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Implementation of WIMAX STBC-OFDM (IEEE802.16.d) Baseband Transceiver on a Multi-Core Software-Defined Radio Platform

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Abstract: IEEE 802.16d-2004 has been developed for WIMAX wireless communication which is based on OFDM technology and this enables going towards the 4G , in wireless communication reception This paper investigates approach to the adaptation of the WIMAX IEEE802.16d baseband the Physical Layer performance of single-input single-output (SISO) wireless communications systems, as well as multi antenna techniques such as multiple-input single-output (MISO) and multiple-input multiple-output (MIMO) systems, the last two utilizing the Alamouti-based space-time block coding (STBC) technique. All cases are based on the IEEE 802.16d standard with OFDM using halves values of coding rates, 16-QAM, OFDM using the SFF SDR Development Platform. These modeled are tested, and its performance was found under International Telecommunications Union (ITU) channel models are selected for the wireless channel in the simulation process. The performance results of the simulated SISO, MISO and MIMO systems are compared among themselves.

Key words: WIMAX, SFF SDR, OFDM, RS, Coding, AWGN

INTRODUCTION

Multiple antennas can be used at the transmitter and receiver, now widely termed a MIMO system. A MIMO system takes advantage of the spatial diversity obtained by spatially separated antennas in a dense multipath scattering environment. MIMO systems may be implemented in a number of different ways to obtain either a diversity gain to combat signal fading or to obtain a capacity gain. Generally, there are three categories of MIMO techniques. The first one aims to improve the power efficiency by maximizing spatial diversity. Such techniques include delay diversity, space-time block codes (STBC) (V.Tarokh *et al*. 1999) and space-time trellis codes (STTC) (V.Tarokh *et al*. 1999). The second type uses a layered approach to increase capacity (GD Golden *et al*. 1999). One popular example of such a system is the vertical-Bell Laboratories layered space-time (V-BLAST) architecture, where independent data signals are transmitted over antennas to increase the data rate, but full spatial diversity is usually not achieved. The third type exploits knowledge of the channel at the transmitter. It decomposes the channel matrix using singular value decomposition (SVD) and uses these decomposed unitary matrices as pre- and post-filters at the transmitter and receiver to achieve capacity gain (J Ha et al. 2002). MIMO opens a new dimension, space, to offer the advantage of diversity, and therefore has been adopted in various standards. For instance, MIMO may be implemented in the high-speed downlink packet access (HSDPA) channel, which is a part of the Universal Mobile Telecommunications System (UMTS) standard. Preliminary efforts are also underway to define a MIMO overlay for the IEEE 802.11 standard for WLAN under the newly formed Wireless Next Generation (WNG) group and also implemented in The WIMAX standard has emerged to harmonise the wide variety of Broadband Wireless Access (BWA) technologies. The design of the STBC-OFDM simulations results and evaluation tests of these proposed systems will be given using the SFF SDR development platform. The results of both systems in the International Telecommunications Union (ITU) channel models will be examined and compared. In the STBC-OFDM system the two types of the WIMAX IEEE802.16d baseband the Physical Layer performance SISO, MISO and MIMO the last two utilizing the Alamouti-based space-time block coding (STBC) technique. In this paper further performance when using the STBC-OFDM in WIMAX technology and compare between SISO, MISO and MIMO in different International Telecommunications Union (ITU) channel models

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Proposed System for STBC- OFDM for WIMAX:

The Block diagram in Figure 1 represents the whole system model or signal chain at the base band. This figure illustrates a typical STBC-OFDM system used for multicarrier modulation. The block system is divided into three main sections: the transmitter, receiver, and channel. 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 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 ((2^8)) and an inner convolutional 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 due to 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)(http://standards.ieee.org/getieee802/802.16.htl%3e>). 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/)) is divided into N equally spaced subcarriers at frequencies $(k\Delta f), k=0,1,2,...,N-1$ with $\Delta f=B/N$ and , , the sampling interval. At the transmitter, information bits are grouped and mapped into complex symbols. In this system, (QAM) with constellation is assumed for the symbol mapping. The Space-time block-coded code is transmitted from the two antennas simultaneously during the first symbol period (l=1) for each. During the second symbol period, (l=2) are transmitted from the two antennas for each. The setis the set of data-carrying sub-carrier indices, and is the number of sub-carriers carrying data. N is the multicarrier size; consequently, the number of virtual carriers is N-. We assume that half of the virtual carriers are on both ends of the spectral band (Andrews *et al.* 2007). Both the OFDM modulator and demodulator of the OFDM are shown in Figure 1. The training frame (pilot sub-carriers frame) are inserted and sent prior to the information frame. This pilot frame is used to create channel estimation, which is used to compensate for the channel effects on the signal. To modulate spread data symbol on the orthogonal carriers, an N-point Inverse Fourier Transform IFFT is used, as in conventional OFDM. Zeros are inserted in some bins of the IFFT 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 (Nc) of total subcarriers (Nf) is used. Therefore, the number of bits in OFDM symbol is equal to (M)*. Orthogonality between carriers is normally destroyed when the transmitted signal is passed through a dispersive channel. When this occurs, the inverse transformation at the receiver cannot recover the data that was transmitted perfectly. Energy from one sub-channel leaks into others, leading to interference. However, it is possible to rescue orthogonality by introducing a cyclic prefix (CP). This CP consists of the final v samples of the original K samples to be transmitted, prefixed to the transmitted symbol. The length v is determined by the channel's impulse response and is chosen to minimize ISI. If the impulse response of the channel has a length of less than or equal to v, the CP is sufficient to eliminate ISI and ICI. The efficiency of the transceiver is reduced by a factor of; 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 types of channels, multicarrier modulation has long been known to be optimum when the number of sub-channels is large. The size of sub-channels required t approximate optimum performance depends on how rapidly the channel transfer function varies with frequency .The computation of 1D-FFT and IFFT, for 256 point. After which, the data converted from parallel to serial are fed to the channel WIMAX model and the receiver performs the same operations as the transmitter, but in a reverse order. It further includes operations for synchronization and compensation for the destructive channel.

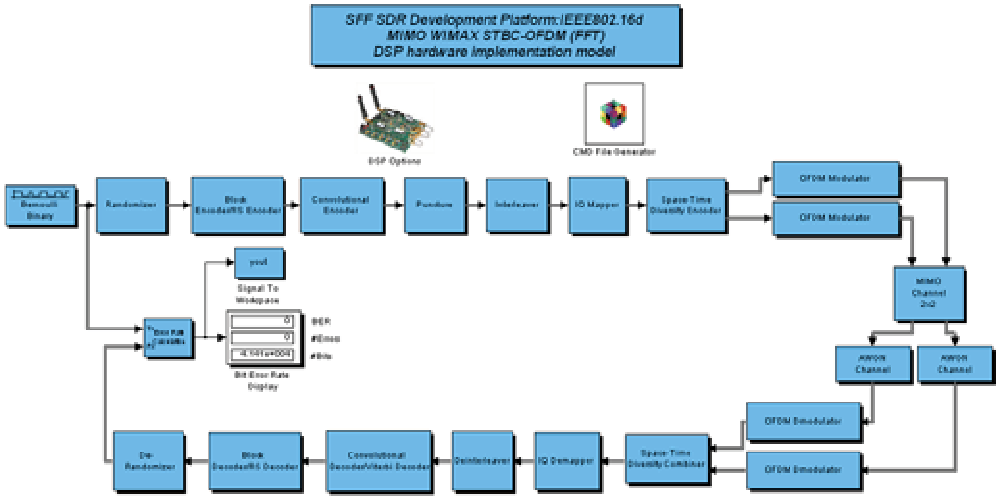

Fig. 1: Block Diagram of Proposed IEEE802.16d WIMAX based STBC-OFDM

SFF SDR Development Platforms:

The SFF SDR Development Platform 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 (Texas Instruments Incorporated 2007).

Fig. 2: SFF SDR Development Platform (Texas Instruments Incorporated 2007).

System Performance Analysis and Optimization Target:

MathWorks and Texas Instruments (TI), the two companies responsible for the development of Matlab/Simulink, are currently working on the development of a DSP development tool that users can use through Simulink. The object modules, designed to meet their own needs, the programming system, which is implemented through Real- Time Workshop, and the S-function with the TLC (Target Language Compiler) Function of the system design, when completed, can be directly converted to the most commonly used DSP programming language. The DSP, in conjunction with the TI software, Code Composer Studio, is completed in combination with the DSP hardware. Thus, through this development tool, users can work together to complete the design and simulation on the Simulink; however, it cannot provide the convenience of design that could increase the set count on the efficiency.

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System Integration and Implementation of Workflow:

In the development and testing of IEEE 802.16d Wireless MAN-OFDM PHY, the specifications of communication transfer have varying systems, which are based on our needs under Simulink mentioned in the proposed system for STBC- OFDM for WIMAX. For our study, we used the standard communication system box with a map provided by Matlab, which contains the following: Internal Communications Blockset, Signal processing Blockset, and Simulink Blockset. These correspond to our use of the hardware development platform for SFF SDR DP Blockset. The overall WIMAX PHY system construction is opened in the Simulink interface and Matlab is used to communicate the internal functions of RTW and TLC. We intend to build a finished system into a module, in accordance with the code of each block. Through this, we can perform the compilation and completion that will be automatically compiled in Matlab CCS connecting knot. The CCS establishes a corresponding module under the file name "Project." We then correct the generated C code and conduct compilation, debugging, and analysis. We then download our work into to the DSP. The overall system workflow is shown in Figure 3. The figure shows the system built based on the Simulink-established IEEE 802.16d Wireless MAN-OFDM PHY standard modules. The first step is the configuration by Simulink of the parameters interface and development platform into the conduct of the connecting node configuration. Information will be set to leave the bulk form of a fixed number of patterns, and the RTW system development module is set to be transferred and replaced by C language. Meanwhile, the TLC file option SDR development of modules and the set up Simulink system development are scheduled for DSP link module by an external module through the executive. Configuration of the IEEE 802.16d Wireless MAN-OFDM PHY may be achieved through the DSP Options Block Simulink to develop interfaces connecting node, development platform, and CCS. The use of the DSP Options Block and the Compiler Options allow us to optimize the system and the executive profit use. Moreover, future compiler optimization can be conducted through the Block. In the SFF SDR Development Platform of the DSP configuration, three kinds of memory are used: L1DRAM (8 KB), L2RAM (64 KB), and SDRAM (8 MB). The L1DRAM and L2RAM are used for the internal memory, while the SDRAM is used for the external memory. Due to the retention of internal memory, the speeds become quicker; thus, if information is to be placed in the internal memory in the system as a whole, the speeds and the executive would enhance performance Thus, the CMD File Generator Block for Development Platform can be conducted into the memory settings.

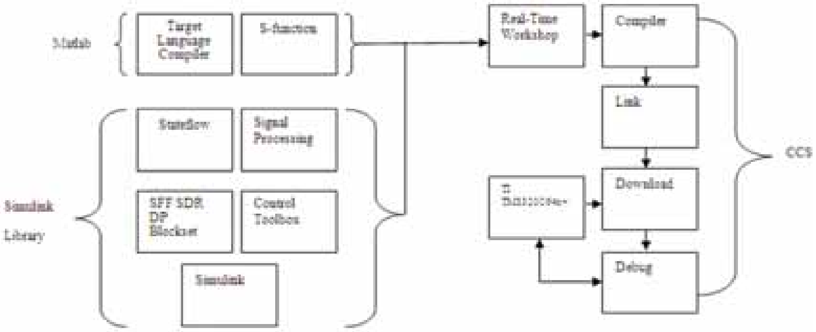

Fig. 3: Schematic diagram of the system workflow actions (Texas Instruments Incorporated 2007).

TLC and RTW:

Target Language Compiler (TLC) is a Matlab program that uses syntax. Developers using the RTW tool can use the TLC to create self-designed C syntax language code by adding to the executive after the RTW-generated C language code or design. The use the S-function in the input and output of the set can design its own system for C programming and create Simulink objects in the box to use; however, RTW is only responsible for producing the C language program yards. It will not check the correct use of grammar; thus, performing actions or debugging code requires conducting C into the editor. Moreover, in the design of TLC, all of the program features in metropolis are the function of the type, as shown in Figure 4. Thus, the designer can use the RTW to generate the required developer as long as the C program is appropriately used together with the TLC syntax. The source code, TLC, and RTW program application flowchart is shown in Figure 5 (Math Works, 2002).

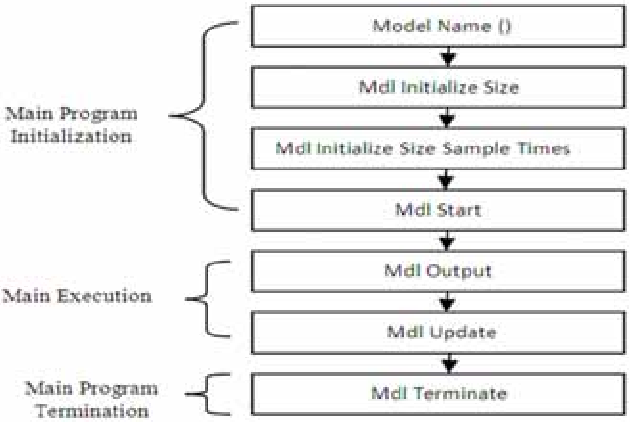

Fig. 4: Target Language Compiler grammatical structure (Math Works 2002).

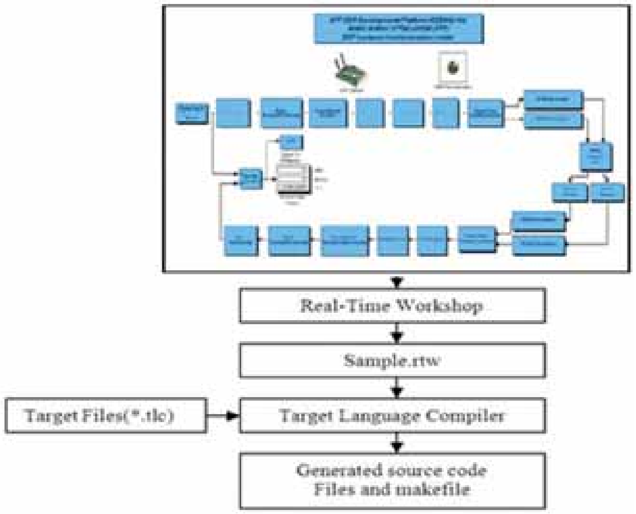

Fig. 5: TLC and the RTW program application flowchart

Simulation Settings:

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

Table 1: System parameters

Number of FFT points	Modulation type	Coding rate	Channel bandwidth B	Carrier frequency fc	MISO& MIMO fading correlations	MISO & MIMO random phases	NCPC	NCBPS	Number of data bits transmitted	cyclic prefix
256	16-QAM	1/2	3.5MHz	2.3GHz	ρ_T=0.5 ρ_R=0.5	$\Phi_{1=}1.8$ $\Phi_{2=}2$ $\Phi_{3=}0.23$ $\Phi_{4=}0.9$	4	768	10^6	1/8

Simulation Results of the Proposed Systems:

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 SISO, MISO and MIMO the last two utilizing the Alamouti-based space-time block coding (STBC) technique, 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.

Performance of AWGN channel:

In this section, the result of the simulation for the proposed STBC-OFDM system are shown The results obtained for this case are depicted in Figure 6 ,which gives the BER performance of STBC in AWGN channel. It is shown clearly that the MIMO is much better than the two previous systems MISO and SISO.

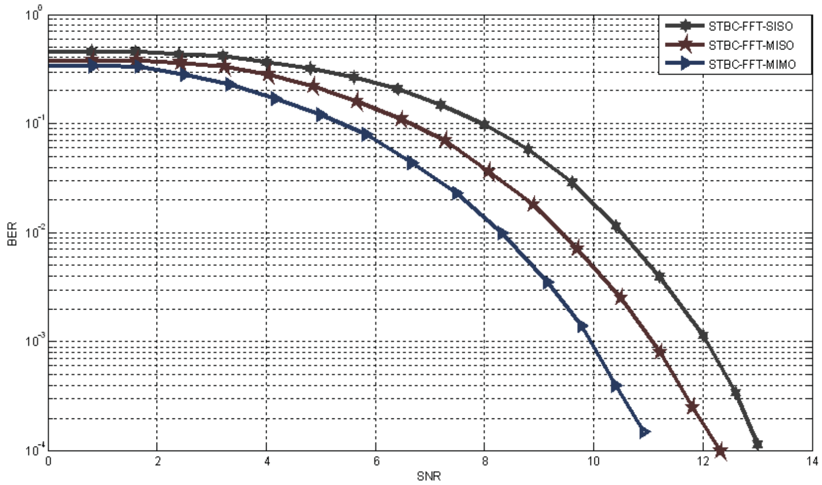

Fig. 6: BER performance of WIMAX STBC-OFDM in AWGN channel model.

AWGN plus Multipath Channel Performance:

In this general channel scenario, all ITU profiles presented in (International Telecommunication Union 2002). In the next sections the relevant results are discussed

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 7 it can be seen that for BER=10^{-3} the SNR required is approximately 14.8 dB for MIMO, 15.95 dB for MISO and 17.5dB for SISO. Figure 7 clearly illustrates the MIMO significantly outperformed the other system for this channel model.

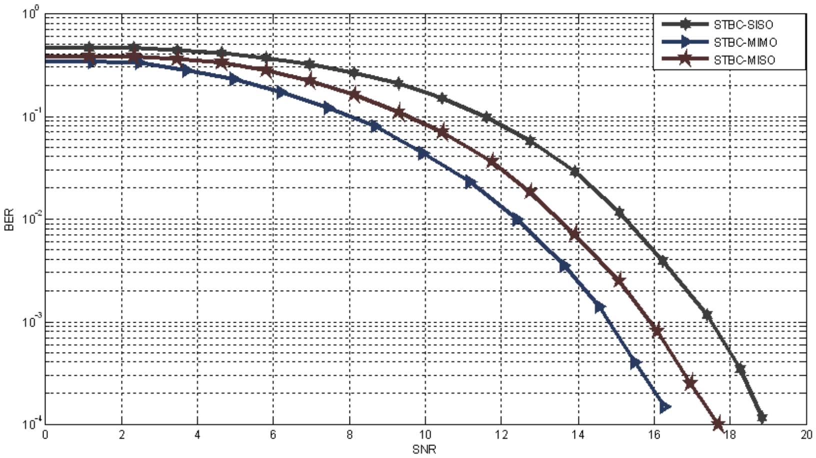

Fig. 7: BER performance of WIMAX STBC-OFDM in AWGN plus Multipath Indoor Channel A

b. 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 both Figure 9, that BER performance of MIMO is better also than the two systems which are MISO and SISO. The MIMO has BER performance of 10^{-3} about 21.2dB and the MISO has the same BER performance at 23dB also has same BER performance for SISO at 25.1dB. From these results it can be concluded that the MIMO is more significant than the two systems based of MISO and SISO in this channel that have been assumed.

b. 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 huge role in the systems' performances. Observing both Figure 8, the performance of the MIMO is better also than the two systems which are MISO and SISO. The STBC-OFDM had a BER performance of 10^{-3} approximately 7.5dB for MIMO, 12.5dB for MISO and 25.1dB for SISO. From these results it can be concluded that the MIMO is more significant than the other system in the different channels that have been assumed.

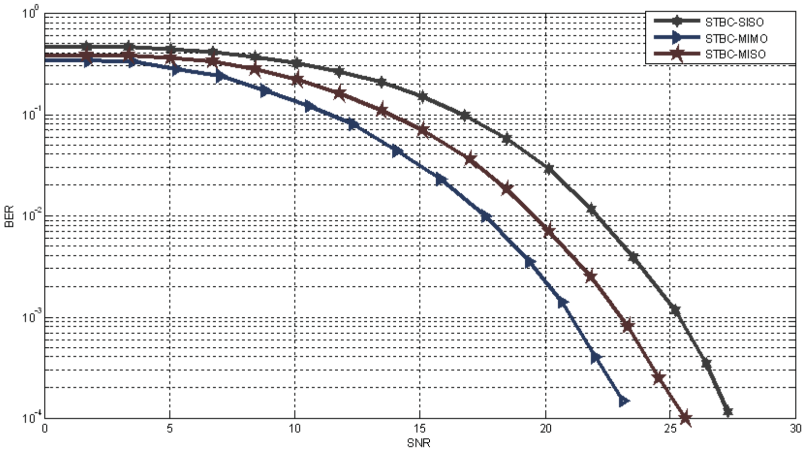

Fig. 8: BER performance of WIMAX STBC-OFDM in AWGN plus Multipath Indoor Channel B

c. Pedestrian Channel A

In the pedestrian profile, two different situations were considered: a moving and a stationary person. These results are depicted in figure 9 and 10. Figure 9 represents the case of the stationary person. It can be seen that for BER=10^{-3} the SNR required for STBC-OFDM was approximately 14.9 dB for MIMO, 15.95dB for MISO and 17.3dB for SISO. Figure 10 presents the case of a moving person. It can Also be seen that for BER=10^{-3} the SNR required for STBC-OFDM is approximately 18 dB for MIMO, 19.9dB for MISO and 22.2dB for SISO. Figures 9 and 10 clearly illustrate that the MIMO significantly outperforms other system for this channel model.

d. Pedestrian Channel B:

Using the same methodology as in the previous section, simulations for both active and stationary pedestrians were carried out. In case Stopped Pedestrian B channels. The result depicted in Figure 12 it can be seen that for BER=10^{-3} the SNR required for MIMO is about 26 dB, while in MISO the SNR about 28 dB and for SISO about 30.1dB. Also the result in active pedestrians is depicted in Figure 13 and Also from Figure 12 and Figure 13 it is found that the MIMO outperforms significantly other two systems for this channel model.

d. 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 11, which shows that for BER=10,$^{-3}$ the SNR required for STBC- OFDM is approximately 26 dB, for MIMO, 28 dB for MISO and 30.1dB for SISO. The results for the case of the active pedestrians are depicted in Figure 12, it clearly showed overall poor performance, Figures 11 and 12 clearly show that the MIMO significantly outperformed the other two systems for this channel model.

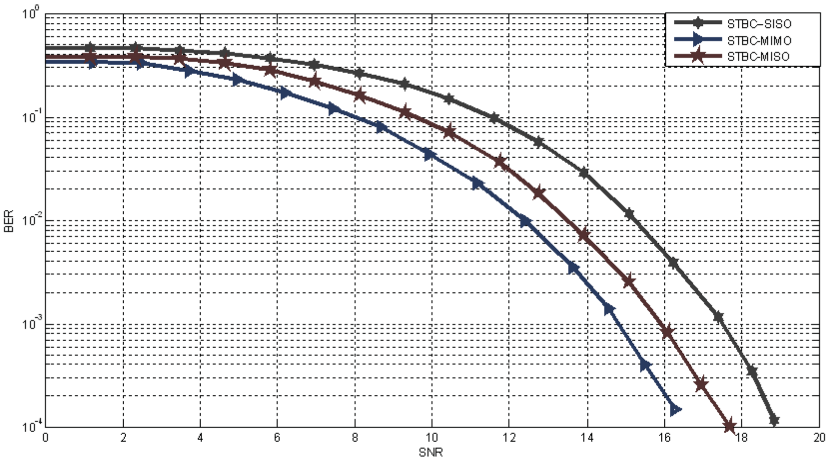

Fig. 9: BER performance of WIMAX STBC -OFDM in AWGN & Multipath stationary Pedestrian A channel

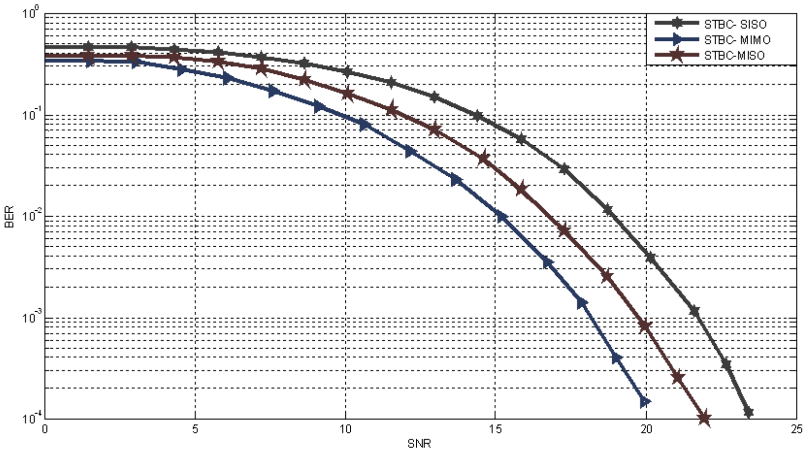

Fig. 10: BER performance of WIMAX STBC -OFDM in AWGN & Multipath Active Pedestrian A channel

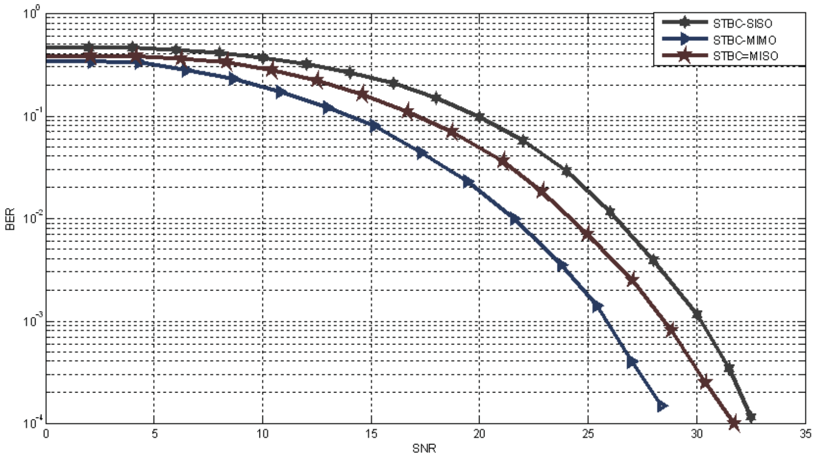

Fig. 11: BER performance of WIMAX STBC -OFDM in AWGN & Multipath stationary Pedestrian B channel.

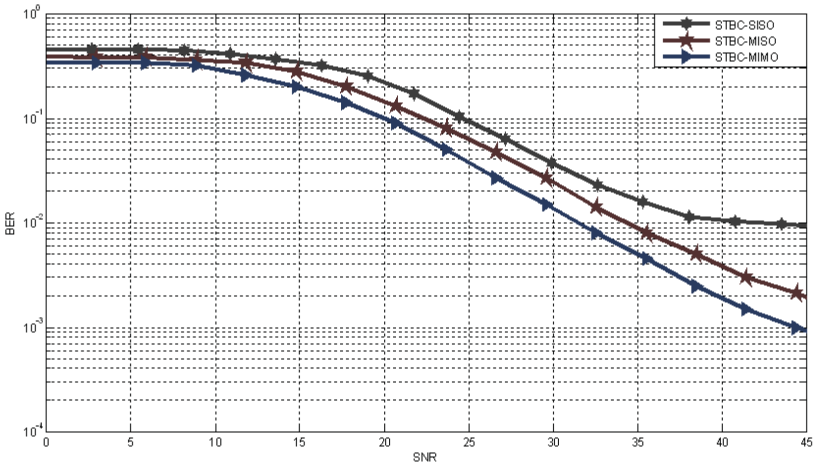

Fig. 12: BER performance of WIMAX STBC -OFDM Performance in AWGN & Multipath Active Pedestrian B channel

Conclusion:

The DSP of the SFF SDR Development Platform are completely integrated to the model based design flow, which integrates MATLAB, Simulink, and Real-Time Workshop from The MathWorks. The SFF SCA Development Platform optional package allows SCA waveform development and implementation. In this paper, the STBC-OFDM structure was proposed and tested. These tests were carried out to verify its successful operation and its possibility of implementation. It can be concluded that this structure achieves much lower bit error rates assuming reasonable choice of the bases function and method of computation. In AWGN, and other channels the MIMO outperform than MISO and SISO Therefore, this structure can be considered as an alternative to the conventional STBC-OFDM. It can be concluded from the results obtained, that S/N measure can be successfully increased using the proposed MIMO designed method. The key contribution of this paper was the implementation of the IEEE 802.16d PHY layer based the MIMO structure on The SFF SDR Development Platform, was proposed simulate and tested. Simulations provided proved that proposed design achieves much lower bit error rates and better performance than MISO and SISO Proposed MIMO systems is robust for multi-path channels, which means that it obtains higher spectral efficiency than other systems and it can be used at high transmission rates.

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