Design of Fixed WiMAX Transceiver on SUI Channels Based Wavelet Signals

Md Aboud Kadhim, Hazim Salah, Abdulsatar, Tahseen Flaih Hasan

Abstract— *As the application for wireless communications increases, even in wideband and fast fading channels, there is always a need to develop systems that are more efficient and robust. The work done in this paper is our effort in this direction. Based on the wavelet transform, we develop an OFDM WiMAX system with good performance for Stanford University Interim (SUI) channels rich in multipath. As of fundamental wavelet transform characteristics and expressing the temporal and frequency information in two independent dimensions, delay and scale, we develop a theoretical system model for SUI channels. Considering the computational complexity, the models are designed using the Haar wavelet transform. Using the wavelet transform to calculate the channel delay information is the core component of the system .It is found that proposed wavelet design to attain much lower bit error rates, increases signal to noise power ratio (SNR), and can be used as an alternative to the conventional OFDM WiMAX. The proposed OFDM system was modelled tested, and its performance was found under different SUI channel models. This paper performs a new approach to the adaptation of the Fixed WiMAX IEEE802.16d base band, OFDM based on wavelet)DWT-OFDM) in SUI channel.*

Index Terms— *WiMAX, SUI, OFDM, DWT, IDWT, FFT, IFFT.*

I. INTRODUCTION

WiIMAX is one of the hottest broadband wireless technologies around today. WiMAX systems are expected to deliver broadband access services to residential and enterprise customers in an economical way. The facility to remove delay spread**,** Inter Symbol Interference **(**ISI**)** and multi-path in a proficient manner allows for higher data rate throughput. It is simpler to equalize the individual Orthogonal Frequency Division Multiplexing (OFDM) carriers than it is to equalize the broader single carrier signal. For these entire reasons modern international standard such as those set by Fixed WiMAX IEEE 802.16d, have created Orthogonal Frequency Division Multiplexing (OFDM) as the ideal technology. Multi carrier modulation (MCM) has attracted considerable attention in recent years as a practical and viable technology for high-speed data transmission channels [1], [2]. Orthogonal frequency division multiplexing (OFDM) is widely used in wireless communication. Cyclic prefix samples are added to each block of data to compensate for multipath channel distortion [3]. Cosine modulated filter banks (CMFBs) working at maximally decimated rate, on the other hand, are widely used for signal compression as well as realization of Trans multiplexer systems [4]. Their application to MCM [1] has been studied by many researchers. The major disadvantage with discrete wavelet multi-tone (DWMT) is its computational complexity. A set of special equalizers, one for each sub-channel, is needed. These equalizers are referred to as post combiners [1], [5]. Adaptive modulation provides the possibility of decreasing the complexity. In the general Pilot Symbol Assistant Modulation (PSAM) systems, pilot symbols are sent to obtain the channel status information and additional power is needed for sending the pilot symbols. Wavelet theory is the mathematics of modeling a signal, system, or process with a set of scaled and shifted versions of the basis functions called wavelets [6]. It can be used in many applications such as wireless communications, image processing, control systems, etc [7], [8], [9]. The fundamentals of wavelet theory are scaling and translating. Wavelets can be used to represent objects, such as signals and processes, or operations, such as channels, filters and systems. Two main aspects of analyzing signals with wavelet transform are signal decomposition and reconstruction. When using the wavelet transforms to analyze the system, we can analyze the shifting and scaling of the signal that passes through the system. These two properties enable us to detect multiple shifts or delays in the channel as well as equalize the multipath channel in wireless communications .In wireless communications, the wireless channel may be rich in both Doppler shift and delay with Doppler shift and delay coexisting in a single path. If the channel is a single path channel, the received signal can be moved back to the desired frequency. However, wireless channels typically contain multiple paths, and the overlapping of paths from multiple signals makes detection difficult. An alternative way to look at a communication system is to consider that the transmitted symbol can be seen as one pixel in the wavelet domain using that signal as the mother wavelet: an image with one dimension representing delay, another representing scale. The other transmitted symbols are the scaled and delayed versions of the basic transmitted symbol. The channel operator has the same effect to every transmitted symbol in the wavelet domain image. By channel estimation, we can detect the channel information, which can be seen as a filter to blur the pixel. De convolution needs the information regarding how the signal is scaled and delayed. Using the wavelet transform, we can detect when the delays occur and how much it is scaled. Since the early 1990s, the wavelet transforms and wavelet packet transform have been widely used in wireless communication. A number of modulation system based on wavelets have been proposed [10], [5], [11].

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In [12], Zhang et al proved that the space-time channel has fractal characteristic according to the dynamic mechanism of multipath fading. In [10], Graciaseal presented an equalization algorithm for a wavelet packet-based modulation scheme. In their method, a non ideal channel can be divided into a set of bands, and each band can be approximated by a simple attenuation and delay. In [13], an adaptive Bayesian receiver based on wavelet transform was developed for blind detection in flat-fading channels. In [14], a wavelet-based separating kernel was proposed for array processing of cellular DS/CDMA signals in fast fading channel. Because of its local time and frequency analysis property, the majority of the wavelet transforms applications in wireless communications are intended for the wideband channel or fast fading channel. Recently, the wavelet packets have been widely used in Multi-carrier Direct Spread CDMA (MC-DS-CDMA) because of its orthogonality property. In previous my work analysis of MISO WiMAX IEEE802.16d in SUI multipath fading channels [15] and improvement fixed WiMAX based wavelet signals in ITU channels [16]. In this work focus on the improvement fixed WiMAX under the effect of SUI fading channels using wavelet signals.

II. STANFORD UNIVERSITY INTERIM (SUI) CHANNEL MODELS

SUI channel models are an extension of the previously work by AT&T Wireless and Ercegetal [3]. In this model a set of six channels was chosen to address three different terrain types that are typical of the continental US [4]. This model can be used for simulations, design, and development and testing of technologies suitable for fixed broadband wireless applications [5]. The parameters for the model were selected based upon some statistical models. The tables below depict the parametric view of the Six SUI channels.

Table 1: Terrain type for SUI channel

Terrain Type	***SUI Channels***
C (Mostly flat terrain with light tree densities)	**SUI-1, SUI-2**
B (Hilly terrain with light tree density or flat terrain with moderate to heavy tree density)	**SUI-3, SUI-4**
A (Hilly terrain with moderate to heavy tree density)	**SUI-5, SUI-6**

Table 2: General characteristics of SUI channels

Doppler	***Low delay spread***	***Moderate delay spread***	***High delay spread***
Low	SUI-1,2 (High K Factor) SUI3		SUI-5
High		SUI-4	SUI-6

We assume the scenario [6] with the following parameters:

- Cell Size: 7Km
- BTS antenna height: 30 m
- Receive antenna height: 6m
- BTS antenna beamwidth: 120^0
- Receive antenna beamwidth: Omni directional
- Polarization: Vertical only
- 90% cell coverage with 99.9% reliability at each location covered

For the above scenario, the SUI channel parameters are tabulated in Tables 3, 4 and 5 according to [6]

Table 3: Delay spread of SUI channels

Channel model	***Tap1***	***Tap2***	***Tap3***	***Rms delay spread***
		µs		
SUI-1	0	0.4	0.9	0.111
SUI-2	0	0.4	1.1	0.202
SUI-3	0	0.4	0.9	0.264
SUI-4	0	1.5	4	1.257
SUI-5	0	4	10	2.842
SUI-6	0	14	20	5.242

Table 4: Tap power (Omni directional antenna) of SUI channels

Channel model	***Tap1***	***Tap2***	***Tap3***
		dB	
SUI-1	0	-15	-20
SUI-2	0	-12	-15
SUI-3	0	-5	-10
SUI-4	0	-4	-8
SUI-5	0	-5	-10
SUI-6	0	-10	-14

Table 5: 90% K factor (Omni directional antenna) of SUI channels

Channel model	***Tap1***	***Tap2***	***Tap3***
		dB	
SUI-1	4	0	-20
SUI-2	2	0	-15
SUI-3	1	0	-10
SUI-4	0	0	-8
SUI-5	0	0	-10
SUI-6	0	0	-14

In the next section we will talk about t how these parameters have been incorporated to implement SUI channel model for proposed design.

III. BROPOSED SYSTEM FOR DWT-OFDM BASED WIMAX

The Block diagram is simulated in matlab simulink shown in Figure 1:

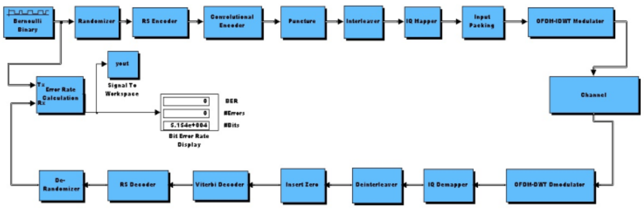

Fig .1.Block Diagram of Proposed WiMAXIEEE802.16d based DWT-OFDM

Represents the whole system model or the signal chain at the base band. The block system is divided into three main sections, namely, the transmitter, the receiver, and the channel. The model has been tested with the channel coding. Data are generated from a random source and consist of a series of ones and zeros. Since the transmission is done block wise, when forward error correction (FEC), the size of the data generated depends on the block size used,

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These data are converts it into lower rate sequences via serial to parallel conversion and randomized after that so as to avoid a long run of zeros or ones. The result is ease in carrier recovery at the receiver. The randomized data are encoded when the encoding process comprise of a concatenation of an outer Reed-Solomon (RS) code. The implemented RS encoder is derivative from a systematic RS Code using field generator GF (2^8) and an inner convolutional code (CC) as an FEC scheme. This method that the first data pass in block format through the RS encoder, and then go across the convolutional- encoder. It is a flexible coding process due to the puncturing of the signal, and it to permit different coding rates. The last part of the encoder is a handle of interleaving to prevent long error bursts using tail biting convolutional codes(CC) with a different coding rate of (puncturing of codes is provided in the standard) [17]. Finally, interleaving is done by a two-stage permutation; the first aims to avoid the mapping of adjacent coded bits on adjacent subcarriers, and the second insures that adjacent coded bits are mapped alternately onto more or less significant bits of the constellation, thus avoiding long runs of lowly reliable bits. The training frame (pilot sub-carriers frame) shall be inserted and sent prior to information frame. This pilot frame shall been used to make channel estimation that's used to compensate the channel effects on the signal. Symbol mapping the coded bits are then mapped to shape symbols. The modulation scheme used is 16QAM (1/2) coding rate with gray coding in the constellation map. anyway, the symbol is normalized so that the average power is unity irrespective of the modulation scheme used. The process will convert data to corresponding value of M-ary constellation which is complex word, i.e. real and imaginary part. The bandwidth(B =(1/ T_s))is divided into$N$ equally spaced subcarriers at frequencies ($k\Delta f$),$k=0,1,2,\ldots,N-1$ with $\Delta f=B/N$ and T_s as the sampling interval. At the transmitter, information bits are classified and mapped into complex symbols. In this system, (QAM) with constellation C_{QAM} is the modulation scheme used to map the bits to symbols 16QAM with (1/2) coding rate To modulate spread data symbol on the orthogonal carriers, an N-point Inverse wavelet Transform IDWT shall be used, as in conventional OFDM. Zeros will be inserted in some bins of the IDWT in order to make the transmitted spectrum compact and reduce the adjacent carriers' interference. The added zeros to some sub-carriers will limit the bandwidth of the system, while the system without zeros pad has a spectrum which is spread in frequency. The last case is unacceptable in communication systems, whereas one limitation of communication systems is the width of bandwidth. The addition of zeros to some sub-carriers means that not all the sub-carriers will be used; only subset (N_c) of total sub-carriers (N_F) will be 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 SUI channel. When this occurs, the inverse transformation at the receiver cannot repossess the data that was transmitted perfectly. Energy from one sub channel leakage into others, leading to interference. However it is possible to Rescue orthogonality by introducing a cyclic prefix (CP). This CP comprises of the final v samples of the original K samples to be transmitted, prefixed to the transmitted symbol. The length v is known by the channel's impulse response and is chosen to minimize ISI. If the impulse response of the channel has length lesser than or equal to v, the CP is sufficient to completely eliminate ISI and ICI. The efficiency of the transceiver is lowered by a factor of $\frac{K}{K+V}$ so it is desirable to make v as small or K as large as possible. So the obstacles of the CP are the loss of data throughput as precious bandwidth is wasted on repeated data. For this reason it is needed to find another structure for OFDM to mitigate these obstacles. 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 kinds of channels, Multicarrier modulation has long been determined to be optimum when number of sub-channels is large. The size of sub-channels needed to approximate optimum performance depends on how rapidly the channel transfer function varies with frequency [18]. Computation IDWT 256 point for data after that the data convert from parallel to serial these data are fed to the channel WiMAX model the receiver performs the same operations as the transmitter, but in a reverse order. It also contains operations for synchronization and compensation for the destructive channel.

IV. SIMULATION RESULTS OF THE PROPOSED SYSTEMS:

The reference model specifies a number of parameters that can be found in Table (6).

Table (6) System parameters

Number of sub-carriers	256
Number of DWT points	256
Modulation type	16-QAM
Coding rate	1/2
Channel bandwidth B	3.5MHz
Carrier frequency fc	2.3GHz
N cpc (Number of transmitted bits per symbol)	4
N cbps(number of coded bits per the specified allocation)	768
Number of data bits transmitted	10^6

In this part the simulation of the proposed DWT-OFDM system WiMAX and comparing with FFT -OFDM (with cyclic prefix 1/8 in case OFDM-FFT only) system is achieved, beside the BER performance of the OFDM system considered in Six SUI channel models

A. Performance of SUI-1 channel:

In this scenario, the results obtained were encouraging. With OFDM- DWT and OFDM-FFT it can be seen that for BER=10^{-3} the SNR required for OFDM- DWT is about 5.5 dB while in OFDM- FFT the SNR about 9.5dB From Figure 2 it is found that the DWT-OFDM outperforms significantly other system for this channel model.

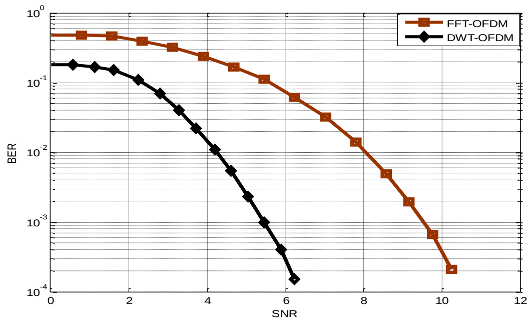

Fig .2. BER performance of WiMAX DWT -OFDM in SUI-1 channel

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B. Performance of SUI-2 channel:

In this simulation profile some influential results were obtained. With OFDM- DWT and OFDM-FFT it can be seen that for BER=10^{-3} the SNR required for OFDM- DWT is about 6.2 dB while in OFDM- FFT the SNR about 10dB From Figure 3 it is found that the DWT-OFDM outperforms significantly other system for this channel model. it can be concluded that the DWT-OFDM is more significant than the OFDM systems based FFT in this channel that have been assumed.

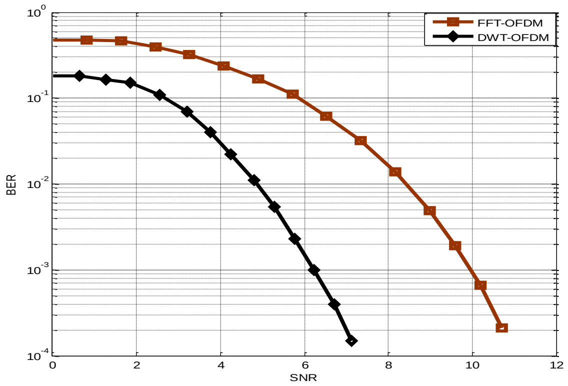

Fig .3. BER performance of WiMAX DWT -OFDM in SUI-2 channel

C. Performance of 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 DWT-OFDM is about 7.5 dB, while in FFT-OFDM the SNR about 11.8dB, From Figure 4 it is found that the DWT-OFDM outperforms significantly than FFT-OFDM systems for this channel model.

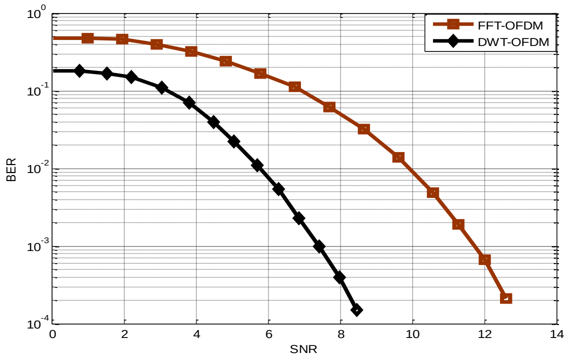

Fig .4. BER performance of WiMAX DWT -OFDM in SUI-3 channel

D. Performance of 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 DWT-OFDM is about 11.8 dB, while in FFT-OFDM the SNR about 17.6dB. Also from Figure 5 it is found that the DWT-OFDM outperforms significantly than FFT-OFDM systems for this channel model.

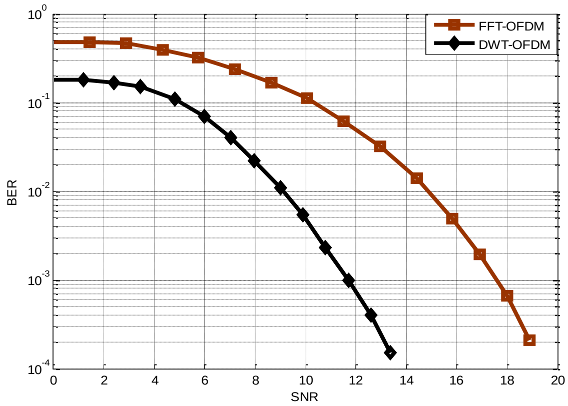

Fig .5. BER performance of WiMAX DWT -OFDM in SUI-4 channel

E. Performance of SUI-5 channel:

In this model, the results obtained were encouraging. With OFDM- DWT and OFDM-FFT it can be seen that for BER=10^{-3} the SNR required for OFDM DWT is about 13 dB while in OFDM-FFT the SNR about 21dB From Figure 6, it is found that the DWT-OFDM best significantly other system for this channel model.

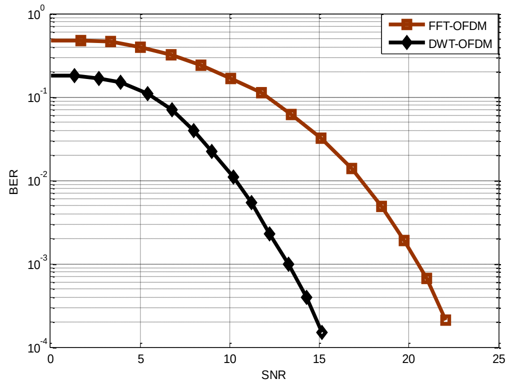

Fig .6. BER performance of WiMAX DWT -OFDM in SUI-5 channel

F. Performance of SUI-6 channel:

In this state, the results obtained were hopeful. With OFDM-DWT and OFDM-FFT it can be seen that for BER=10^{-3} the SNR required for OFDM DWT is about 14.9 dB while in OFDM- FFT the SNR about 23dB From Figure 7 it is found that the DWT-OFDM better significantly other system for this channel model

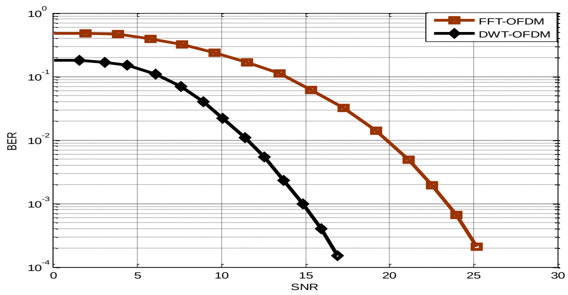

Fig .7. BER performance of WiMAX DWT -OFDM in SUI-6 channel

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Table (7) Comparison between results

Channel for BER= 10^{-3}	SUI 1 dB	SUI2 dB	SUI3 dB	SUI4 dB	SUI5 dB	SUI6 dB
FFT OFDM	9.5	10	11.8	17.6	21	23
DWT OFDM	5.5	6.2	7.5	11.8	13	14.9

A number of important results can be taken from Table (7); In this simulation, in most scenarios, the DWT-OFDM system was better than the 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 SUI channels with larger delay spread are a bigger challenge to any system. DWT-OFDM system proved its effectiveness in combating the multipath effect on the SUI fading channels.

V. CONCLUSIONS

The key contribution of this paper was the implementation of the fixed IEEE 802.16d PHY layer based the DWT-OFDM structure was proposed simulate and tested. Simulations provided proved that proposed design achieves much lower bit error rates and better performance than FFT-OFDM assuming reasonable choice of the bases function and method of computations. Proposed DWT-OFDM systems is robust for SUI channels and does not require cyclically prefixed guard interval, which means that it obtains higher spectral efficiency than conventional OFDM and it can be used at high transmission rates. From obtained results it can be concluded, that SNR can be successfully increased using proposed wavelet designed method and using a desired wavelet bases function. Therefore this structure can be considered as an alternative to the conventional OFDM.

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