MC-DS-CDMA System based on DWT and STBC in ITU Multipath Fading Channels Model

Nader Abdullah Khadam[1]*, Laith Ali Abdul -Rahaim[2]†, Arash Ahmadi [3], Seyed Vahab Makki[4] and Golamreza Karimimi[5]

[1]*Electrical Engineering Department, College of Engineering, University of Babylon, Babylon, Iraq, Email: Drnader89@yahoo.com*

[2]*Electrical Engineering Department, College of Engineering, University of Babylon,Babylon, Iraq*

Email: drlaihanzy@yahoo.com

[3]*Electrical Engineering Department, College of Engineering, Razi University, Kermanshah, Iran*

[4] *Electrical Engineering Department, College of Engineering, Razi University, Kermanshah, Iran*

[5]*Electrical Engineering Department, College of Engineering, Razi University, Kermanshah, Iran*

Abstract

In this paper, the performance of multicarrier direct sequence code division multiple access (MC-DS-CDMA) in fixed MC-DS-CDMA and Mobile MC-DS-CDMA applications have been improved by using the compensations of space time block coding and Discrete Fast Fourier transforms (FFT) or Discrete Wavelets transform DWT. These MC-DS-CDMA systems had been simulated using MATLAB 2015a. Through simulation of the proposed system, various parameters can be changed and tested. The Bit Error Rate (BERs) of these systems are obtained over wide range of signal to noise ratio. All simulation results had been compared with each other using different subcarrier size of FFT or DWT with STBC for 1,2,3 and 4 antennas in transmitter and under different ITU multipath fading channels and different Doppler frequencies (*fd*). The proposed structures of STBC-MC-DS-CDMA system based on (DWT) batter than based on (FFT) in varies Doppler frequencies and subcarrier size. Also, proposed system with STBC based on 4 transmitters better than other systems based on 1 or 2 or 3 transmitters in all Doppler frequencies and subcarrier size in all simulation results.

Keyword: MC-DS-CDMA, STBC, ITU Channels model, FFT, DWT, OFDM.

الخلاصة

في هذه الورقة، تم تحسين أداء النفوذ المتعدد بالتقسيم لرمز السلسلة المباشر متعدد الموجات (MC-DS-CDMA) في تطبيقات MC-DS-CDMA الثابتة والتطبيقات MC-DS-CDMA المتنقلة باستعمال تعويضات التشفير الزمنية الفضائية وتحويل فورير السريعة المنفصلة (FFT) أو تحويل المويجات المنفصلة DWT. وقد تمت محاكاة أنظمة MC-DS-CDMA باستخدام ماتلاب a2015. من خلال محاكاة النظام المقترح، يمكن تغيير المعالم المختلفة واختبارها. ويتم الحصول على معدل خطأ البيانات (BER) لهذه الأنظمة على مدى واسع من نسبة الإشارة إلى الضوضاء. وقد قورنت جميع نتائج المحاكاة مع بعضها البعض باستخدام حجم الموجة الحاملة الفرعية المختلفة FFT أو DWT مع STBCل 1،2،3 و 4 هوائيات في المرسل وفي مختلف قنوات الخبو في متعددة الممرات ITU ومختلف ترددات دوبلر (*fd*).

وتختلف الهياكل المقترحة لنظام STBC- MC-DS-CDMA على أساس الخليط (DWT) استنادا إلى (FFT) في ترددات دوبلر وحجم الموجة الحاملة الفرعية. كما أن النظام المقترح مع STBC يستند إلى 4 مرسلات أفضل من الأنظمة الأخرى القائمة على مرسلات 1 أو 2 أو 3 في جميع ترددات دوبلر وحجم الموجة الحاملة الفرعية في جميع نتائج المحاكاة.

الكلمات المفتاحية:– النفوذ المتعدد بالتقسيم لرمز السلسلة المباشر متعدد الموجات، نموذج القناة.

1- Introduction

Wireless communication is considered as one of the big engineering success stories over the last two decades. It is one of the rapidly changing fields that demand for faster data rates with longer transmission ranges to meet the standards of new applications [1]. Wireless technologies, such as cellular systems and wireless LANs, along with devices such as small portable computers, PDAs and mobile phones, have enabled the growth of wireless networking such that now mobile users expect to be able to use the same multimedia applications as fixed users. Satellite networks can provide global coverage for urban and remote areas with low traffic density. Cellular networks such as Universal Mobile Telecommunications Systems (UMTS) [2] can cover macro cells of rural or suburban areas with low or medium traffic density. An alternative for macro coverage is Wireless Metropolitan Area Networks (WMANs), such as IEEE 802.16 [3]. Multicarrier Direct sequence code division multiple access (MC-DS-CDMA) is one of the newest technologies in broadband wireless access which enables high speed fixed wireless communication. Broadband wireless access provides high-rate wireless communications between a fixed access point and multiple terminals [4]. MC-DS-CDMA is defined the standard of point-to-multipoint wireless networking. MC-DS-CDMA has the capability that connects to the ISP (Internet Service Provider) even when you are roaming outside home or office. The MC-DS-CDMA technology is becoming the way to avert the impending crisis of rural connectivity [5]. MC-DS-CDMA is intended for wireless metropolitan area networks (MAN). In a MAN, the MC-DS-CDMA can provide broadband wireless access (BWA) up to 30 miles (50 km) for fixed stations, and 3 - 10 miles (5 - 15 km) for mobile stations [6]. STBC Based MC-DS-CDMA based solutions are more flexible and secured. STBC based MC-DS-CDMA technology is 30 times faster than the third generation and 100 times faster than the wireless data rates. The two-main application of STBC Based MC-DS-CDMA are Fixed STBC Based MC-DS-CDMA, which are point to multipoint enabling broadband access to homes and offices, and Mobile STBC based MC-DS-CDMA, which offers the full mobility of cellular networks at true speeds. STBC Based MC-DS-CDMA provide fixed, nomadic, portable and mobile wireless broadband connectivity without the need for a direct line - of - sight [7]. One way to effectively combat the multipath channel impairments and still provide high-data rates in a limited bandwidth is the use of an orthogonal frequency-division multiplexing (OFDM) modulation method and multiple antennas at the transmitting end [8][9]. In short, OFDM delivers a wireless signal much farther with less interference than competing technologies [10]. Furthermore, the inter-symbol interference (ISI) and intercarrier interference (ICI) can be easily eliminated by inserting a cyclic prefix (CP) in front of each transmitted OFDM block [11]. Transmitter diversity can effectively combat multipath channel impairments due to the dispersive wireless channel that can cause deep fades in some sub channels [12][13]. The combination of the two techniques, OFDM and transmitter diversity, can further enhance the data rates in a frequency-selective fading environment. One attractive approach to transmit diversity is space time block coding [14][16] in which full diversity is achieved while a very simple maximum likelihood decoding algorithm is used at the decoder. An STBC is usually represented by a matrix each row represents a time slot and each column represents one antenna's transmissions over time. It was shown in [15] that there exists no complex orthogonal code which satisfies the full diversity and the full transmit rate simultaneously in more than 3 transmit antenna. In other words, not only can the two-antenna transmission system to get the full diversity and full transmission rate, and this symbol as planned Alamouti scheme [14]. Therefore, systems employing 3 or more transmit antennas need to sacrifice either diversity or transmission rate. The wavelet transforms (WT) is inserted in OFDM transmitter in order to introduce many versions for central carrier frequency providing some sort of frequency diversity that is capable of mitigating time variant fading channel. The wavelet transforms (WT) representation basically involves the decomposition of the signals in terms of small wave components called wavelets. It has the ability to compact the signal energy into few large coefficients. The original signal can be reconstructed perfectly from these few coefficients while suppressing the other coefficients without losing most of the features of the signal [8, 17, 18]. There are many previous works duels with the design and evaluation of potential gains of LTE or OFDM system. Reference [1] propose a novel approach to transmit parallel information through a terrestrial channel that could render it a more flexible alternative to OFDM in the future using Orthogonal Wavelet Division Multiplex but there work still have many limitations in BER performance and their step of design. Reference [2] propose the use of wavelet transform in (LTE) cellular systems with Mathematical expressions are derived to represent data rate in LTE downlink transmission based on Wavelet and Fourier Transforms and the get good results for small range of multicarrier. In reference [2], the performance of wavelet based OFDM (WOFDM) is studied and compared to that of conventional OFDM over multipath Rayleigh fading channels with exponential power delay profile. In reference [4], proposed a new method to design OFDM based on multiwavelet packet. The design has more much lower side lobes and flexible data rate and more band efficiency and lower peak-to-average power ratio. In reference [9], provides a way to improve the MIMO of OFDM system by proposing a new way to address the reduction of the proportion of peak-to-average power (PAPR) This reference adds only the using of MIMO technique in OFDM based wavelet transform. In reference [10], presents a new proposed structure for WIMAX based on Discrete Wavelets Transform (DWT) as multicarrier and Space Time Block Coding. The new proposed structures improve the performance of bit error rate (BER) in many channel models. Reference [12] show Discrete multiwavelet critical-sampling transform (DMWCST) has been proposed instead of fast Fourier transform (FFT) in the realization of the orthogonal frequency division multiplexing (OFDM) system. Reference [13] show turbo codes effectiveness as new approach for an OFDM system based on "Discrete Multiwavelet Critical-Sampling Transform OFDM-DMWCST" and how useful of using this technique to providing good BER performance at higher data rates. A proposed novel method based on the Multiwavelet Transform MWT for applying the OFDMA in LTE have been given in [14]. Reference [16] presents new technique to improve BER performance using "Space Time Block Coding Multicarrier Direct Sequence World Interoperability for Microwave Access STBC-MC-DS-WIMAX" based on "Discrete Wavelet Transform DWT and Phase Matrix (PM)" at high data rate. This paper given two models for phase matrix and did not using 2D transformations in phase matrix model. Reference [22] presents new proposed structures for LTE based on "Space Time Block Coding (STBC-LTE) and Discrete Wavelets Transform (DWT) as multicarrier". The purpose of these new proposed structures is to improve the performance of bit error rate (BER) compared with the conventional LTE. Reference [23] proposes DMWT based orthogonal modulator. By DMWT implementing, a good spectral efficiency and BER can be achieved compare to FFT and DWT. Reference [24] proposed a work to achieve good spectral efficiency and reduction of interference by introducing multiwavelet with MIMO technology to reduction. BER for a given

SNR. And also given Implementation of the proposed scheme in FPGA.

The structured of this paper is as follows. Section 2 describes the Proposed STBC based MC-DS-CDMA Structure. Section 3 presents Proposed STBC based MC-DS-CDMA Systems Simulation Results in terms of performance. Finally, the main conclusions of the work are summarized in Section 4

2. The Proposed STBC based MC-DS-CDMA systems:

The STBC based MC-DS-CDMA can implement using Discrete Fourier transform (DFT) or fast Fourier transforms (FFT) as complex exponential functions. So, it can be replaced by Discrete Wavelets transform (DWT). This replacement will decrease the interference level. From many research, it's found that uses of discrete orthonormal wavelets will reduce the ICI and ISI because the DWT will Strengthens the orthogonality between the subcarrier [10]. The simulation results in [11][12][13] show this idea of replacement FFT by DWT in some multicarrier system and calculate the BER performance with these orthogonal bases. The simulations of STBC Based MC-DS-CDMA system with new transform have shown the dependence of channel on the performance of DWT and FFT. The main idea for using DWT in STBC based MC-DS-CDMA system is the excellent spectral containment wavelet filters properties over Fourier filters. Under certain channel conditions, it has been found that DWT based MC-DS-CDMA does outperform better than FFT based MC-DS-CDMA. The implementations of MC-DS-CDMA by using FFT and its inverse operation IFFT in practice today (or DWT and IDWT) to substitute multicarrier operations. The Intersymbol interference (ISI) can be eliminated almost completely by adding a guard time interval in each packet of MC-DS-CDMA frame and this will cause a lose about 25%-40% from data rate and this is one of the disadvantage of FFT-MC-DS-CDMA. So, the uses of DWT instead of DFT will increase the orthogonality between the subcarrier of the MC-DS-CDMA packet and will be combat the narrowband interference and so no need to adding a guard time interval [14][15]. The second proposed idea to MC-DS-CDMA system is adding space time blocks coding (STBC) to the system. The STBC reduce the effect of multipath frequency selective Multipath fading channel. The aims this paper are designing a wireless communication system with least bit error rate (BER) for high data rate to fix stationary nodes and mobile users under multichannel models. These ideas will be implemented in MC-DS-CDMA system by adding STBC with more than two antennas and using DFT or DWT [1][16][17]. The proposed STBC-MC-DS-CDMA transceiver is shown in Fig. (1). All the type of space-time block codes with three transmitters or more has a coding rate of 1/2, to satisfy orthogonality condition. The space-time block code for four transmits antennas N = 4, with input symbols (S_1, S_2, S_3, S_4), the output will be over T = 8 symbol periods, thus the coding rate R =1/2 [18][19]. At a given symbol period, four antennas transmitted four signals simultaneously. At time slot T0, transmitted signal from first transmitter (T_{x1}) is denoted by S_1, the signal from second transmitter (T_{x2}) by S_2 and the signal from third transmitter (T_{x3}) by $S_3$and the signal from fourth transmitter (T_{x4}) by S_4. This process will go on in the same manner for each time slot until transmitting the last row of Table 1. This table has a rate of (1/2) and encode any complex signal constellations to transmit antennas [20][21]. For the four transmit and one receive antenna system, the channel coefficients are modeled by complex multiplicative distortions, h_1 for the first transmit antenna, h_2 for the second transmit antenna and h_3 for the third transmit antenna and h_4 for the fourth transmit antenna [22]. Since some models used in this work are time varying and frequency selective for wide band mobile communication systems, so a dynamic estimation of channel is necessary to compensate STBC Based MC-DS-CDMA signal [4]. The DWT computation in the implementation of STBC Based MC-DS-CDMA systems satisfy the multiresolution conditions. In this case, “the lower resolution coefficients can be calculated from the higher resolution coefficients by a tree-structured algorithm called filter-bank” [12]. The multiresolution idea is better understood as shown in [13][14]. The computation steps for a single level DWT and a single level IDWT for 1-D signal was shown in [23].

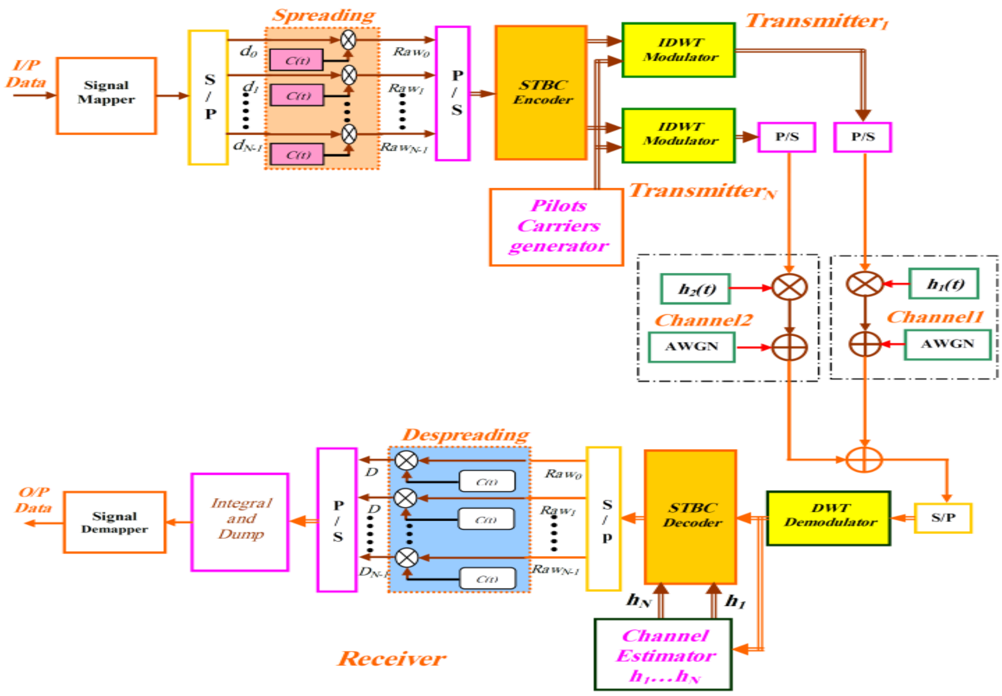

FIGURE (1) Proposed STBC- MC-DS-CDMA

Time slot	*Four transmit antennas*			
	Three transmit antennas			
	T_{x1}	T_{x2}	T_{x3}	T_{x4}
Slot T0	S_1	S_2	S_3	S_4
Slot T1	$-S_2$	S_1	$-S_4$	S_3
Slot T2	$-S_3$	S_4	S_1	$-S_2$
Slot T3	$-S_4$	$-S_3$	S_2	S_1
Slot T4	S_1^*	S_2^*	S_3^*	S_4^*
Slot T5	$-S_2^*$	S_1^*	S_4^*	S_3^*
Slot T6	$-S_3^*$	S_4^*	S_1^*	$-S_2^*$
Slot T7	$-S_4^*$	$-S_3^*$	S_2^*	S_1^*

Table (1): STBC mapping for four transmit antennas using complex signals

The channel transfer function estimation, and the inverse of it are applied to each STBC Based MC-DS-CDMA packet to reduce the channel effects, much like equalization [12]. There are two types of channel estimations, block type and comb-type pilot channel estimation as shown in [15]. After pilot-carrier (training sequence) is generated as a bipolar sequence {±1}, the receiver previously knows this sequence. So the system can estimate the channel transfer function h1(t) ,h2(t) ,h3(t) and h4(t). The inverse of these channels can be calculated. Using channels and there inverse to compensate the received packet and reduce the errors. The training sequence will be inserted in each STBC stream of the transmitter. Training sequences will be added in the receiver to form single training sequence, then spread the training sequences and used each one to estimate the corresponding channel transfer function h1(t), h2(t), h3(t) and h4(t) using the following equation:

$$H_{1or2,3,4}(k)=\frac{\text{Received Training Sample}_{1or2,3,4}(k)}{\text{Transmitted Training Sample}(k)}, ...k=0,1....,N/2-1 \qquad (1)$$

After this process h1(t) ,h2(t) ,h3(t) and h4(t) are estimated

2.1 Spreading Codes (Gold codes):

The Gold sequence set is best known binary sequences which have good correlation values. The Gold sequences is generated from a distinguish pair of *m*-sequences, *x* and *y*, having same length *Q*. Each Gold sequence set is generated by a modulo-2 sum (XOR) of *x* and cyclic shifts of *y*. The entire set of Gold sequences having a period of *Q* is given by

$$Sg=\{x,y,x\oplus y,x\oplus T^{-1}y,x\oplus T^{-2}y,.......,x\oplus T^{-(Q-1)}y\} \qquad ...(2)$$

where T-qy for q=1, 2, ….. Q-1, represents a cyclic shift of y by q chip intervals; and the symbol ⊕ represents modulo-2 addition [23]. the system employs a set of spreading sequences for each user. Each user, in turn, applies a different sequence from that set to each of his sub-carriers. These sequences are Pseudo Noise (PN) sequences. A binary sequence (with elements {0,1}) is mapped into a corresponding sequence of positive and negative pulses according to the relation

$$P_i\,(t)\;=(2b_i\;-1)\,p(t\;-it) \qquad ...(3)$$

Where pi(t) is the pulse corresponding to the element bi in the sequence with elements {0,1}. Spreading sequences can be bipolar or poly-phase. The different sequences which can be used as spreading sequences are Gold sequences, Kasami sequences, Poly phase sequences, Four Phase sequences, and Mutually Orthogonal Complementary sets of sequences (MOCS).

2.2. Signal model

Multiple accesses can be generated by using any spreading code to each user in the CDMA system. The used of DWT in multicarrier direct sequence CDMA is like using DWT in OFDM system [16]. The DWT symbols duration consider of T, bandwidth 20MHz, spanning Ns =256 samples (equivalent to 256 sub-carriers of OFDM) to be transmitted in different sub-bands [18]. The output of this operation can express in this equation:

$$y(k,n)\;=\;\sum_{M=1}^{4}H_M(k)s_M(k,n)\;+\;N(k,n), \qquad (4)$$

where N(k, n) (2 × 1) is a complex-valued additive white Gaussian noise vector with entities of zero mean and variance σ_Z^2; H(k) (4 × 1) denotes the channel frequency response according to the ITU channel models [18]. The channel assumed that certain frequency band keeps constant within the time interval of N OFDM symbols. The (i, j)th element of H(k) is given by

$$[H(k)]_{i,j} = X\sum_{l\geq 0}\sum_{m\geq 0}\alpha_{m,l}^{i,j} e^{-j2\pi k\Delta f(T_l^{i,j}+\tau_{m.l}^{i,j})} \qquad (5)$$

where Δf is the frequency difference between two adjacent subcarriers; $\alpha_{m,l}^{i,j}$ is the gain of multipath to cluster l and path m between the jth transmit antenna and the ith receive antenna; the lth cluster arrives at $T_l^{i,j}$ and its kth path arrives at $\tau_{m,l}^{i,j}$; X represents the shadowing of Rayleigh's distributed random variable, i.e., 20 log10 X ∝ N(0, σ_X^2), while the total energy contained in the terms $\alpha_{m,l}^{i,j}$, ∀m, l for each couple (i, j), is normalized to unity for each channel realization. For simplicity of notation, the indices of k and n, and denote hi,j = [H(k)]i,j and ci,j = $\sum_{l\geq 0}\sum_{m\geq 0}\alpha_{m,l}^{i,j} e^{-j2\pi k\Delta f(T_l^{i,j}+\tau_{m.l}^{i,j})}$, respectively. Thus, it shows that

$$h_{i,j} = Xc_{i,j} \qquad (6)$$

When the Alamouti coding is applied, the system is equivalent to independent single-input single-output systems defined as [15, 17]

$$u_j = \phi d_j + \varsigma_j \qquad (7)$$

Where $\phi = \sum_{i=1}^{2}\sum_{j=1}^{2}\left|h_{i,j}\right|^2$, dj denote original symbols before dispreading and ҫj is an equivalent complex Gaussian random variable with zero mean and variance ф σ_Z^2
From (5), it can rewrite $\phi = \sum_{i=1}^{2}\sum_{j=1}^{2}\left|c_{i,j}\right|^2$. Therefore, the output signal to noise ratio (SNR) in (7) can be expressed as

$$\gamma = \frac{\rho_s}{\sigma_z^2}X^2\chi \qquad (8)$$

Where $\chi = \sum_{i=1}^{2}\sum_{j=1}^{2}\left|c_{i,j}\right|^2$ and ρs denotes the averaged power of transmitted symbols.

Therefore, the SNR, (S/N), at the output of receiver, can be written as

$$\left(SNR = \frac{E\{X_I|\alpha_I^{(1)}\}^2}{VAR\{X_I|\alpha_I^{(1)}\}}\right) \equiv N^2 E_C\gamma \qquad (9)$$

For BPSK signaling, the evaluation of average BER for different scenarios can be approximately achieved by [26]:

$$P_{BER}^{su} = \int_0^\infty Q\left\{\frac{E(\xi_U)}{\sqrt{VAR(\xi_U)}}\right\} f\left(\alpha^{(1)}\right) \overbrace{d\alpha_1^{(1)} \ldots d\alpha_M^{(1)}}^{M\ folds}$$

$$= \int_0^\infty Q\left(\sqrt{N^2 E_{C\gamma su}}\right) f_\gamma(\gamma_{su}) d(\delta_{su}) \quad (10)$$

The Q(x) in (10) is the Gaussian Q-function. Hereafter, the average BER of an STBC BASED MC-DS-CDMA system over fading channel can be calculated from (10).

2.3. Propagation Loss Models in STBC BASED MC-DS-CDMA System

Choosing the right propagation models of wireless channel is critical in the design of any wireless networks. These models are used to predict the path loss between the transmitter and the receiver, which represents the combined effects on signal level attenuation due to the free space propagation, reflection, diffraction and scattering, etc. There are a number of empirical and statistical propagation models for outdoor and indoor environments, these models include the “Okumura-Hata model, COST 231-Hata Model, COST 231 Walfish-Ikegami model, Erceg Model, Stanford University Interim (SUI) Channel Models and ITU Path Loss Models” and the define of each one of them shown in [16][26]. Each propagation model is defined for a specific environment. In this paper, ITU Path Loss Models will be use.

2.3.1. ITU Path Loss Models

A set of commonly used experimental channel models and identified in the ITU-R Recommendation M.1225. Recommendation defines three different environments to test: “Indoor office, outdoor-to indoor pedestrian, and vehicular”. Since the spread of the delay can vary significantly, identifies the recommendation of the spread of two different delays for each test environment: low delay spread, and medium delay spread in all there are 6 cases. Each case of these have a specified multipath tap delay profile. The multipath have different number of components in each model. Table 2 show the list the specified parameters of [M.1225] in low delay spread like “ITU Channel Model for Indoor Office test, ITU Channel Model for Outdoor to Indoor and Pedestrian Test and ITU Channel Model for Vehicular Environment Test” [21].

Table 2: ITU Channel Models for Indoor Office and Outdoor to Indoor and Pedestrian and Vehicular Environment

Path #	ITU Channel Model for Indoor Office test		ITU Channel Model for Outdoor to Indoor and Pedestrian Test		ITU Channel Model for Vehicular Environment Test	
	delay	power	delay	power	delay	power
	in nsec	in dB	in nsec	in dB	in nsec	in dB
1	0	0	0	0	0	0
2	50	-3.0	110	-9.7	310	-1.0
3	110	-10.0	190	-19.2	710	-9.0
4	170	-18.0	410	-22.8	1090	-10.0
5	290	-26.0	-	-	1730	-15.0
6	310	-32.0	-	-	2510	-20.0

2.4. Channel Estimation of STBC based MC-DS-CDMA Systems

Since the radio channel is frequency selective and time varying for mobile communications system, and dynamic estimation of channel is necessary to retrieve STBC-based MC-DS-CDMA signal in the receiver side [12]. In block-type pilot-based channel estimation, as shown in figure (2), STBC Based MC-DS-CDMA channel estimation symbols are transmitted periodically, and all subcarriers are used as pilots. The task here is to estimate the channel conditions given the pilot signals and received signals, with or without using certain knowledge of the channel statistics. The receiver uses the estimated channel conditions to decode the received data inside the block until the next pilot symbol arrives. If the channel is constant during the block, there will be no channel estimation error since the pilots are sent at all carriers.

For least square (LS), the estimate channel frequency response is given by

$$H_e = X^{-1}Y \qquad (11)$$

and this estimated channel He is used to f estimated the approximate transmitted signal Xe(k)

$$X_e(k) = \frac{Y(K)}{H_e(K)}, \quad K = 0,1,\ldots\ldots,N-1 \qquad (12)$$

When the channel is slowly fading, channel estimation can be updated within a block using equalizer decision feedback each sub-carrier [12].

The comb-type pilot channel estimation has been introduced to satisfy the need for equalization when the channel changes fast, even in one STBC Based MC-DS-CDMA block. In comb-type pilot based channel estimation, as shown in Figure (2), for each transmitted symbol, N*p* pilot signals are uniformly inserted into *X(k)* according to the following equation:

$$X(k) = X(mL+l) = \begin{cases} X_p(m), l = 0 \\ \text{inf.}data, l = 1,\ldots\ldots\ldots,L-1 \end{cases} \qquad (13)$$

where L=number of carriers/Np and $X_P(m)$ is the m^{th} pilot carrier. The $H_P(k)$ is the channel frequency response at the pilot sub-carriers. The estimation of the channel at pilot sub-carriers based on LS estimation is given by

$$H_e(k) = \frac{Y_p(k)}{X_p(k)} \qquad ,k = 0,1,\ldots\ldots,N_p - 1 \qquad (14)$$

where $Y_P(K)$ and $X_P(K)$ are the received and transmitted signals at k^{th} pilot subcarrier respectively.

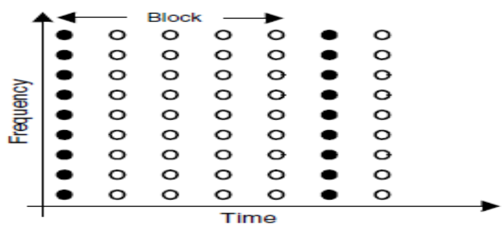

FIGURE (2) Block-Type Pilot Channel Estimation.

In comb-type pilot based channel estimation, an efficient interpolation technique is necessary in order to estimate channel at data sub-carriers by using the channel information at pilot sub-carriers.

3. Proposed Systems Simulation Results in ITU Channel Models

The simulation of the proposed STBC DWT-MC-DS-CDMA systems was done by MATLAB R2015a. The BER performance of the MC-DS-CDMA systems had been calculated and computed in AWGN and flat fading channel. The carrier frequency used is 5.8 GH for fixed and mobile STBC-MC-DS-CDMA system with three values of fd "10.7Hz with speed 2km/hr, 241.7Hz with speed 45 km/hr, and537Hz with speed 100 km/hr". Table (3) shows the parameters of the system used in the simulation.

Table (.3): Simulation Parameter

Parameter	Fixed MC-DS-CDMA	Mobile MC-DS-CDMA Scalable			
FFT or DWT size	256	128	512	1024	2048
Number of used data subcarriers	96	64	180	360	720
Modulation types	BPSK				
Cyclic prefix or guard time (Tg/Tb)	1/16				
Channel bandwidth (MHz)	20	20	20	20	20
Channel types	ITU Channel Models				
Carrier frequency *fc*	5.8GHz				

The proposed STBC-MC-DS-CDMA DWT and FFT systems had been simulated using MATLAB R2015a in three different test environments: "indoor office, outdoor-to indoor pedestrian, and vehicular according to ITU-R Recommendation" as shown in table (2). The BER performance of the proposed STBC based MC-DS-CDMA system considered in different type of channel models mentioned above, "the AWGN channel, the flat fading channel, and multipath fading channel". The other parameters the same in table 3 above to simulate the proposed STBC based MC-DS-CDMA systems.

Four antennas at the transmitter and one antenna at the receiver are sufficiently spaced, such that the channels between different transmit-receive antenna pairs are independent. Each channel is frequency-selective with respect to the overall system bandwidth, but each sub-band is assumed to be frequency non-selective with Rayleigh-distributed fade amplitudes. In selective multipath fading channel, many parameters like the influence of the attenuation, delay and maximum Doppler shift of the echo considered to compare the BER performance of the proposed systems. In these cases of channels, the frequency components of the transmitted signal are affected by uncorrelated changes, where the parameters of the channel in this case corresponding to multipath, the six paths are chosen, the Line of Sight (LOS) is one of them and the five others paths are the reflected paths.

3.1. ITU Indoor Office Channel Model:

The model of this channel was shown in table (2) first column. The simulation had been done to all scenario of STBC-MC-DS-CDMA with DWT and FFT and the simulation result shown in fig. (3) to fig. (6). In fixed STBC-MC-DS-CDMA system, it is noted that the proposed STBC-MC-DS-CDMA based on DWT performs better than STBC-MC-DS-CDMA based on FFT. The SNR at a BER 10-4 is about 19 dB for STBC-MC-DS-CDMA based on DWT with 4 antennas and about 37 dB for STBC-MC-DS-CDMA based on FFT with also using 4 antennas. A gain about 18 dB has been achieved by using DWT way over using FFT system and this value is much need in the communications systems to save transmitted power and increase data rate.

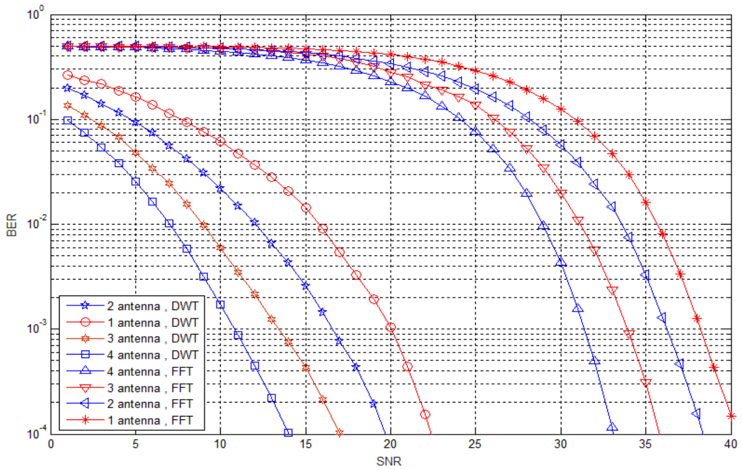

FIGURE (3). SNR Versus BER to Fixed STBC-MC-DS-CDMA-256 subcarriers in ITU Indoor Office Channel Model

For mobile STBC-MC-DS-CDMA system, the results of 128 and 1024 subcarriers (the size of DWT or FFT) only have been found in three cases of MDS (10.7 Hz, 241.7 Hz and 537 Hz). It can be seen from fig. (4) (for small MDS=10.7 Hz) that the proposed STBC-MC-DS-CDMA based on DWT still performs better than STBC-MC-DS-CDMA based on FFT and the system of STBC still gives good results for small and large subcarriers (128 and 1024 respectively). The SNR at a BER 10-4 is about 12 dB for 4 antennas in proposed system of 128 and about 17 dB in 1024, while it’s not reach the desired value in STBC-MC-DS-CDMA based on FFT with 128 and 1024 subcarriers. In addition, a wide improvement span is obtained for all values of SNR in these systems. It can be seen from figures (5a), (6a) for 241.7 Hz and (5b) ,(6b) for 537 Hz that the STBC- MC-DS-CDMA based on DWT is performing better than the STBC-MC-DS-CDMA based on FFT but without STBC, MC-DS-CDMA based on DWT is better because of the effect of STBC is eliminated in high Doppler frequency larger than 50 Hz and the same for other systems .

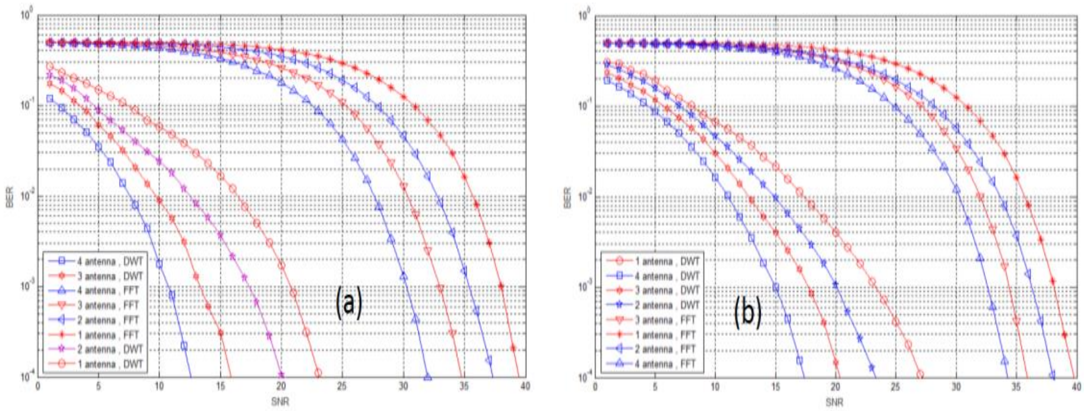

FIGURE (4). SNR Versus BER to Mobile STBC-MC-DS-CDMA ITU Indoor Office Channel Model - MDS=10.7Hz; a) -128 subcarriers, b) -1024 subcarriers

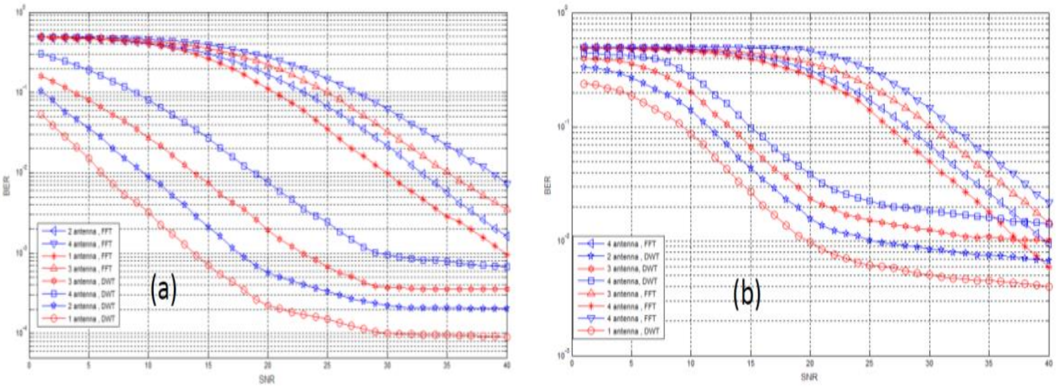

FIGURE (5). SNR Versus BER TO Mobile STBC-MC-DS-CDMA-128 subcarriers in ITU Indoor Office Channel Model; a) MDS=241.7Hz, b) MDS=537Hz

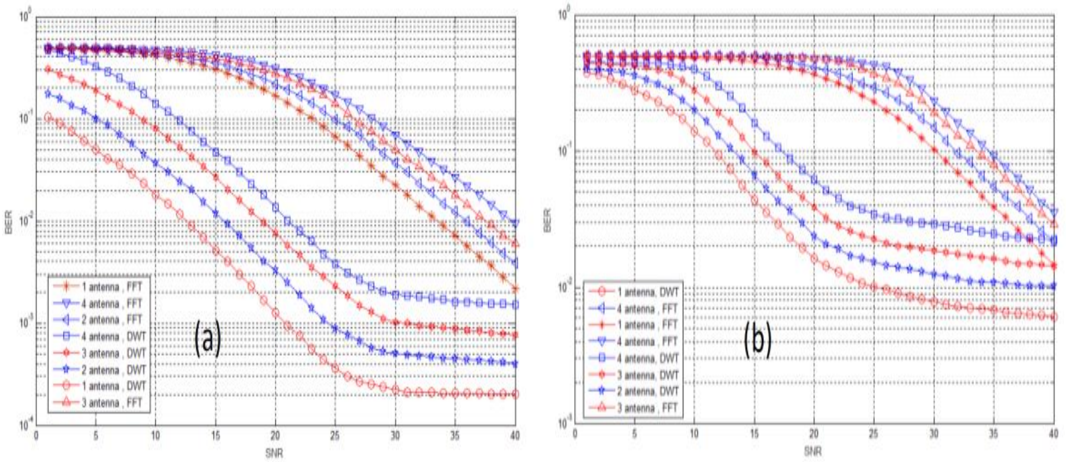

FIGURE (6). SNR Versus BER to Mobile STBC-MC-DS-CDMA-1024 subcarriers ITU Indoor Office Channel Model; a) MDS=241.7Hz, b) MDS=537Hz

3.2. ITU Channel Model for Outdoor to Indoor and Pedestrian Test

In this section the results of ITU Channel Model for Outdoor to Indoor and Pedestrian Test will be simulated according to the table (2) second column. For fixed proposed STBC-MC-DS-CDMA system, it is clear from Fig. (7) that BER performance of STBC-MC-DS-CDMA based on DWT is better than STBC-MC-DS-CDMA based on FFT system. The SNR at a BER=10-4 is about 21dB for 4 antennas at proposed system and cannot been reached for STBC-MC-DS-CDMA based on FFT system and this will give losses in the gain about 20 dB for proposed system against STBC-MC-DS-CDMA with FFT system when compared with ITU Channel Model for Outdoor to Indoor and Pedestrian Test.

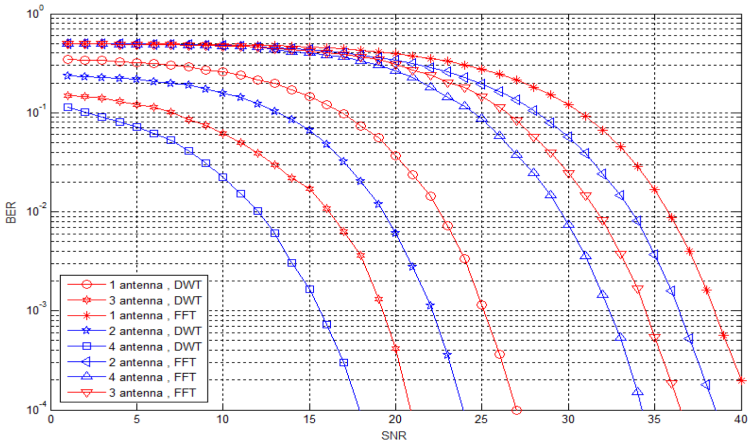

FIGURE (7). SNR Versus BER to Fixed STBC-MC-DS-CDMA-256 subcarriers in ITU Channel Model for Outdoor to Indoor and Pedestrian Test

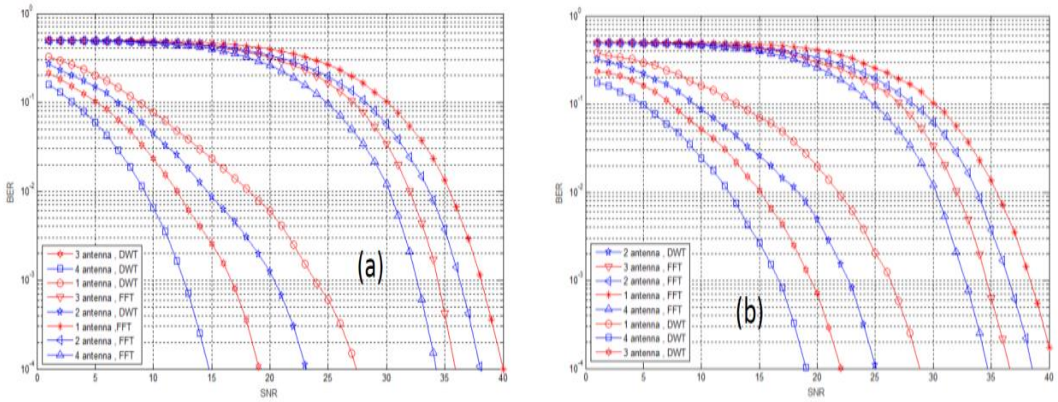

FIGURE (8). SNR Versus BER to Mobile STBC- MC-DS-CDMA- in ITU Channel Model for Outdoor to Indoor and Pedestrian Test - MDS=10.7 Hz; a) 128 subcarriers, b) 1024 subcarriers

Also for mobile system, the results have simulated only for 128 and 1024 (the size of DWT or FFT) in three cases of MDS=(10.7 Hz, 241.7 Hz and 537 Hz). From figures (8) and (10), it can be seen that the proposed DWT based STBC-MC-DS-CDMA still performs better than FFT based STBC-MC-DS-CDMA and the system of STBC still gives good results. The SNR at a BER 10-4 is about 15 dB for 4 antennas at proposed system of 128 and about 19 dB for 1024, while it is cannot been reach in FFT based STBC-MC-DS-CDMA system of 128 and 1024, this means losses in gain is about 20 dB for the proposed STBC-MC-DS-CDMA system and cannot been reach for the traditional system in comparison with the ITU Channel Model for Outdoor to Indoor and Pedestrian Test at MDS of 10.7 Hz. It can be seen from figures above that the losses will be increased for both systems due to Doppler Effect.

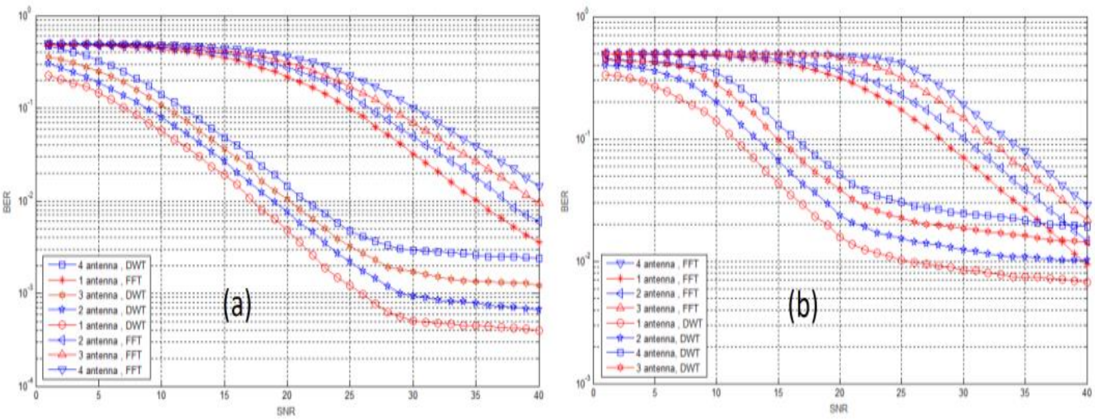

FIGURE (9). SNR Versus BER to Mobile STBC-MC-DS-CDMA in ITU Channel Model for Outdoor to Indoor and Pedestrian Test -128 subcarriers; a) MDS=241.7Hz, b) MDS=537Hz.

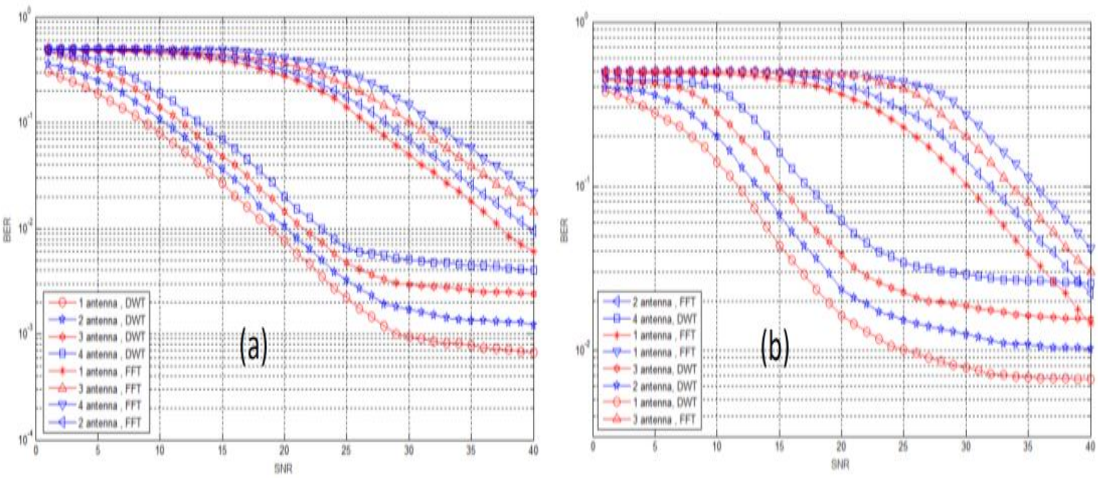

FIGURE (10). SNR Versus BER to Mobile STBC-MC-DS-CDMA-1024 subcarriers in ITU Channel Model for Outdoor to Indoor and Pedestrian Test; a) MDS=241.7Hz, b) MDS=537Hz.

3.3. ITU Channel Model for Vehicular Environment Test

In this section the results of ITU Channel Model for Vehicular Environment Test for vehicular test environment will be achieved. In this case the results will be worse than two other channel models because there are six cases with higher relative delay. For fixed MC-DS-CDMA, it can see that the proposed DWT based STBC-MC-DS-CDMA still performs better than FFT based STBC-MC-DS-CDMA. The SNR at a BER 10-4 is about 21 dB for 4 antennas at the proposed system and non-at FFT based STBC-MC-DS-CDMA.

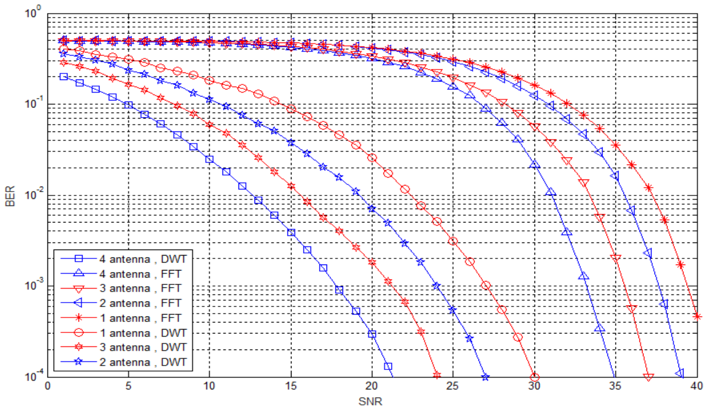

FIGURE (11). SNR Versus BER to Fixed STBC-MC-DS-CDMA-256 subcarriers in ITU Channel Model for Vehicular Environment Test

For mobile system, the effect of MDS will appear and will directly effect on the system of STBC in the case of MDS higher than 50 Hz and the BER will increase as the Doppler frequency increases in both models. This will lead to results worse than the results of ITU Channel Model for Vehicular Environment Channel model as display in the below figures. All the results present in paper computed after testing the system by transmitted over 10M bits.

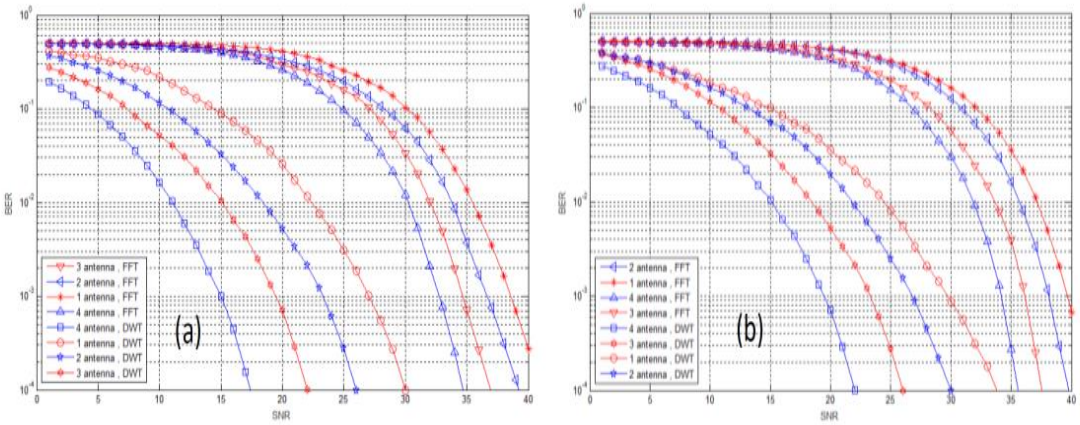

FIGURE (12). SNR Versus BER to Mobile STBC- MC-DS-CDMA- in ITU Channel Model for Vehicular Environment Test - MDS=10.7Hz; a) 128 subcarriers, b) 1024 subcarriers

The BER performance of AWGN channel as show from the simulation results is the best of all channels as it has the lowest bit error rate (BER) and power losses with using BPSK modulation schemes. The amount of noise occurs in the BER to this channel type is quite slighter than flat fading channels models. Simulations proved that the accumulation STBC and DWT improved the bit error rates BER performance than accumulation STBC and FFT in MC-DS-CDMA system. The STBC-MC-DS-CDMA with FFT shows that it requires a longer time adapting to noise and performs poorly to system parameter changes. It can be concluded from the comparison of the performance results of new STBC-MC-DS-CDMA based DWT structure with the STBC-MC-DS-CDMA based FFT that for the same model it gives a robust implementation and still performs better BER performance than FFT in all values of the Doppler frequencies model of flat fading Channel. In the case of selective multipath fading channel, the simulation done in three cases of propagation losses model according to MC-DS-CDMA channels models. Therefore it clear from the simulation results that DWT based STBC-MC-DS-CDMA performs better than FFT based STBC-MC-DS-CDMA ,but STBC advantage will be eliminated in high Doppler shift like at 241.7 Hz and 537 Hz because of each antenna attenuate each other and the losses in ITU Channel Model for Vehicular Environment Test is the worst case among other channel models, because of the combined effects of signal level attenuation in vehicular channel model due to the free space propagation, reflection, diffraction and scattering is more than those occurring in the other two channel models.

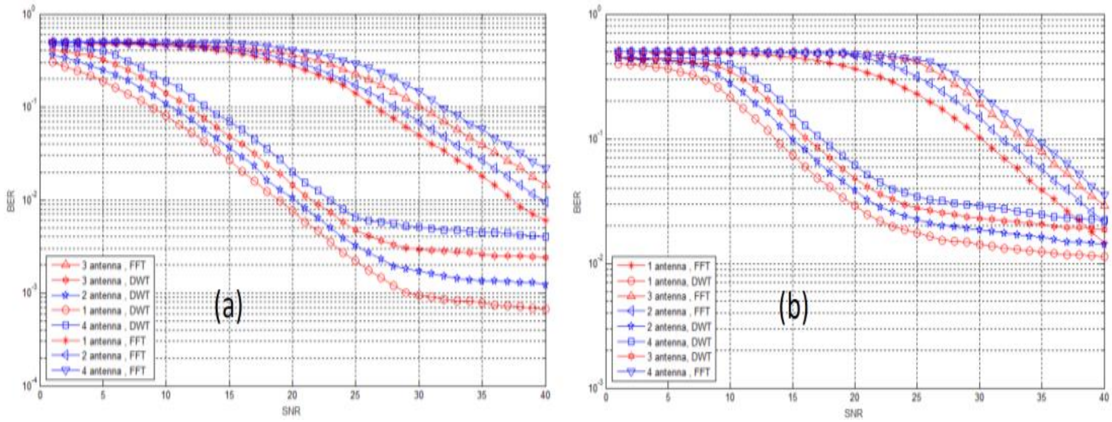

FIGURE (13). SNR Versus BER to Mobile STBC-MC-DS-CDMA-128 subcarriers in ITU Channel Model for Vehicular Environment Test; a) MDS=241.7Hz, b) MDS=537Hz.

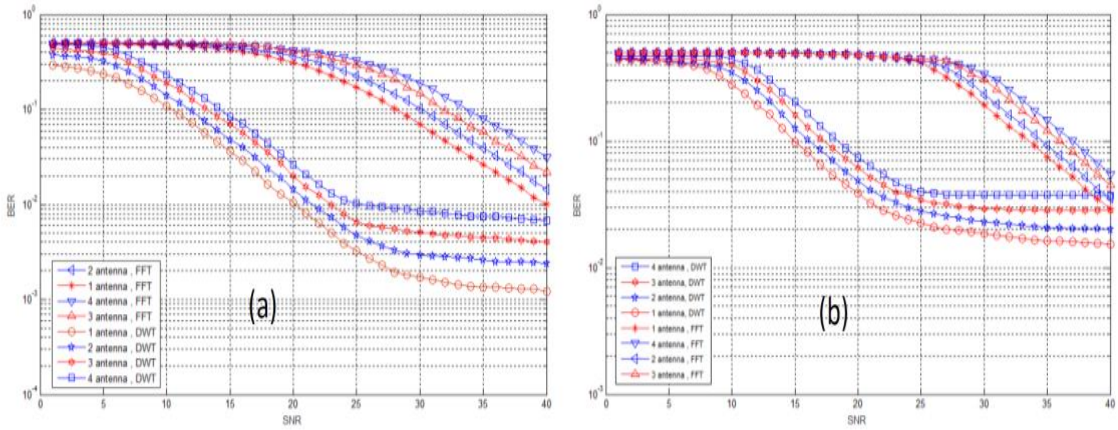

FIGURE (14). SNR Versus BER to Mobile STBC-MC-DS-CDMA-1024 subcarriers in ITU Channel Model for Vehicular Environment Test; a) MDS=241.7Hz, b) MDS=537Hz.

All the results present in this section are summarized in table (4) for Multipath fading channel. These results were computed after testing the system used transfer over 10M symbols and the tables present only the SNR that get BER of (10-4).

Table (4): SNR of the system that get BER of (10-4) for Selective Fading Channel

System type	Size	Channel model	MDS(Hz)	FFT				DWT			
				1ant. (dB)	2ant. (dB)	3ant. (dB)	4ant. (dB)	1ant. (dB)	2ant. (dB)	3ant. (dB)	4ant. (dB)
Fixed	256	Ind.	-	non	non	non	37	27	25	21	19
		Out.	-	non	non	non	non	32	27	25	21
		Veh.	-	non	non	non	non	38	31	25	21
Mobile	128	Ind.	10.7	non	non	non	non	30	21	15	12
			241.7	non	non	non	non	non	non	non	non
			537	non	non	non	non	non	non	non	non
		Out.	10.7	non	non	non	non	35	30	21	14
			241.7	non	non	non	non	non	non	non	non
			537	non	non	non	non	non	non	non	non
		Veh.	10.7	non	non	non	non	35	30	24	19
			241.7	non	non	non	non	non	non	non	non
			537	non	non	non	non	non	non	non	non
	1024	Ind.	10.7	non	non	non	non	32	25	21	17
			241.7	non	non	non	non	non	non	non	non
			537	non	non	non	non	non	non	non	non
		Out.	10.7	non	non	non	non	35	30	24	19
			241.7	non	non	non	non	non	non	non	non
			537	non	non	non	non	non	non	non	non
		Veh.	10.7	non	non	non	non	39	32	26	21
			241.7	non	non	non	non	non	non	non	non
			537	non	non	non	non	non	non	non	non

4. Discussion of Simulation results:

In the case of multipath fading channel, we can see there are three cases of propagation losses model according to the ITU-R of STBC based MC-DS-CDMA channel. Channel model is helpful in determining the mechanisms that the deployment in an environment that is happening, which is useful in the development of the communications system in return. By studying the details of how to deploy a signal from the transmitter to the receiver for a number of pilot sites, can be developed in a form highlights the important characteristics due to the indoor environment. In experimental models, and all the environmental effects are taken into account implicitly, regardless of whether they can be identified separately. This is the main feature of these models, due to the adoption of deterministic models on the principles of physics that can be applied to different environments without affecting the accuracy. Propagation within a building (indoor) is yet another problem of interest and has a source within the building. Indoor propagation varies greatly with the type of buildings, and the position of access points within the building – how far from wall, how high compare to obstructions and furniture and is different when signal comes from the outside because the signal will affect by indoor multipaths and outdoor multipaths. Vehicle Loss given the mobile nature of wireless communications, penetration loss into vehicle is important as well. Precise characterization of in-vehicle penetration is difficult as well, and varies with type of vehicles, frequency, polarization, antenna placement in the vehicle, and direction of incidence. Therefore , we can see from table (4) that DWT performs better than FFT ,but STBC is eliminated in high Doppler shift like at 241.7 Hz and 537 Hz because of each antenna attenuate each other and the losses in vehicular channel model is the worst case among other channel models because of the combined effects of signal level attenuation in vehicular channel model due to the free space propagation, reflection, diffraction and scattering is more than those occurring in the other channel models. It is clear when bit rate increases the bit error rate increase in all systems, and

DWT system performs better than FFT system because DWT helps to reduce the interference and this will help to maintain the orthogonality between adjust subcarriers and provide higher power, also STBC provide better performance due to use number of transmitter antennas which resist the effect of fading and reduce the BER when we increase the transmitting of data rate.

5. Conclusion

This paper presents a simulation of the proposed MC-DS-CDMA system base FFT then improved its BER performance and diversity by using space time block coding with two, three and forth antennas. Then DWT have been replacing FFT also to improve BER performance and spectrum Efficiency. So, the combination STBC and DWT are given better results especially with four antennas in transmitter this is a reflection of the fact that the orthogonal base of the wavelets is more significant than the orthogonal bases used in FFT and the orthogonal multiple copies of data due use of STBC. Also, this paper focuses on using different multicarrier size (128, and 1024) for mobile wireless communications and 256 for fixed wireless communications. From simulation results when multicarrier size increase BER performance decreased. Also, this paper shows the effect of change Doppler frequencies for different value from walking speed (10.7 Hz) to speed of car in high way (537 Hz) in mobile wireless communications for the proposed systems and also found that when increase Doppler frequency the BER performance of proposed systems will decreased. So, from all simulation results it’s clear that the proposed STBC-MC-DS-CDMA based on DWT was the better system among all system in flat fading channel models at all Doppler frequencies and multicarrier size in fixed and mobile wireless application.

In this paper, first the companion of DWT and STBC in MC-DS-CDMA structure has been designed and simulated for the first time. These simulations confirm successful operation and these structures are possibility of implementation. Also, simulation results demonstrate BER performance enhancement that could achieve by combining the DWT and STBC techniques with very little decoding complexity to STBC based MC-DS-CDMA system. As a result, It is clear that proposed STBC-MC-DS-CDMA structure achieves much lower BER in AWGN, flat fading channel and selective Multipath fading channel. Therefore, this structure can be considered as an alternative to the conventional STBC based MC-DS-CDMA system. Also, it is well known that the worst scenario to all of the STBC-MC-DS-CDMA systems, in terms of performance, occurs when the system parameter is changed. The conventional scheme with FFT shows that it requires a longer time adapting to noise and performs poorly to system parameter changes. It can be concluded from the comparison of the performance of this new structure with the FFT that for the same model it gives a robust implementation. Also in selective Multipath fading channels models, the simulation results are presented by isolating individual propagation effects, to discover which channel parameters have the most significant impact on the performance. In Doppler shift, it is seen that DWT based STBC- MC-DS-CDMA still performs well better than FFT based STBC- MC-DS-CDMA, but STBC advantage will be eliminated or lost in high Doppler shift above 50 Hz because of each antenna attenuate each other and the losses in ITU Channel Model for Vehicular Environment Test is the worst case among other channel models ITU Channel Model for Indoor Office test and ITU Channel Model for Outdoor to Indoor and Pedestrian Test.

References

[1] Linfoot, Scott L., M.K.I. and Al-Akaidi, M.M., 2007, "Orthogonal wavelet division multiplex: an alternative to ofdm". *IEEE Transactions on Consumer Electron- ics"*, **53** (2), 278–284.

[2] Shadmand, Amir, e.a., 2011, "Wavelet-based downlink scheduling and resource allo- cation for long-term evolution cellular systems". *IET communications,* **5** (14), 2091– 2095.

[3] Kumbasar, V. and Kucur., O. , 2012," Performance comparison of wavelet based and conven- tional ofdm systems in multipath rayleigh fading channels." Digital Signal Processing, vol22, no 5, pp 841-846.

[4] Yan, X. and Liu., G. , 2004," Multiwavelet packet based OFDF system." Circuits and Systems, 2004. Proceedings. The 2004 IEEE Asia-Pacific Conference on. Vol. 2. IEEE.

[5] Keita I., D.U. and D., S., 2007, "performance evaluation of wavelet ofdm using ascet". *IEEE*.

[6] C., Y.L. and T., S.L., 2012,"a low-latency scanning with association mechanism for real-time communication in mobile wimax". *IEEE Transactions On Wireless Communications,*.

[7] Qinghua Shi, Yong Liang Guan, Y.G. and Law, C.L., 2009, "receiver design for multicarrier cdma using frequency-domain oversampling". *IEEE Transactions on Wireless Communications*, **8** (5).

[8] Shi, J. and Yang, L.L. , Oct. 2014," Novel subcarrier-allocation schemes for downlink mc ds-cdma systems," in *Wireless Communications, IEEE Transactions on*, vol.13, no.10, pp.5716-5728.

[9] Daoud O. , 2012, Performance improvement of wavelet packet transform over fast fourier transform in multiple-input multiple-output orthogonal frequency division multi- plexing systems." IET communications, vol 6, no 7, pp765-773.

[10] Abdul-Rahaim, L.A. , 2015,"Dwt based wimax system with four stbc transmit antennas in multipath fading lte channels models." International Journal of Advancements in Computing Technology 7, no. 6, 1.

[11] Ali, A., Abdul-Rahaim, L., and Ali, A.A.; Abdul-Rahaim L. , July 2008, Discrete wavelets transform based space time block code multicarrier direct sequence cdma. IEEE SSD 2008. 5th International Multi-Conference in Systems, Signals and Devices, pp. 1–4–20–22.

[12] Dawood, Sameer A., *et.al.*, 2015. "Discrete multiwavelet critical-sampling transform-based ofdm system over rayleigh fading channels." Hindawi, Mathematical Problems in Engineering.

[13] Dawood, Sameer A., F.M. and Anuar., M.S. , 2015, Enhancement the performance of ofdm based on multiwavelets using serial-and parallel-turbo codes."

TELKOMNIKA (Telecommunication Computing Electronics and Control), vol 13, no.4, pp1225-1232..

[14] Chisab, R.F. and Shukla, C.K. , 2014."The downlink 4g-lte in fading channel based on the multiwavelet transform." Computational Intelligence and Communication Networks (CICN), 2014 International Conference on. IEEE.

[15] Şimşir, Ş. and Taşpınar, N., 2017. Pilot tones design using Grey Wolf Optimizer for OFDM–IDMA system. Physical Communication, 25, pp.259-267.

[16] Bagadi, K.P., Annepu, V. and Das, S. , 2016,. Recent trends in multiuser detection techniques for SDMA–OFDM communication system. Physical Communication, 20, pp.93-108.

[17] Nagaradjane P., Rajan, Y.A., Muralidharan, P. and Sarathy, S.K.V., 2013 . Performance of multi-user transmitter preprocessing assisted MIMO system over correlated frequency-selective channels. Physical Communication, 7, pp.61-72

[18] Zakaria, R. and Le Ruyet, D., 2014. Intrinsic interference reduction in a filter bank-based multicarrier using QAM modulation. Physical Communication, 11, pp.15-24

[19] Zarrinkoub, H. 2014 "understanding lte with matlab: from mathematical foundation to simulation, performance evaluation and implementation". John Wiley & Sons, Ltd.

[20] P. Tong, R.C.d.L. and Schmeink, A. , Jul. 2013, "adaptive distributed space-time coding based on adjustable code matrices for cooperative mimo relaying systems,". IEEE Trans. Commun., 61 (7), 2692–2703.

[21] (3GPP), T.G.P.P., 2009, Evolved universal terrestrial radio access (e-utra)physical channels and modulation. standard specifications TS 36.211,.

[22] Abdul-Rahaim, L.A., 2015, "Enhancement lte system based on dwt and four stbc transmit antennas in multichannel models". American Journal of Networks and Communications 4, (2), 10–20.

[23] Ahmadinejad A. and Talebi S., 2016, "Performance evaluation of chaotic spreading sequences in a multi-user mimo-ofdm system". Physical Communication, (19), 11–17.

[24] Lavanya, R. Vidhya, and M. Madheswaran, 2014 . "Wimax (IEEE 802.16 m) system based on space time block code and discrete multiwavelet transform and implementation in FPGA." Telecommunication Systems, vol 56, no. 3, pp 327-334.