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Performance Analysis of Physical Layer-Based Multiple-Input Multiple-Output on WiMAX (MIMO-WiMAX) †

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Abstract: High data transmission rates over wide regions and to clients in locations where broadband service is not accessible are provided by WiMAX, based on IEEE 802.16 standards for Broadband Wireless Access (BWA). The use of several antennas for sending and receiving data is a common feature of MIMO systems in wireless communications. WiMAX-MIMO devices are designed to improve WiMAX system performance. An analysis of MIMO-WiMAX systems using various modulations and coding rates in a Rayleigh fading channel is presented in this work. Matlab software version (R2018a) is used to examine the relationship between bit error rates and signal-to-noise ratios with various cyclic prefixes and single/multiple transceivers. The codes of Alamouti STBC are used to examine the BER performance of MIMO-WiMAX.

Keywords: MIMO; STBC; WIMAX

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1. Introduction

High-speed web access can be provided through WiMAX, based on IEEE 802.16 standards. Wireless MAN appellations are also used to describe these standards, and thus, may be used in metropolitan area networks in bridging the gap between WLANs and wireless wide area networks. WiMAX is considered a Wireless MAN technology [1]. In places where conventional broadband connections are useless, WiMAX offers a cheap option for internet access, reducing expenses, and making technology more accessible. WiMAX connections can achieve transmission data speeds of up to 75 Mbps, making internet access possible across distances of up to 30 miles (50 km). To prevent inter-symbol interferences, IEEE 802.16e WiMAX air interfaces use Orthogonal Frequency Division Multiplexing (OFDM) (ISI) [2]. Fixed WiMAX operates in 10–66 GHz frequency spectrums and has line-of-sight requirements, making them principal versions of IEEE 802.16. (LOS). A 2–11 GHz frequency range has been added to the WiMAX standard, enabling non-line-of-sight transmission and reception between the transmitter and receiver.

2. WIMAX Physical Layer Model

The Orthogonal Frequency Division Multiplexing (OFDM) constructs the WiMAX physical layers (OFDM) [3]. It is the primary goal of the physical layer to transform data frames from the top layers into a wireless communication format [4]. In order to increase capacity and performance, channel coding is utilized in the WiMAX transmitter [5].

2.1. Randomizer

Coding speed may be improved by avoiding extended sequences of ones and zeros in a random sequence, and by randomizing the input data [6]. A 15-stage shift register with XOR gates in a feedback arrangement is used to eliminate mistakes, as depicted in Figure 1. Figure 2 shows the PRB generator for randomization.

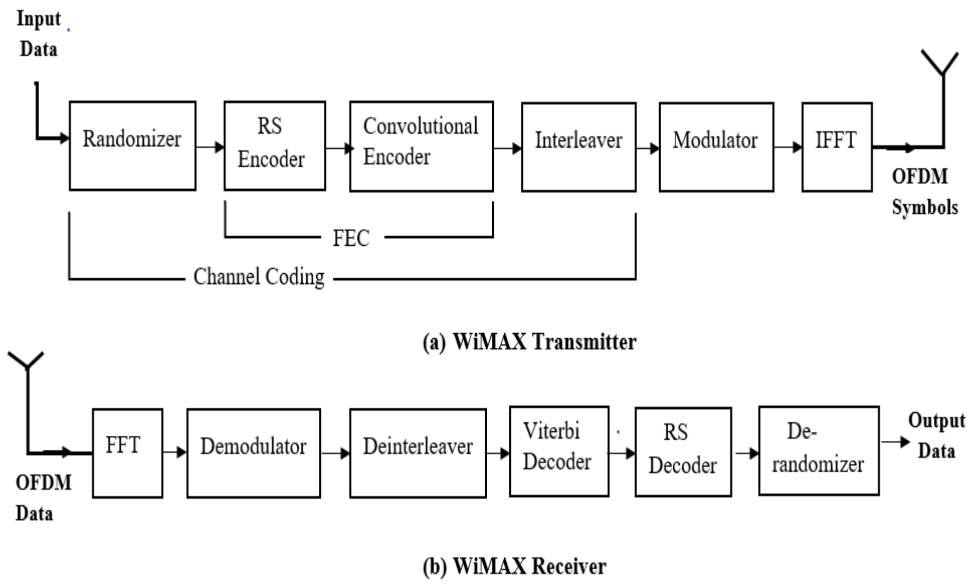

Figure 1. Block diagram of WiMAX.

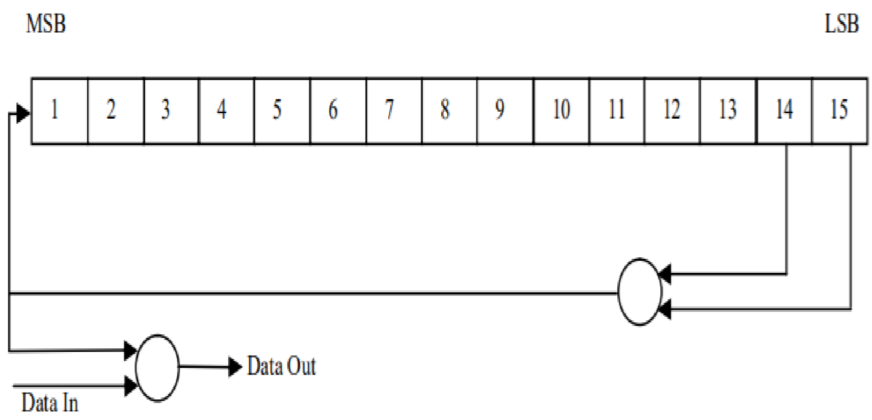

Figure 2. PRB generator for randomization.

2.2. Forward Error Correction

After randomization, the output bits from the randomizer are input into the FEC encoder, which encrypts data bursts on both the uplink and the downlink using a concatenated outer RS code and an inner convolutional code [7]. RS codes are utilized for the purposes of error detection, as well as error repair.

REED SOLOMEN CODE (RS): RS codes are used to change block size, and are responsible for correcting block faults. In order to include superfluous bits in the initial bit stream, the encryption technique for the RS encoder depends on Galois field calculation to do its job. The Galois field F (28), on which WiMAX is built, correlates to RS (N = 255, K = 239, T = 8).

CONVOLUTIONAL CODES (CC): outer RS codes are concatenated with a punctured inner convolutional code. These convolutional codes are used to repair random faults, and they are easier to build than RS codes [8].

These programs use linear shift memory registers to add unnecessary bits to the data stream (k). Changing the encoded bit ’m’ into an n-bit symbol is how the convolutional code, also known as CC, is defined. The pace of the code may be expressed as m/n [9]. At the receiving end, the Viterbi algorithm is used to decipher the encoded sequence.

2.3. Modulation

The QPSK, 16-QAM, and 64-QAM bit modulations may be supported by the bits that are interleaved and given serially to the constellation mapper [10]. To guarantee that the symbols all have the same amount of average powers, complex constellations are normalized using predetermined multiplication factors for each modulation technique. The mapped data in the constellation are distributed evenly throughout all OFDM symbol's data sub-carriers, with the distribution order determined by the rising frequency offset index. Because the channel operates in the time domain, the data change from being in frequency domains to time domains, so that they may be represented as OFDM subcarriers [11]. This creates a waveform that meets the orthogonality criteria automatically. In the same way that IFFT acts in the opposite direction, FFT turns data from the time domain into data from the frequency domain. This is necessary, since our work is done in the frequency domain. Figure 3 depicts the Convolutional encoder with a code rate of 1/2.

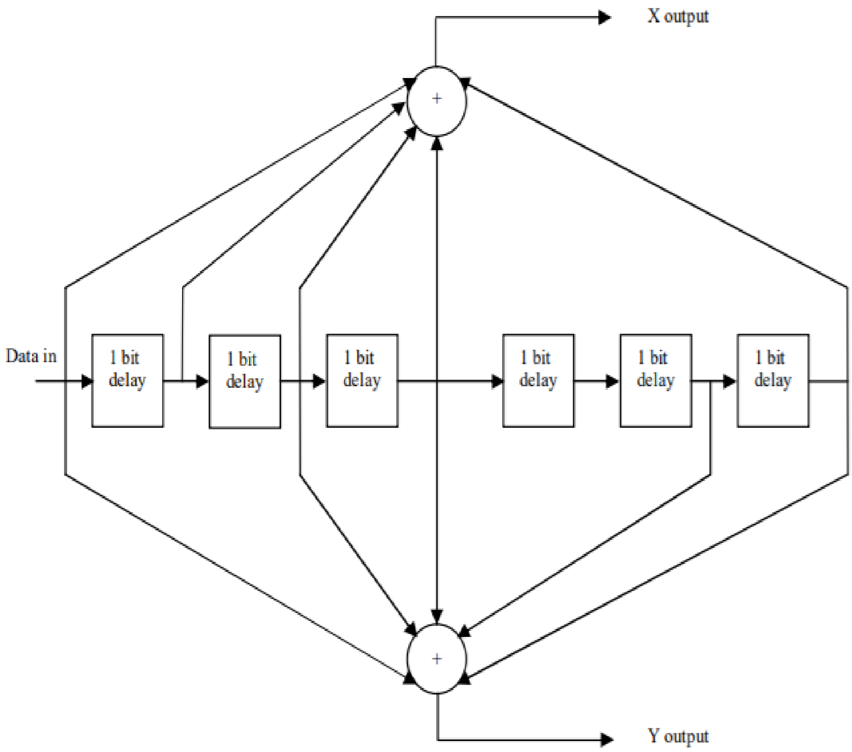

Figure 3. Convolutional encoder of code rate, 1/2.

2.4. Cyclic Prefixes

To avoid the guard interval of analog transmission, a cyclic prefix is added to the time domain samples, and used in time-defined multicarrier transmitter implementations.

The cyclic prefix is first removed at the receiver in a manner similar to the guard interval removal. At the same time, the channel effect is transformed into a cyclic convolution of the discrete-time channel with the IDFT of the data symbol. Figure 4 shows the cyclic prefix.

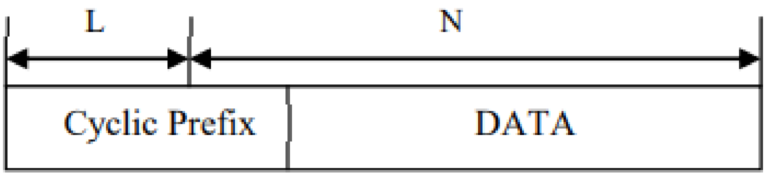

Figure 4. Cyclic prefix.

2.5. Communication Channel

WiMAX uses wireless channels to handle the communication that takes place between the transmitter and receiver sides of the system. Within the scope of this work, the Rayleigh fading channel is taken into consideration [12].

3. MIMO-WIMAX System

In order to provide customers with high-speed broadband internet access, WiMAX-MIMO systems were developed. These systems incorporate the benefits that are associated with WiMAX technology and MIMO systems [13]. The goal of this research is to obtain diversity gain by combining WiMAX technology with the spatial diversity approach used in MIMO systems. In order to evaluate how well MMO-WIMAX is functioning, Alamouti Space Time Block Codes are included [14]. The schematic of blocks is shown in Figure 5.

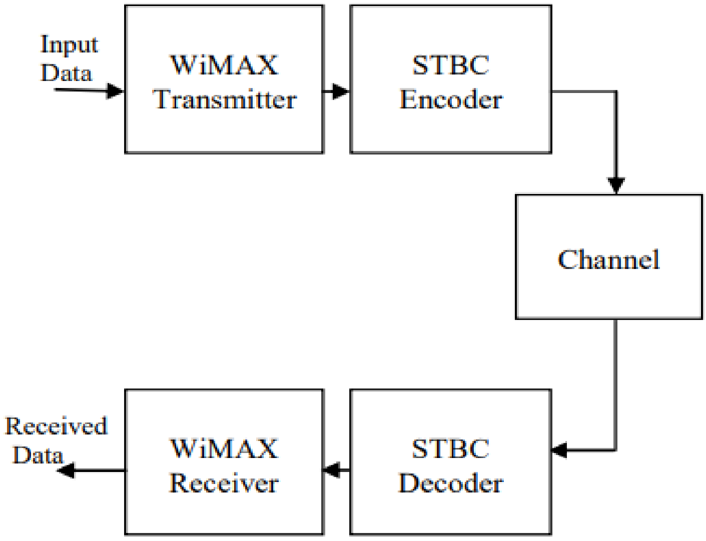

Figure 5. MIMO-WiMAX system.

The high data rate transmission that arises from the combination of WiMAX with MIMO technology is one of the ways the performance of WiMAX-MIMO systems may be improved over that of normal WiMAX systems. The performance of this technology is superior to that of standard WiMAX, which does not make use of MIMO systems for both BER and SNR. Alamouti systems are implemented using two transmit antennas and nr reception antennas, and are capable of having a maximum diversity order of 2Nr. Maximum Likelihood Decoding is used at receivers for Alamouti code encoding.

4. Simulation Results

The high data rate transmission that arises from the combination of WiMAX with MIMO technology is one way to improve the performance of WiMAX-MIMO systems over normal WiMAX systems. The performance of this technology is superior to that of standard WiMAX, which does not make use of MIMO systems for BER and SNR values. Alamouti systems are implemented using two transmit antennas and nr reception antennas, and are capable of having max. diversity order of 2Nr. Maximum Likelihood Decoding is used at the receiver for Alamouti code encoding. The performance of MIMO-WiMAX for BER vs. SNR was analyzed. Comparing lower modulation schemes like QPSK to higher modulation schemes like 64-QAM, simulation results illustrated in Figure 6 suggest that lower modulation schemes, such as QPSK, have lower bit error rates. Transmission quality deteriorates as the number of symbols sent in each block increases. This occurs as a direct result of the mapping that is carried out inside the transmission values. The number of possible mapping arrangements has a direct correlation with the error rate, which rises as choice counts increase, as shown in Figure 6.

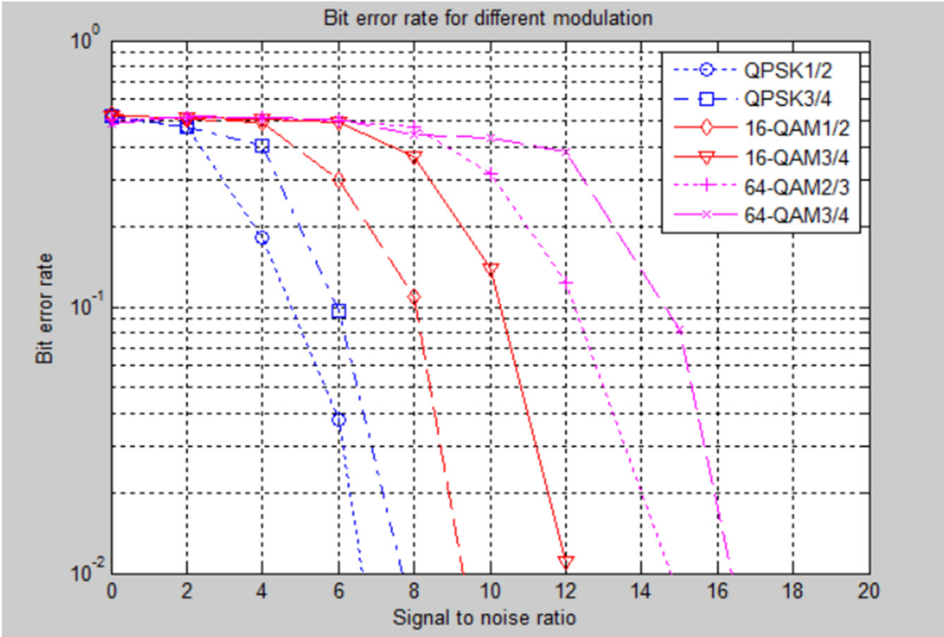

Figure 6. BER estimations for various modulation approaches in MIMO−WiMAX.

In this case, the cyclic prefix (CP) choices utilized are 1/4, 1/8, and 1/16 of the symbol time, which corresponds to the number of FFT samples. Findings indicate that the cyclic prefix of 1/4 had a lower BER compared to the cyclic prefixes of 1/8 and 1/16. The greater the cyclic prefix, the more effective it is in avoiding interference between symbols; nevertheless, the higher the full time of symbol, the longer it takes to communicate the same information [15]. Therefore, a lower cyclic prefix, such as 1/4, has a better bit error rate than higher cyclic prefixes, such as 1/8 and 1/16, as shown in Figure 7.

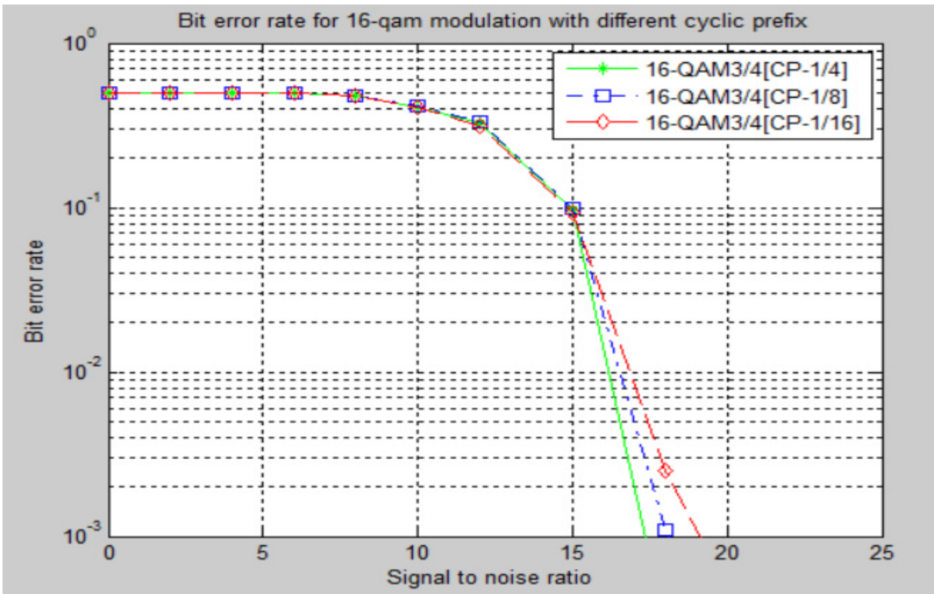

Figure 7. BER performance of 16−QAM at different cyclic prefixes.

In this part of the article, BER vs. SNR graphs for MIMO-WiMAX are generated using Alamouti 2 × 1 and 2 × 2 schemes [16]. The simulation uses QPSK modulation, and the bit error rate (BER) of 2 × 1, 2 × 2, and 1 × 1 (basic WiMAX) are studied and compared with one another, as shown in Figure 8.

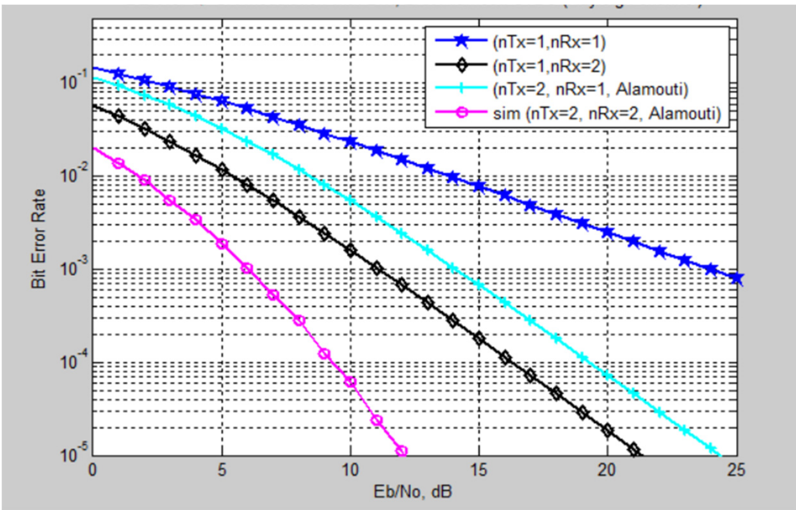

Figure 8. BER performance of MIMO−WiMAX Alamouti 2 × 1, 2 × 2.

The simulation results of Alamouti 2 × 1, 2 × 2 are compared with each other in the above figure, demonstrating a steady drop in the BER rate as receive diversity increases. Results obtained with Alamouti 2 × 2 have been shown to be superior to those obtained with Alamouti 2 × 1 and 1 × 1 [17]. It is clear from the results that MIMO (2 × 2) has a reduced BER in comparison to both MISO (2 × 1) and standard WiMAX (1 × 1). According to the findings, combining the MIMO strategy with WiMAX results in a better bit error rate (BER) than using WiMAX alone [18–20].

5. Conclusions

BER and SNR are two of the measures that are used in the analysis of the performance of the WiMAX PHY layer, based on the OFDM protocol. On the transmitter side, forward error correction encoding is used so that the data sent is completely free of error. According to the results of the simulations, lesser modulation schemes have superior performance compared to higher modulation schemes. According to the findings that were produced by the simulation model, BER is improved whenever there is a greater value of SNR. On the MIMO system, space-time block coding, abbreviated as STBC, was been applied. Based on the findings of the simulation, we have reached the conclusion that Alamouti 2 × 2 has a lower BER compared to Alamouti 2 × 1 and 1 × 1. MIMO and WiMAX working together exhibit lower bit error rates (BERs) and greater spectral efficiencies than WiMAX working alone.

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Conflicts of Interest: The authors and coauthors declare no conflict of interest.

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