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Design and Improvement of WiMAX OSTBC–OFDM Transceiver Based Multiwavelet Signals by Tomlinson-Harashima Precoding on SFF SDR Development Platform

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Abstract—In this paper, a new robust transceiver design with Tomlinson-Harashima precoding (THP) for multiple-input multiple-output (MIMO) for fixed (Worldwide Interoperability for Microwave Access) WiMAX Transceiver Based on multiwavelet signals is investigated.THP is adopted to mitigate the spatial inter symbol interference. All cases are based on the IEEE 802.16d standard using** Orthogonal Frequency-Division Multiplexing (OFDM) **based multiwavelet to further reduce the level of interference and increase spectral efficiency and 16-**Quadrature amplitude modulation (QAM) **half-values of coding rates, using** Small Form Factor (SFF) **Software Defined Radio** (SDR) Development Platform. **The proposed THP design achieves considerably lower** bit error rate **or** bit error ratio (BER) **and higher signal-to-noise power ratio than not using THP. The proposed TH pre-coding system was modeled-tested, and its performance is found to comply with International Telecommunications Union channel models (ITU) that have been elected for the wireless channel in the simulation process. Finally, the performance advantage of the proposed robust with THP design over non-robust design is demonstrated by simulation results

Index Terms— THP, WiMAX, SFF SDR, OFDM, OSTBC, DMWT, Precoding.

I. INTRODUCTION

WiMAX is a wireless technology that provides broadband data at rates over 3 bits/second/Hz. In order to increase the range and reliability of WiMAX systems, the IEEE 802.16-2004 standard supports optional multiple-antenna techniques such as Orthogonal Space-Time Block Code **(OSTBC),** Adaptive Antenna Systems (AAS) and Multiple-Input Multiple-Output (MIMO) systems. In closed-loop systems, transmit precoding reacts to channel conditions in order to improve the system capacity or bit error rate (BER). OFDM is being widely adopted in several wireless standards due to its spectrum efficiency and other advantages. Recent integration with multiple-antenna techniques promises a significant boost in performance of OFDM. However, OFDM is sensitive to frequency offset, which immediately results in inter-symbol interference (ISI) and degrades the system performance. Now-a-days wireless networks such as cellular communication have deeply affected human lives and became an essential part of it.

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The demand to buy high capacity and better performance devices and cellular services has been rapidly increased. There are more than two hundred different countries and almost three billion users all over the world which are using cellular services provided by Global System for Mobile (GSM), Universal Mobile Telecommunication System (UMTS), Wireless Local Area Network (WLAN) and WiMAX. In the past decade, one antenna is connected to only one communication radio device at the same time but currently this scenario has been completely changed. To increase the capacity of the channels and to improve the bit error performance between mobile station and service station, it is now possible to connect one antenna with more than one communication radio device at the same time. MIMO systems are designed to obtain this requirement. In MIMO systems, antennas are combined in the form of small frames like coupling in cellular devices. Diversity means to obtain successful transmission and reception of radio signals with accordance to polarization and correlation. Due to diversity the capacity of the channels and bit error rate are improved, so diversity is one of the main and important properties of MIMO systems in this paper, we examine OFDM based multi-wavelet because of OFDM's robustness to multipath propagation and its ease for utilizing multiple antenna techniques [1]. In this paper, we focus on fixed WiMAX systems based on the IEEE 802.16d-2004 standard [2].WiMAX technologies have recently made great advances. Personal communication devices now enable ubiquitous communications. The spectacular growth of data communication, voice and video service over Internet, justify great expectations for high data rates in radio communication systems. Current communication systems integrate various functions and applications, such high-rate data in a wireless local area network (WLAN), which is expected to provide its users with over 100 Mbps information rates. Since radio spectrum is limited, supporting such high data rates and overcoming the radio channel impairments presents challengs to the design of future high-speed radio communication systems. The performance improvement that results from the use of diversity in wireless communications is well known and often exploited. On channels affected by Rayleigh fading, the BER is known to decrease proportionally to SNR^{-d} where SNR designates the signal-to-noise ratio and d designates the system diversity obtained by transmitting the same symbol through d independently faded channels. Diversity is traditionally achieved by repeating the transmitted symbols in time, in frequency or using multiple antennas at the receiver. In the latter case, the diversity gain is compounded to the array gain, consisting of an increase in average receive SNR due to the coherent combination of received signals, which results in a reduction of the average noise power even in the absence of fading. Here, the situation is more complex, with a greater deal of flexibility in the design and potential advantages at the price of a larger system complexity. In fact, in addition to array gain and diversity gain, one can achieve spatial multiplexing gain, realized by transmitting independent information from the individual antennas, and interference reduction. The enormous values of the spatial multiplexing gain potentially achieved by MIMO techniques have had a major impact on the introduction of MIMO technology in wireless systems. Current trends in wireless system design focus on MIMO techniques to provide capacity (data rate) gains [3, 4]. Transmit diversity one of the WiMAX system profiles is the simple STC scheme proposed by Alamouti [4] for transmit diversity on the downlink. In the IEEE 802.16d-2004 specifications, Originally, Alamouti's transmit diversity was proposed to avoid the use of receive diversity and keep the subscriber stations simple. This technique is applied subcarrier by subcarrier. Closed-loop techniques to offer capacity gains or bit-error rate (BER) performance improvements [5, 6], and orthogonal frequency-division multiplexing (OFDM) to facilitate the utilization of these performance gains on frequency-selective channels [7, 8]. THP was invented independently by Tomlinson [9], and Harashima and Miyakawa [10] for equalization of dispersive SISO channels. It is a very efficient strategy to remove ISI in single-carrier systems. It enables the application of coded modulation in a seamless fashion and is able to come close to the channel capacity of the underlying channel [11]. Spatial separation in MIMO systems is tightly related to temporal equalization for SISO transmission over ISI channels. The THP is then extended to MIMO channels to combat the interference between different spatial transmission layers [12, 13]. Further performance gains can be made by looking at alternative orthogonal basis functions and found a better transform rather than Fourier and wavelet transform. The implementations in practice of OFDM today have been done by using FFT and its inverse operation IFFT inverse operation to represent data modulation and demodulation. In [14, 15] a new OFDM system was being introduced, based on multi-filters called multiwavelets. It has two or more low-pass 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 important multiwavelet filter is the Geronimo, Hardian, and Massopust (GHM) filter. The GHM basis offers a combination of orthogonality, symmetry, and compact support, which cannot be achieved by any scalar wavelet basis. The GHM will be used in the OFDM system block [15]. In multiwavelet setting, GHM multi-scaling and multiwavelet 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 [15]. In previous my work design transmitter diversity THP for SOTBC-OFDM-FFT for Fourier signals in fixed WiMAX system [16]. The new robust proposed transmitter diversity THP for OSTBC-OFDM-DMWT for multiwavelet signals in fixed WiMAX systems are introduced in this work. The simulations results and evaluation tests of these proposed systems are given. The results of both systems in the International Telecommunications Union (ITU) channel models will be examined and compared.

II. PROPOSED TOMLINSON –HARASHIMA PRECODING (THP) FOR WIMAX OSTBC-DMWT OFDM TRANSCEIVER

WiMAX IEEE 802.16d is a current trend in the development of high-data-rate wireless systems. Transmit reacts to channel conditions to improve the system capacity or bit error rate (BER). OFDM is being widely adopted in several wireless standards because of its spectrum efficiency and other advantages. Recent integration THP with multiple-antenna techniques promises a significant enhancement in the performance of OFDM system. In this section investigates a new approach to the adaptation of the WiMAX baseband for the physical layer performance of, multi-antenna techniques with THP. THP was devised for equalization of dispersive SISO channels. It is a very efficient approach to remove ISI in single-carrier systems. It enables the application of coded modulation in a without seams fashion and is able to come close to the channel capacity of the underlying channel. Spatial separation in MIMO systems is strongly related to temporal equalization for SISO transmission over ISI channels. The TH precoder is then extended to MIMO channels to combat the interference between different spatial transmission layers .The Block diagram in Figure 1 represents the whole system model or signal chain at the base band. This figure illustrates a typical Transmitter Diversity Tomlinson-Harashima (THP) for WiMAX OSTBC-OFDM system used for multicarrier modulation. Data are generated from a random source, and consist of a series of ones and zeros. Since the transmission is conducted block-wise, when forward error correction (FEC) is applied, the size of the data generated depends on the block size used. These data are converted into lower rate sequences via serial to parallel conversion and convert to sample after that pass through the matlab function modulo arithmetic device and then randomize it 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 consists of a concatenation of an outer Reed-Solomon (RS) code. The implemented RS encoder is derived from a systematic RS Code using field generator GF code (CC) as an FEC scheme. This means that the first data pass in block format through the RS encoder, and goes across the convolutional encoder. It is a flexible coding process caused by the puncturing of the signal, and allows different coding rates. The last part of the encoder is a process of interleaving to avoid long error bursts using tail biting CCs with different coding rates (puncturing of codes is provided in the standard) [2 and 17]. Finally, interleaving is conducted using a two-stage permutation; the first aims to avoid the mapping of adjacent coded bits on adjacent sub-carriers, while the second ensures that adjacent coded bits are mapped alternately onto relatively significant bits of the constellation, thus avoiding long runs of lowly reliable bits.

The training frame (pilot sub-carriers frame) is inserted and sent prior to the information frame. This pilot frame is used to create channel estimation used to compensate for the channel effects on the signal. The coded bits are then mapped to form symbols. The modulation scheme used is 16-QAM coding rate (1/2) with gray coding in the constellation map. This process converts data to corresponding value of M-ary constellation, which is a complex word (i.e., with a real and an imaginary part). The bandwidth ($B=(1/T_s)$) is divided into 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, (QAM) with constellation C_{QAM} is assumed for the symbol mapping. The structures of the proposed improvement Diversity Tomlinson-Harashima (THP) for MIMO WiMAX OSTBC-OFDM-DMWT is shown below in Figures 1. We consider an OFDM of WiMAX system with M_T transmits antennas and M_R receives antennas. Let $X_u[n]$ denote an M-ary QAM symbol on the nth subcarrier of WiMAX OFDM sent by the uth transmit antenna. The length-N input data vector can then be written as $X_u = [X_u(0)X_u(1)\dots X_u(N-1T$, where N is the number of OFDM subcarriers. In MIMO WiMAX OSTBC OFDM-DMWT transmission, each of the M_T time-domain transmitted vectors is generated

By taking an inverse DMWT (IDMWT) of an information vector:

$$X_u = [X_u(0)X_u(1)\dots X_u(N-1)]^T = \text{IDMWT}\, X_u \quad 1$$

Where transforms are the N × N IDMWT matrix According to MIMO WiMAX OSTBC OFDM –DMWT models.

The computation of DMWT and IDMWT 256 point is done by an over-sampled scheme of preprocessing (repeated row), the procedure of computation in details in [15]. 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. Hence, the number of bits in OFDM symbol is equal to log_2 (M)* N_c. Orthogonality between carriers is normally damaged 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 probable 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 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 OFDM to mitigate these drawbacks is necessary. 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 known to be optimum when the number of sub-channels is large. The size of sub-channels required t approximate optimum performance depends on how rapidly the channel transfer function varies with frequency. As shown In Figure below The transmitter includes MIMO WiMAX OSTBC-OFDM-DMWT transmitter, a modulo arithmetic feedback structure employing matrix $B[k]$, and $M_T X M_T$ feedback filter $B-I$ with which the transmitted symbols $X[k]$ are successively calculated for the data symbols $a[k]$ drawn from the initial M-ary QAM signal constellation from MIMO WiMAX transmitter. The receiver structure consists from MIMO WiMAX transmitter, $M_T X M_T$ scaling matrix G, $M_R X M_T$ feed forward filter F, and a modular arithmetic device. The feedback matrix must strictly be upper triangular to enable data in a recursive fashion. Given the data carrying symbols $a[k] \epsilon$ A (the M-ary constellation), where The $N \times N$ identity matrix is I_N the MXN all-zero matrix is 0_{MXN} . The mth row and nth column entry of A are demonstrate as $A(m,n)$. The trace of A is given as $tr(A) = \sum_m A(m,n)$. The $\Re(a)$ and $\Im(a)$ sign to the real and imaginary part of a complex number a. an M-ary quadrature amplitude modulation(QAM) square signal constellation is defined as $A = \{a_1 + jaQ| a_I, a_Q \epsilon \pm 1, \pm 3, \dots, \pm(\sqrt{M}-1)\}$. The transmitted symbols $X[k]$ are successively calculated via the feedback filter as [10 and 17].

$$X[k] = MOD_{2\sqrt{M}} \left\{ a[k] - \sum_{j=0}^{k-1} B(k,j)\,)X[j] \right\}$$

$$= a[k] + q[k] - \sum_{j=0}^{k-1} B(k,j)\,)X[j] \quad 2$$

The initial signal constellation A is periodically expanded by the modulo arithmetic feedback structure at the transmitter. The modulo $2\sqrt{M}$ operation can be considered as the signal-dependent addition $a[k] + q[k]$, where the real and imaginary parts of $q[k]$ are the unique integer multiples of $2\sqrt{M}$ for which $\Re = \{X[k]\} \epsilon \left(-\sqrt{M}, \sqrt{M}\right)$ and $\Im = \{X[k]\} \epsilon \left(-\sqrt{M}, \sqrt{M}\right)$ Thus, the power of the precoded transmitted signals is bounded. If $a[k]$ is an i.i.d. sequence with variance E_s and uniformly distributed on A, then $X[k]$ is also i.i.d. with variance $\left(\frac{M}{M}-1\right) E_s$ and uniformly distributed within bounds slightly larger than those of the initial constellation. The modulo operation employed at the transmitter is nonlinear and a slicer at the receiver uses the same modulo operation in detecting the points of the initial constellation A. In conventional THP for the system described, assuming that G is a G × G square matrix, the feed forward matrix is designed at the receiver by using a QR factorization of the overall channel matrix [13]

$$G = D^H T \quad 3$$

Where the feed forward matrix D is a unitary matrix, and $T = [T(i,j)]$ is an upper triangular matrix. Given the overall channel matrix G, the feedback matrix under the ZF criterion becomes $B = PT$,where the scaling matrix $P = diag[T-1(1,1) \dots T-1(G,G)]$ keeps the average transmit power constant.

THP involves modulo operation at both the transmitter and the receiver. The modulo $2\sqrt{M}$ reduction at the transmitter, applied separately to the real and imaginary parts of the input, constrains the transmitted signals to within the range of $\Re = \{X[k]\} \epsilon \left(-\sqrt{M}, \sqrt{M}\right)$ and $\Im = \{X[k]\} \epsilon \left(-\sqrt{M}, \sqrt{M}\right)$. If the input sequence $a[k]$ is a

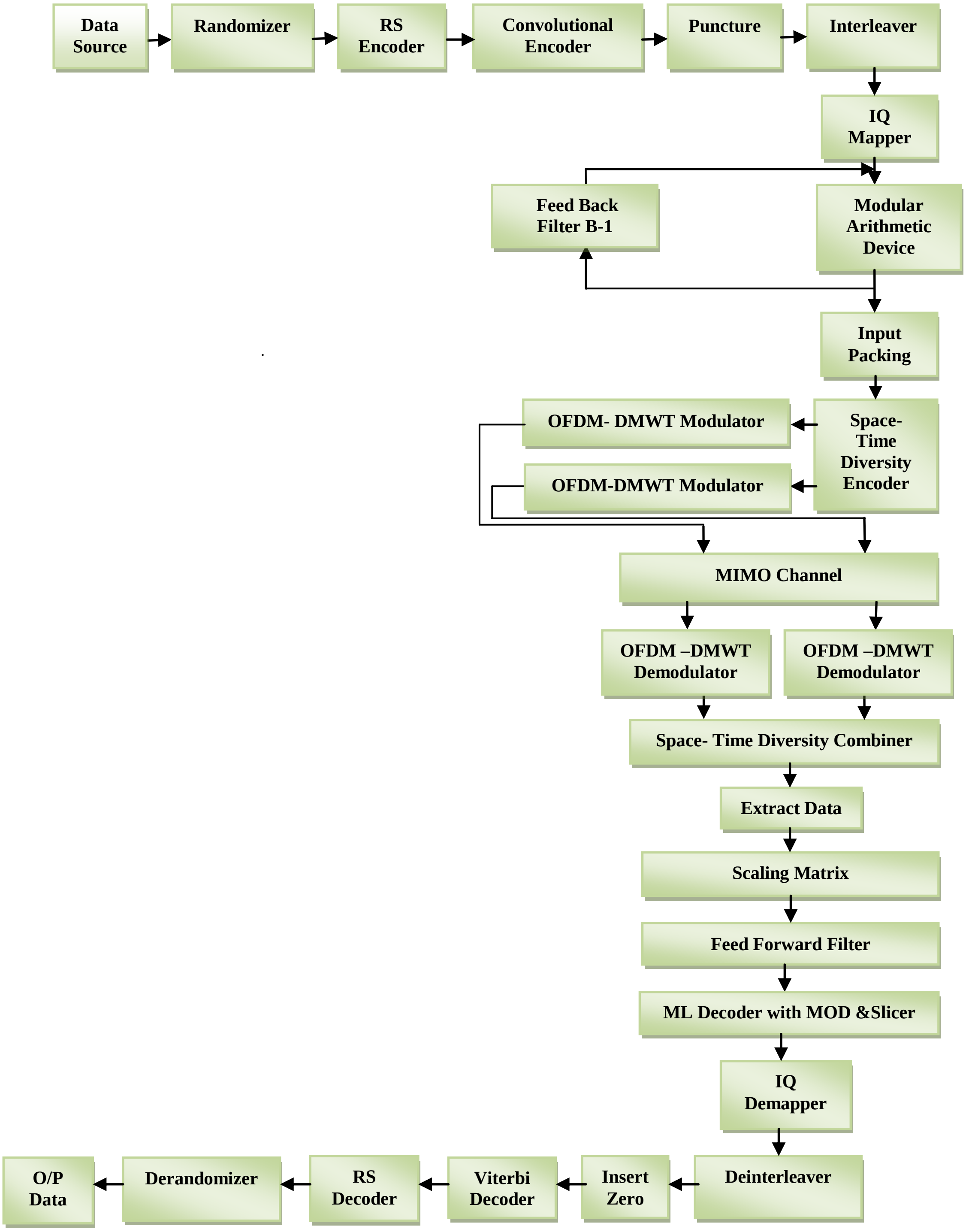

Fig.1. Proposed of Tomlinson-Harashima Precoding (THP) for WiMAX OSTBC- OFDM-DMWT Transceiver.

sequence of i.i.d. samples, the output of the modulo device is as well a sequence of i.i.d. random variables, and the real and imaginary parts are independent, i.e. At the receiver, a slicer, which applies the same modulo operation as that at the transmitter, is used. After discarding the modulo congruence and ML decoding, the unique estimates of the data symbols $\hat{a}[k]$ are obtained. The details of THP operation can be found in Reference [13]. We next consider the important special case of OSTBC, the Alamouti code for 2 transmit antennas and multiple receive antennas. In the Alamouti code is used in space–time transmit diversity, we also generalize the proposed pre-coder design for an arbitrary number of transmit antennas. The Alamouti code can be described by a 2 × 2 code matrix $C = \begin{bmatrix} c_1 & -c_2^* \\ c_2 & c_1^* \end{bmatrix}$ i.e., two symbols c_1 and c_2 and their conjugates are transmitted over two time slots. At the first time slot, the c_1 and c_2 are transmitted from the antenna 1 and 2, respectively; during the next symbol period, $-c_2^*$ is transmitted from the antenna 1, and c_1^* is from the antenna 2. Consequently, in Alamouti-coded OFDM with proposed THP, the output sequence of the feed forward filter can be given as $\begin{bmatrix} \widetilde{A}_1 & \widetilde{A}_3 \\ \widetilde{A}_2 & \widetilde{A}_4 \end{bmatrix} = \Psi \begin{bmatrix} A_1 & -A_2^* \\ A_2 & A_1^* \end{bmatrix} + n'$ where the 2N × 2N matrix $\Psi = \begin{bmatrix} \tilde{\imath}_N & 0 \\ 0 & \tilde{\imath}_N \end{bmatrix}$ $\tilde{\imath}_N$ is approximately an identity matrix [13 and 17]. The vectors $A_1 = [a_1(0) \cdots a_1(N-1)]^T$ and $A_2 = [a_1(0) \cdots a_1(N - 1T$ are transmitted over the first and second antenna at the first time Slot, respectively; and the $-A_2^*$ and A_1^* are transmitted in sequence in consecutive time slots. The received signal matrices can be represented as [13 and 18].

$$\widehat{A}_1 = \widetilde{A}_1 + A_4^* = 2A_1 + n'_1 + n'^*_4$$
$$\widehat{A}_2 = \widetilde{A}_2 - \widetilde{A}_3^* = 2A_2 + n'_2 - n'^*_3 \qquad 4$$

In MIMO WiMAX OSTBC OFDM-DMWT receiver, each of the M_R time-domain received vectors is generated by taking a DMWT to the received signal matrices according to type of models, after that same procedure step in models mention in previous section according to the model type. The calculation of the filters in THP can be considered as performing a QR decomposition of the channel matrix. The computation of DMWT and IDMWT, the 256 point. After which, the data converted from parallel to serial are fed to the channel WiMAX THP MIMO fading channel model and the receiver perform the same operations as the transmitter, but in a reverse order. It further includes operations for synchronization and compensation for the destructive channel. All cases are based on the IEEE 802.16d standard using OSTBC-OFDM-DMWT in simulink applied to the SFF SDR development platform. More details about the system performance analysis and optimization target of SFF SDR development platform in [16, 19 and 20].

III. SFF SDR DEVELOPMENT PLATFORMS

The SFF SDR Development Platform is shown in Figure 2 consists of three distinct hardware modules that offer flexible development capabilities: the digital processing, data conversion, and RF module. The digital processing module uses a Virtex-4 FPGA and a DM6446 SoC to offer developers the necessary performance for implementing custom IP and acceleration functions with varying requirements from one protocol to another supported on the same hardware. The data conversion module is equipped with dual-channel analog-to-digital and digital-to-analog converters. The RF module covers a variety of frequency ranges in transmission and reception, allowing it to support a wide range of applications [21].

Fig .2. SFF SDR Development Platform[21]

IV. SIMULATION RESULTS OF THE PROPOSED TRANSCEIVER DESIGN

The reference model specifies a number of parameters that can be found in Table (1).

Table (1) System parameters

Number of sub-carriers	**256**
Number of DMWT points	**256**
Modulation type	**16-QAM**
Coding rate	**½**
Channel bandwidth *B*	**3.5MHz**
Carrier frequency *fc*	**2.3GHz**
MIMO fading correlations	ρ_T=0.5 ,ρ_R=0.5
MIMO random phases	$\Phi_{1=}1.8$,$\Phi_{2=}2$, $\Phi_{3=}0.2$,$\Phi_{4=}0.9$
Ncpc	**4**
Ncbps	**768**
Number of data bits transmitted	10^6

In this section, the overall performance in terms of measured BER versus the link overall SNR is discussed for several user profiles and channel profiles. In this section the simulation comparing with the two types of the WiMAX IEEE802.16d baseband the Physical Layer performance in with THP for OSTBC– MIMO OFDM-DMWT and open loop OSTBC-MIMO OFDM, without THP on multi-core software defined radio platform is achieved, beside the BER performance of the system considered in different International Telecommunications Union (ITU) channel models**.**

A. Performance of AWGN channel:

In this section, the results of the simulation for the proposed closed loop with THP for OSTBC-MIMO DMWT OFDM system are shown. The results obtained for this case are depicted in Figure 3, which shows the BER performance in AWGN channel. It is shown clearly that the closed loop with THP for OSTBC-MIMO DMWT OFDM is much better than the open loop OSTBC-MIMO DMWT OFDM.

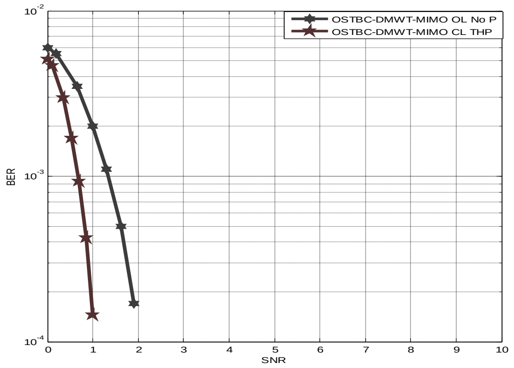

Fig .3. BER performance of WiMAX Closed loop with THP OSTBC-MIMO DMWT OFDM in AWGN channel model.

B. AWGN plus Multipath Channel Performance:

In this general channel scenario, all ITU profiles presented in [22]. Relevant findings are discussed in the following sections.

1) Indoor Channel A:

The indoor location user is a fixed subscriber, thus its Doppler spread is null. Profile A has shorter delay spread when compared to profile B. Profile A replicates rural macro-cellular surroundings in this scenario and the results obtained were encouraging. From Figure 4 it can be seen that for BER=10^{-3} the SNR required is approximately 2.8 dB for closed loop with THP OSTBC-MIMO DMWT OFDM and 3.7 dB for open loop OSTBC-MIMO DMWT OFDM . Figure 4 clearly illustrates the closed loop with THP OSTBC-MIMO DMWT OFDM significantly outperformed the other system for this channel model.

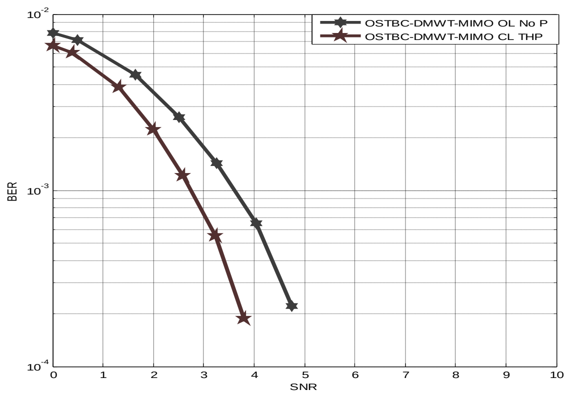

Fig .4. BER performance of WiMAX Closed loop with THP OSTBC-MIMO DMWT OFDM in AWGN plus Multipath Indoor Channel A

2) Indoor Channel B:

In this simulation profile some significant results were obtained. Recall that the profile of channel B has a bigger time delay spread than the profile of channel a, more than twice to be more quantitative. This factor plays a big role in the systems' performances. Observing Figure 5, It is clear from this Figure, that BER performance of closed loop with THP OSTBC-MIMO DMWT OFDM is better than the open loop OSTBC-MIMO DMWT OFDM systems which are closed loop with THP OSTBC-MIMO DMWT OFDM and open loop OSTBC-MIMO DMWT OFDM performance of 10^{-3} approximately 5.2 dB and 6.4 dB respectively from these results it can be concluded that the closed loop with THP OSTBC-MIMO DMWT OFDM is more significant than the open loop OSTBC-MIMO DMWT OFDM in this channel that have been assumed.

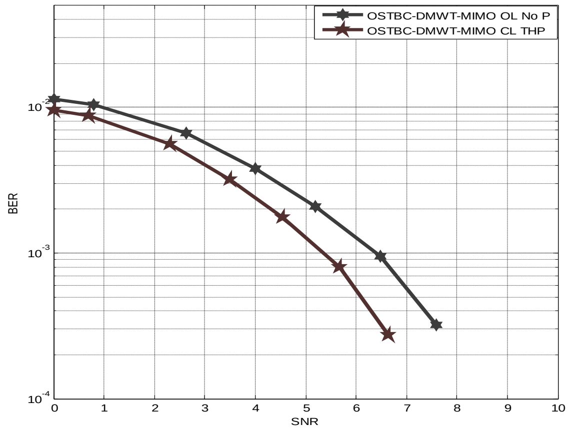

Fig .5 BER performance of WiMAX Closed loop with THP OSTBC-MIMO DMWT OFDM in AWGN plus Multipath Indoor Channel B

3) Pedestrian Channel A

In the pedestrian profile, two different situations were considered: a moving and a stationary person. These results are depicted in Figure 6 and 7. Figure 6 represents the case of the stationary person. It can be seen that for BER= 10^{-3} the SNR required for closed loop with THP OSTBC-MIMO DMWT OFDM was approximately 5.5 dB also for the open loop OSTBC-MIMO DMWT OFDM was approximately 6.1 dB. Figure 7 presents the case of a moving person. It can also be seen that for BER=10^{-3} the SNR required for closed loop with THP OSTBC-MIMO DMWT OFDM is approximately 7.54 dB and for open loop OSTBC-MIMO DMWT OFDM is approximately 8.4 dB. Figures 6 and 7 clearly illustrate that the closed loop with THP OSTBC-MIMO DMWT OFDM significantly outperforms other system for this channel model.

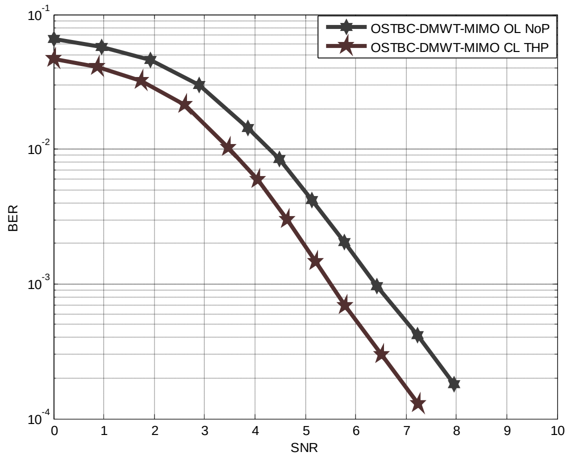

Fig.6. BER performance of WiMAX Closed loop with THP OSTBC-MIMO DMWT OFDM in AWGN & Multipath stationary Pedestrian A channel

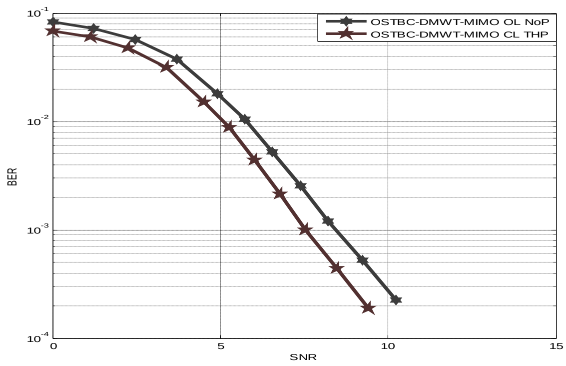

Fig .7. BER performance of WiMAX Closed loop with THP OSTBC-MIMO DMWT OFDM in AWGN & Multipath Active Pedestrian A channel

4) Pedestrian Channel B

Using the same methodology as in the previous section, simulations for both active and stationary pedestrians were carried out. The results for the case of the stationary Pedestrian B channels are depicted in Figure 8, which shows that for BER=10^{-3}, the SNR required for closed loop with THP OSTBC-MIMO DMWT OFDM is approximately 11.3 dB, for open loop OSTBC-MIMO DMWT OFDM is approximately 12.2 dB. The results for the case of the active pedestrians are depicted in Figure 9, It can be seen that for BER=10^{-3}, the SNR required for closed loop with THP OSTBC-MIMO DMWT OFDM is approximately 17.5 dB, for open loop OSTBC-MIMO DMWT OFDM is approximately 18.6 dB, Figures 8 and 9 clearly show that the closed loop with THP OSTBC-MIMO DMWT OFDM significantly outperformed the other two systems for this channel model**.**

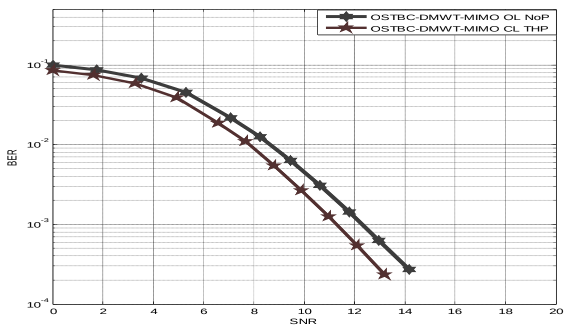

Fig .8. BER performance of WiMAX Closed loop with THP OSTBC-MIMO DMWT OFDM in AWGN & Multipath stationary Pedestrian B channel

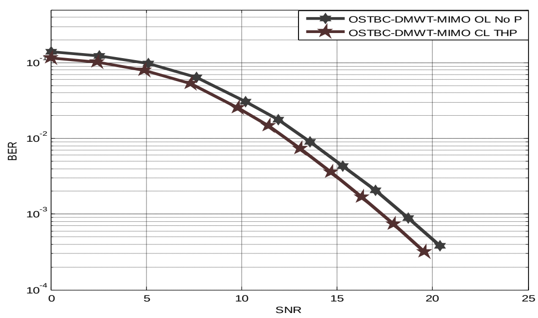

Fig .9 . BER performance of WiMAX Closed loop with THP OSTBC-MIMO DMWT OFDM Performance in AWGN & Multipath Active Pedestrian B channel.

Table (2). BER with THP OSTBC-MIMO DMWT OFDM and THP OSTBC-MIMO DMWT OFDM comparison as a function of the SNR for model proposed in different ITU channels.

Channel For BER=10^{-3}	AWGN	Indoor Channel A	Indoor Channel B	Pedestrian Channel A		Pedestrian Channel B	
				AWGN & Multipath Stopped Pedestrian A	AWGN & Multipath Active Pedestrian A	AWGN & Multipath Stopped Pedestrian B	AWGN & Multipath Active Pedestrian B
NoP Open Lobe of OSTBC-MIMO DMWT OFDM dB	1.4	3.7	6.4	6.1	8.4	12.2	18.6
THP Closed Lobe of OSTBC-MIMO DMWT OFDM dB	0.67	2.8	5.2	5.5	7.54	11.3	17.5

A number of important results can be taken from Table (2); a used the THP enhances its performance of the system. In this simulation, in most scenarios, using THP for the DMWT-OFDM system was better than the system without using THP. User-channel characteristics under which wireless communications is tested or used have important impact on the systems overall performance. In this work, using the IEEE802.16d standard, it became clear that channels with larger delay spread are a bigger challenge to any system. The THP for DMWT-OFDM system proved its effectiveness in combating the multipath effect on the channels and achieves considerably lower bit error rate or bit error ratio **(**BER**)** and higher signal-to-noise power ratio than does not using.

V. CONCLUSION

The DSP of the SFF SDR development platform is completely integrated to the model-based design flow, which integrates MATLAB, Simulink, and Real-Time Workshop from MathWorks. The SFF SCA Development Platform optional package enables SCA waveform development and implementation. In this paper, the WIMAX closed-looping with-THP-OSTBC-MIMO–DMWT-OFDM structure was proposed and tested.

These tests were carried out to verify the successful operation and the possibility of implementation of the WIMAX closed-looping with-THP-OSTBC-MIMO–DMWT-OFDM structure. It can be concluded that this structure achieves considerably lower bit error rates, assuming reasonable choice of base functions and methods of computation. In AWGN and other channels, the closed-looping with THP OSTBC-MIMO DMWT- OFDM outperforms open-looping with OSTBC-MIMO DMWT- OFDM. Therefore, this structure can be considered an alternative to the conventional closed-loop OSTBC-MIMO DMWT OFDM.

It can be concluded from the results obtained that S/N measure can be successfully increased using the proposed THP OSTBC-MIMO DMWT -OFDM-designed method. The key contribution of this paper is the implementation of the IEEE 802.16d PHY layer-based closed-looping with THP OSTBC-MIMO DMWT -OFDM structure on the SFF SDR development platform,. The simulations conducted proved that the proposed design achieves considerably lower bit error rates, and it can be used at high transmission rates.

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