is a kind of robust channel coding. The performance of Turbo codes can be close to the theoretical Shannon capacity limits. The scheme of the Turbo encoder is a Parallel Concatenated Convolutional Code (PCCC) with two 8-state constituent encoders and one Turbo code internal interleaver [6]. The theoretical structure of a Turbo encoder in [6]. As illustrated in **(Figure 1),** the modulation scheme used is the 16 QAM coding rate (1/2) with gray coding in the constellation map. This process converts data to the corresponding value of constellation, which is a complex word (with a real and an imaginary part). The bandwidth ($B = (1/T_s)$) is divided into multicarrier size (N) equally spaced subcarriers at frequencies ($k\Delta f$), $k=0,1,2,...,N-1$ with $\Delta f = B/N$ and, T_s , the sampling interval. At the transmitter, information bits are grouped and mapped into complex symbols. In this system, 16QAM with constellation C_{16QAM} is assumed for the symbol mapping. N_c and is the number of sub-carriers carrying data. Consequently, the number of virtual carriers is $N-N_c$. We assume that half of the virtual carriers are on both ends of the spectral band [7]. Which consists of the OFDM modulator and demodulator. The training frame (pilot sub-carriers frame) are inserted and sent prior to the information frame. This pilot frame is used to create channel estimation, which is used to compensate for the channel effects on the signal. To modulate spread data symbol on the orthogonal carriers, an N-point Inverse multi-wavelet transform IDMWT is used, as in conventional OFDM. Zeros are inserted in some bins of the IDMWT to compress the transmitted spectrum and reduce the adjacent carriers' interference. The added zeros to some sub-carriers limit the bandwidth of the system, while the system without the zeros pad has a spectrum that is spread in frequency. The last case is unacceptable in communication systems, since one limitation of communication systems is the width of bandwidth. The addition of zeros to some sub-carriers means not all the sub-carriers are used; only the subset (N_c) of total subcarriers (N_F) is used. Therefore, the number of bits in OFDM symbol is equal to $\log_2$ (M)* N_c. Orthogonality between carriers is normally destroyed when the transmitted signal is passed through a dispersive channel. When this occurs, the inverse transformation at the receiver cannot recover the data that was transmitted perfectly. Energy from one sub-channel leaks into others, leading to interference. However, it is possible to rescue orthogonality by introducing a cyclic prefix (CP). This CP consists of the final *v* samples of the original K samples to be transmitted, prefixed to the transmitted symbol. The length v is determined by the channel's impulse response and is chosen to minimize ISI. If the impulse response of the channel has a length of less than or equal to v, the CP is sufficient to eliminate ISI and ICI. The efficiency of the transceiver is reduced by a factor of $\frac{K}{K+V}$; thus, it is desirable to make the v as small or K as large as possible. Therefore, the drawbacks of the CP are the loss of data throughput as precious bandwidth is wasted on repeated data. For this reason, finding another structure for FFT-OFDM as DWT-OFDM to mitigate these drawbacks is necessary. The Fourier based OFDM uses the complex exponential bases functions and it's replaced by orthonormal wavelets in order to reduce the level of interference. It is found that the Haar-based orthonormal wavelets are capable of reducing the ISI and ICI, which are caused by the loss in orthogonality between the carriers. Further performance gains can be made by looking into alternative orthogonal basis functions and finding a better transform rather than Fourier and wavelet transform, multiwavelet is a new concept has been proposed in recent years. Multiwavelets have several advantages compared to single wavelets. A single wavelet cannot possess all the properties of orthogonality, symmetry, short support, and vanishing moments at the same time, but a multiwavelet can [8], for all the priorities of multiwavelet, a natural thought is applying it in OFDM. The multiwavelet transform is a newer alternative to the wavelet transform. Multiwavelets are very like to wavelets but have some important differences. In particular, whereas wavelets have associated scaling $\phi(t)$ and wavelet functions $\psi(t)$, For notational convenience, the set of scaling functions be able to be written using the vector notation $\Phi(t) = [\phi 1(t)\ \phi 2(t) \cdots \phi r(t)]\ T$, where $\Phi(t)$ is called the multiscaling function. The multiwavelet function is defined from the set of wavelet functions as $\Psi(t) = [\psi 1(t)\ \psi 2(t) \cdots \psi r(t)]T$ When $r = 1$, $\Psi(t)$ is called a scalar wavelet, or simply wavelet. as in basically n can be arbitrarily large, the multiwavelets studied to date are primarily for $r = 2$. The multiwavelet two scale equations resemble those for scalar wavelets more information found in [9,10]

$$\Phi(t) = \sqrt{2}\sum_{k=-\infty}^{\infty} \mathrm{H_k}\, \Phi(2\mathrm{t}-\mathrm{k}), \qquad (1)$$

$$\psi(t) = \sqrt{2}\sum_{k=-\infty}^{\infty} \mathrm{G_k}\, \Phi(2\mathrm{t}-\mathrm{k}) \qquad (2)$$

However H_k and G_k, and are matrix filters (i.e., H_k and G_k *are* $n \times n$ matrices instead of scalars). a new OFDM system was being introduced, based on multifilters called multiwavelets. It has two or more lowpass and high-pass filters; the purpose of this multiplicity is to achieve more properties which cannot be combined in other transforms (Fourier and wavelet). A very significant multiwavelet filter is the GHM filter suggested by Geronimo, Hardian, and Massopust [11-13].In Multi-wavelet setting, Geronimo, Hardian, and Massopust (GHM) multi-scaling and multi-wavelet function coefficients are 2×2 matrices, and during transformation step they must multiply vectors (instead of scalars). This means that multi-filter bank needs 2 input rows. The aim of preprocessing is to associate the given scalar input signal of length N to a sequence of length-2 vectors in order to start the analysis algorithm, and to reduce the noise effects. In the one dimensional signals the “repeated row” scheme is convenient and powerful to implement. If the number of sub-channels is sufficiently large, the channel power spectral density can be assumed virtually flat within each sub-channel. In these types of channels, multicarrier modulation has long been known to be optimum when the number of sub-channels is large. The size of sub-channels required time (t) approximate optimum performance depends on how rapidly the channel transfer function varies with frequency. The computation of DMWT and IDMWT for 256 point as in [8]. After this, the data converted from the parallel to the serial form are fed to the Stanford University Interim (SUI) Channel Models are an extension of the previously work by AT&T Wireless and Ercegetal [14]. In this model a set of six channels was chosen to address three different terrain types that are typical of the continental US [15]. This model can be used for simulations, design, and development and testing of technologies suitable for fixed broadband wireless applications [16]. The parameters for the model were selected based upon some statistical models. The tables below depict the parametric view of the Six SUI channels more information about SUI channels in [17]. The receiver performs the same operations as the transmitter, but in a reverse order. In addition, multiwavelet OFDM includes operations for synchronization and compensation for the destructive SUI channels.

III. Simulation Results of the Proposed Design:

In this part the simulation of the proposed modified LTE transceiver structure based OFDM-DMWT and comparing with OFDM-DWT and OFDM-FFT system is achieved, beside the BER performance of the modified LTE transceiver structure considered in Six SUI channel models as shown below:

A. Performance of Modified LTE Transceiver in SUI-1 Channel:

In this scenario, the results obtained with OFDM-DMWT, OFDM-DWT and OFDM-FFT it can be seen that for BER=10^{-3} the SNR required for OFDM-DMWT is about 3.6 dB and for OFDM-DWT the SNR required is about 5.6 dB while in OFDM-FFT the SNR required is about 13.13 dB. From (**Figure 2**) it is found that the OFDM-DMWT outperforms significantly other system for this channel model.

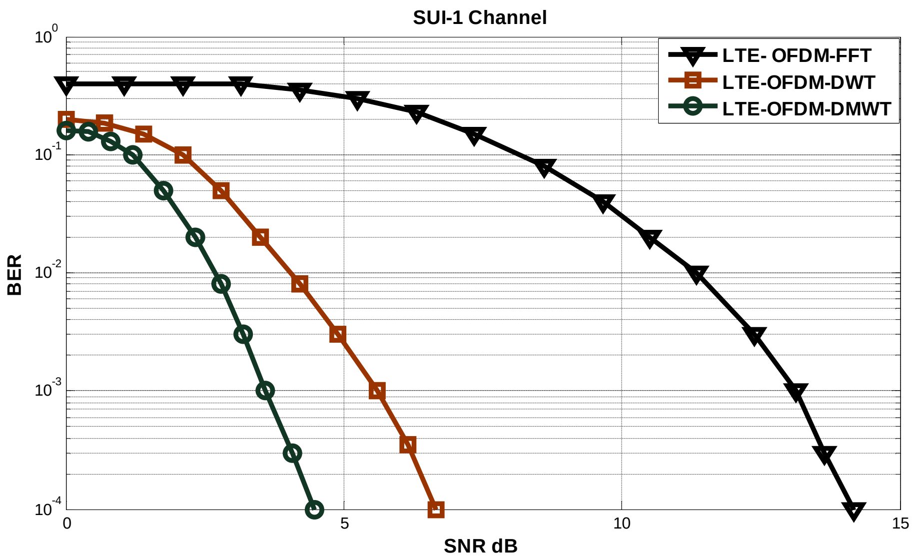

Fig .(2) BER performance of LTE Transceiver based OFDM DMWT in SUI-1 Channel

B. Performance of Modified LTE Transceiver in SUI-2 Channel:

In this simulation profile some influential results were obtained. With OFDM-DMWT, OFDM-DWT and OFDM-FFT it can be seen that for BER=10^{-3} the SNR required for OFDM-DMWT is about 5.85 dB and for OFDM-DWT the SNR required is about 7.8 dB while in OFDM-FFT the SNR required is about 17.5 dB. From **(Figure 3**) it is found that the OFDM-DMWT outperforms significantly other system for this channel model. It can be concluded that the OFDM-DMWT is more significant than the OFDM system based DWT and FFT in this channel that have been assumed.

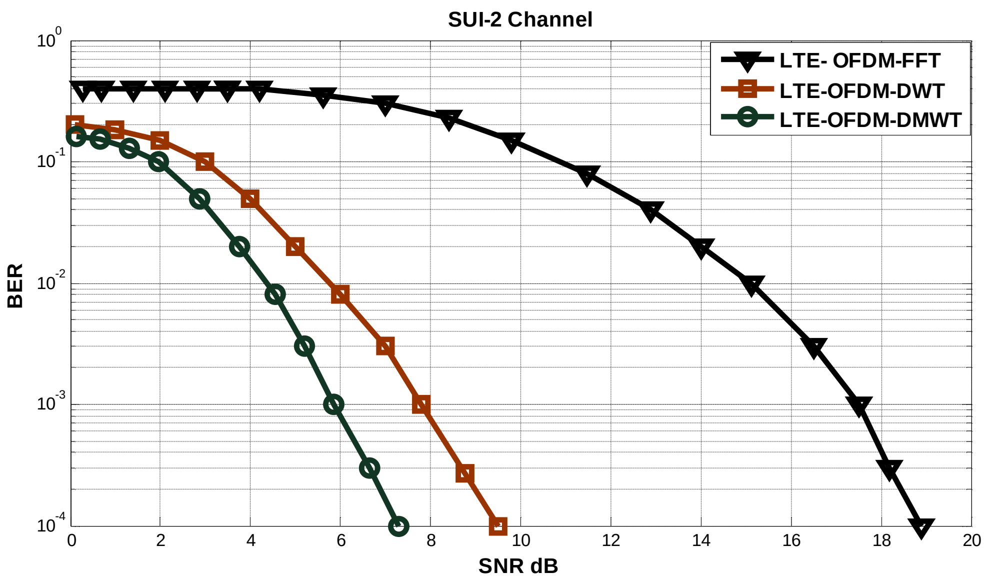

Fig .(3) BER performance of LTE Transceiver based OFDM DMWT in SUI-2 Channel

C. Performance of Modified LTE Transceiver in SUI-3 Channel:

In the SUI-3 channel, the results are depicted in **(Figure 4**) it can be seen that for BER=10^{-3} the SNR required for OFDM-DMWT is about 9 dB and for OFDM-DWT the SNR required is about 11.7 dB, while in OFDM-FFT the SNR required is about 22.5dB.From **(Figure 4**) it is found that the OFDM-DMWT outperforms significantly than OFDM-DWT and OFDM-FFT systems for this channel model.

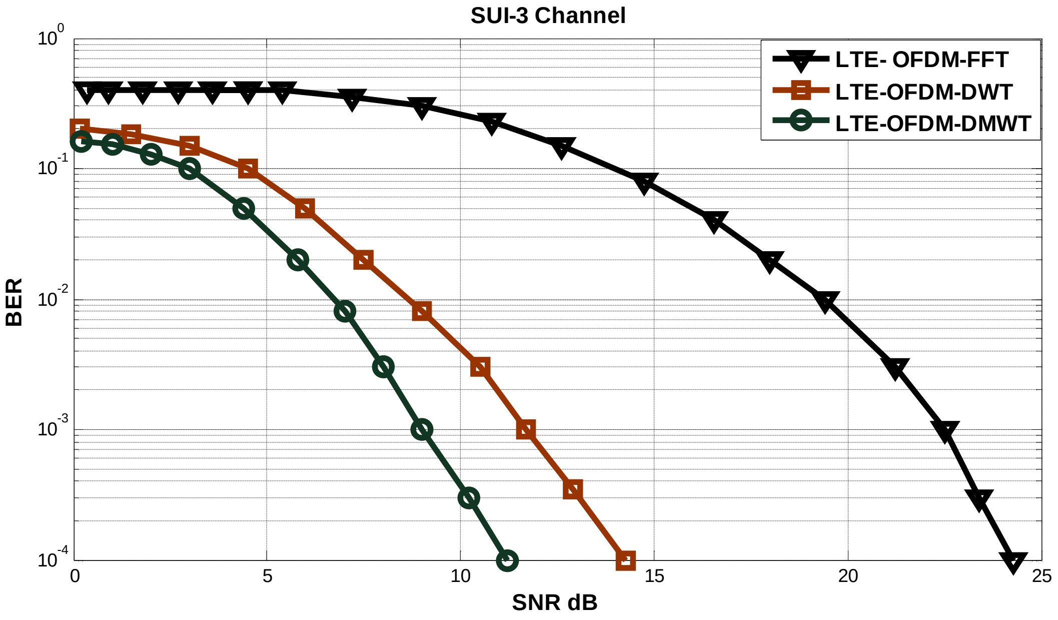

Fig .(4) BER performance of LTE Transceiver based OFDM DMWT in SUI-3 Channel

D. Performance of Modified LTE Transceiver in SUI-4 Channel

Using similar methodology as in the previous section, simulations for SUI-4 channel the result depicted in Figure 5 it can be seen that for BER=10^{-3} the SNR required for OFDM-DMWT is about 12.6 dB, and for OFDM-DWT the SNR required is about 15.6 dB, while in OFDM-FFT the SNR required is about 27.5dB. Also from (**Figure 5**) it is found that the OFDM-DMWT outperforms significantly than OFDM-DWT and OFDM-FFT systems for this channel model.

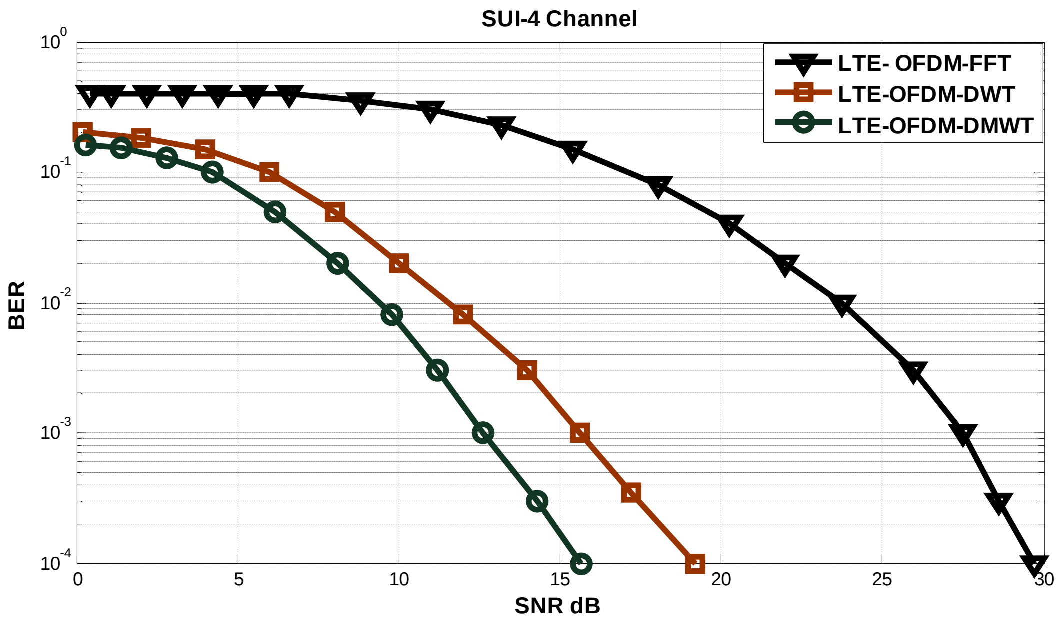

Fig .(5) BER performance of LTE Transceiver based OFDM DMWT in SUI-4 Channel

E. Performance of Modified LTE Transceiver in SUI-5 Channel

In this model, the results obtained with OFDM-DMWT, OFDM-DWT and OFDM-FFT it can be seen that for BER=10^{-3} the SNR required for OFDM-DMWT is about 15.75 dB and for OFDM-DWT the SNR required is about 19.5 dB while in OFDM-FFT the SNR required is about 32.5dB. From (Figure 6), it is found that the OFDM-DMWT best significantly other system for this channel model.

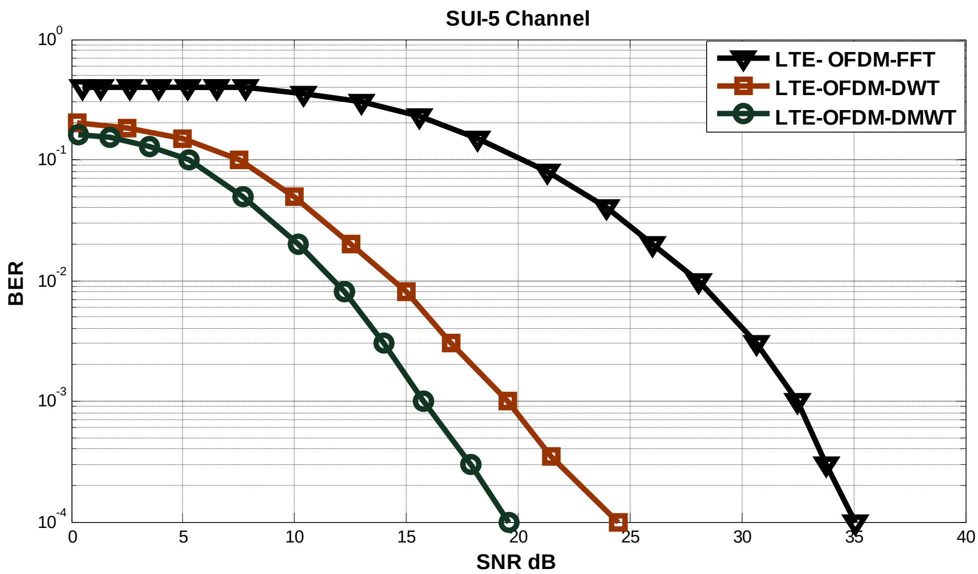

Fig .(6) BER performance of LTE Transceiver based OFDM DMWT in SUI-5 Channel

F. Performance of Modified LTE Transceiver in SUI-6 Channel:

In this state, the results obtained were hopeful. With OFDM-DMWT, OFDM-DWT and OFDM-FFT it can be seen that for BER=10^{-3} the SNR required for OFDM-DMWT is about 20.7 dB and for OFDM-DWT the SNR required is about 24.8 dB, while in OFDM-FFT the SNR required is about 37.75dB. From (**Figure 7**) it is found that the DMWT-OFDM better significantly other system for this channel model

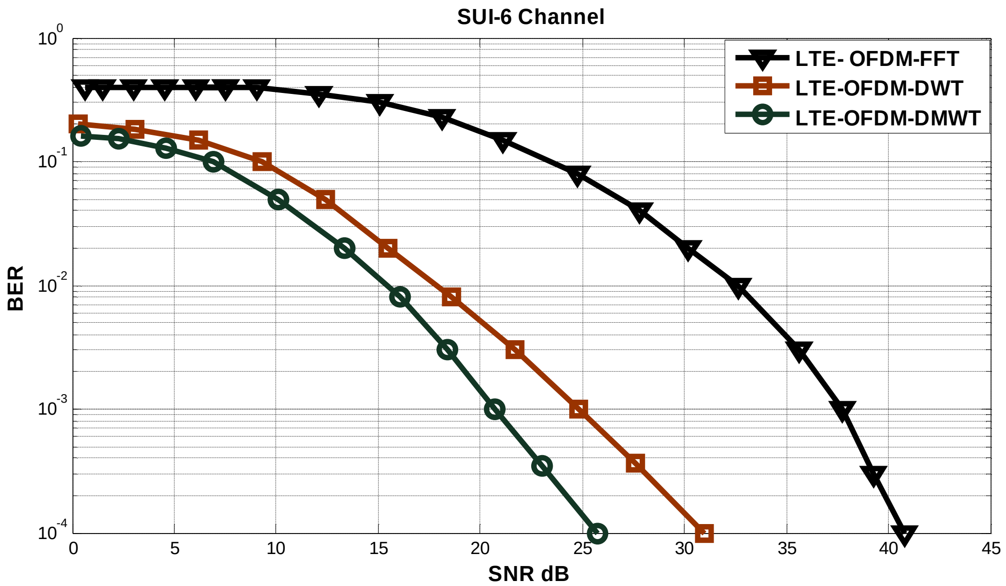

Fig .(7) BER performance of LTE Transceiver based OFDM DMWT in SUI-6 Channel

Table (2) Comparison between results

Channel for BER= 10^{-3}	SUI- 1 dB	SUI-2 dB	SUI-3 dB	SUI-4 dB	SUI-5 dB	SUI-6 dB
LTE OFDM- FFT	13.13	17.5	22.5	27.5	32.5	37.75
LTE OFDM- DWT	5.6	7.8	11.7	15.6	19.5	24.8
LTE OFDM- DMWT	3.6	5. 85	9	12.6	15.75	20.7

A number of important points can be conclude from **(Table 2);** the proposed model using DMWT-OFDM system was better than the DWT and FFT OFDM system. User-channel characteristics under which wireless communications is tested or used have important impact on the systems overall performance. It became clear that channels with larger delay spread are a bigger challenge to any system, the proposed model using DMWT-OFDM system proved its effectiveness in combating the multipath effect on the channels. In both large and small delay spread conditions of all SUI channels.

IV. Conclusion

In this paper, an effective study, analysis and evaluation of the LTE transceiver performance with different SUI channel has been carried out. The performance is evaluated with definitive metrics namely throughput and BER, considering the use of soft sphere decoders at the receiver, for higher order of modulation (16QAM), The vision of LTE Transceiver is therefore nothing less than an actual possibility and a true reality as this evaluation has demonstrated that the design goals and targets of LTE transceiver can be met with a high degree of reliability and certainty. This performance evaluation also provides useful information on LTE Transceiver planning, design and optimization for deployment. The key contribution of this paper is the implementation of the LTE transceiver based OFDM- DMWT structure PHY-layer which was proposed, simulated, and tested. These tests were carried out to verify its successful operation and possibility of implementation. It can be concluded that this structure achieves much lower bit error rates assuming reasonable choice of the bases function and method of computation. In SUI channels, Simulations proved that the proposed design achieved much lower bit error rates and better performance than OFDM-FFT and OFDM- DWT assuming reasonable choice of the bases function and method of computations. The proposed OFDM-DMWT system is robust for multipath channels and does not require cyclically prefixed guard interval, which means that it obtains higher spectral efficiency than conventional OFDM and OFDM based wavelet, therefore, this structure can be considered an alternative to the conventional OFDM, and can be used at high transmission rates.

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