Performance Analysis of Mobile WiMAX System using Forward Error Correction and Space Time Coding Techniques

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***Abstract*-WiMAX is a wireless broadband solution that offers a rich set of features with a lot of flexibility in terms of deployment options and potential service offerings. Broadband access not only provides faster web surfing and quicker file downloads but also enables several multimedia applications such as real-time audio and video streaming, multimedia conferencing and interactive gaming. WiMAX (Worldwide Interoperability for Microwave Access) technology is designed to accommodate both fixed and mobile broadband applications. User demands are growing and the available spectrum is limited. This problem can be overcome by WiMAX. WiMAX supports high data rates. The performance of mobile WiMAX system can be enhanced by using channel and space-time coding techniques. The BER (bit-error rate) can be reduced by using better channel coding techniques. In this paper, mobile WiMAX system using LDPC (Low Density Parity Check) and Turbo coding is simulated. STBC and STTC techniques are also employed to analyze the bit-error rate.**

Index Terms—WiMAX, Low Density Parity Check Codes, Turbo Coding, Space Time Block Codes, Space Time Trellis Codes, Bit-error Rate

I.INTRODUCTION

WiMAX technology is based on wireless metropolitan area networking (WMAN) standards developed by the IEEE 802.16 group adopted by both IEEE and the ETSI HIPERMAN group. WiMAX is capable of supporting very high peak data rates. The peak physical data rate can be as high as 74Mbps when operating using a 20MHz wide spectrum. Under very good signal conditions, even higher peak rates may be achieved using multiple antennas and spatial multiplexing. WiMAX has a scalable physical layer architecture that allows for the data rate to scale easily with available channel bandwidth. WiMAX supports a number of modulation and forward error correction (FEC) coding schemes. Adaptive modulation and coding (AMC) is an effective mechanism to maximize throughput in a time-varying channel [4].

The WiMAX MAC layer has a connection-oriented architecture that is designed to support a variety of applications, including voice and multimedia services. The system offers support for constant bit-rate, variable bit-rate, real-time and non-real-time traffic flows, in addition to best-effort data traffic. WiMAX MAC is designed to support a large number of users with multiple connections per terminal, each with its own QoS requirement. Mobile WiMAX uses OFDMA (Orthogonal Frequency Division Multiple Access) as a multiple-access technique, whereby different users can be allocated different subsets of the OFDM tones.

WiMAX supports strong encryption using Advanced Encryption Standard (AES) and has a robust privacy and key-management protocol. The system also offers a very flexible authentication architecture based on Extensible Authentication Protocol (EAP), which allows for a variety of user credentials, including username/password, digital certificates and smart cards. The WiMAX system has a number of hooks built into the physical-layer design, which allows for the use of multiple-antenna techniques, such as beamforming, space-time coding and spatial multiplexing. These schemes can be used to improve the overall system capacity and spectral efficiency by deploying multiple antennas at the transmitter or the receiver.

Channel coding technique is used for providing reliable information through the transmission level to users. It reduces noise and interference in wireless communication medium. The effectiveness of error detection depends on the signal to noise ratio (SNR). MIMO based wireless systems equipped with multiple antennas at both transmitting and receiving ends have promised enormous capacity gains over SISO (Single-Input Single-Output) based wireless systems [8]. MIMO is considered suitable technology for WiMAX because they can exploit non-line-of-sight channels. In this paper, an attempt has been made to implement mobile WiMAX system using LDPC and turbo coding techniques. BER is analyzed by using these coding techniques. An attempt has also been made to implement WiMAX system using MIMO considering space-time coding techniques. Rayleigh channel is considered for simulation. This paper is organized as follows. Section II deals with WiMAX physical layer model. Section III deals with channel coding techniques. Section IV deals with space-time coding techniques. Simulation results are discussed and analyzed in section V. Conclusion is drawn in section VI.

II. WIMAX PHYSICAL LAYER MODEL

The WiMAX physical layer is based on OFDM (Orthogonal Frequency Division Multiplexing). OFDM is a scheme that offers good resistance to multipath and allows WiMAX to operate in NLOS (non line-of-sight) conditions. OFDM is now widely recognized as the method of choice for mitigating multipath for broadband wireless. OFDM is the transmission scheme of choice to enable high-speed data, video and multimedia communications and is used by a variety of commercial broadband systems, including DSL, Wi-Fi, Digital Video Broadcast-Handheld (DVB-H) and MediaFLO, besides WiMAX. OFDM is based on a transmission scheme called multi-carrier modulation, which divides a high bit stream into a number of low bit streams, which are each modulated by separate carriers called subcarriers or tones. The WiMAX RF signals use OFDM techniques and its signal bandwidth can range from 1.25 to 20 MHz. To maintain orthogonality between the individual carriers the symbol period must be reciprocal of the carrier spacing.

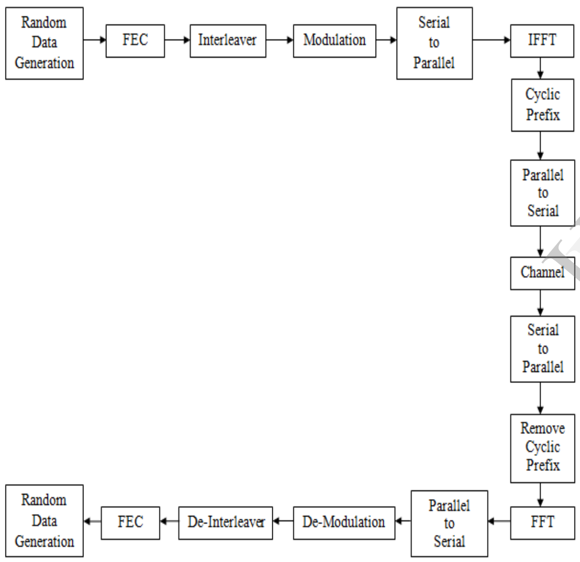

Figure 1: WiMAX OFDM physical layer model

The physical layer model of WiMAX system is shown in figure 1. The various blocks of this model are explained below:

1. *Random Data Generation*

This block converts an input string into a random output string of the same length, avoiding long sequences of bits of the same value.

2. *FE C*

FEC (Forward Error Correction) is a technique used for controlling errors in data transmission over noisy communication channels. The main idea is to encode the message by the sender in a redundant way by using an error-correcting code.

3. *Interleaver*

Here, data is written in either row or column wise and read in column or row manner respectively. This enhances the performance of coding.

4. *Modulation*

The interleaved and rearranged data are digitally modulated by different modulation schemes such as PSK and QAM.

5. *Serial to parallel conversion*

In OFDM a serial to parallel conversion stage is needed to convert the input serial bit stream to a parallel data stream, which is to be transmitted in each OFDM symbol. The data assigned to each symbol depends on the modulation scheme used and the number of sub carriers. At receiver, the reverse process takes place with the data from the sub carriers being converted back to the original serial data stream.

6. *IFFT*

The IFFT (Inverse Fast Fourier Transform) is used to convert frequency domain signal to time domain signal. In frequency domain, each of the discrete samples of IFFT corresponds to an individual subcarrier. Most of the subcarriers are modulated with data. The outer subcarriers are unmodulated and set to zero amplitude. These zero sub carriers provide a frequency guard band before the Nyquist frequency and effectively act as an interpolation of the signal.

7. *Cyclic prefix*

Refers to prefixing of a symbol with a repetition to the end. It serves as a guard interval and the receiver is typically configured to discard cyclic prefix samples. It eliminates the ISI (Inter-Symbol Interference) from the previous symbol.

8. *Rayleigh Fading Channel*

Rayleigh fading channel is a statistical model for propagation environment on the radio signal used by wireless networks [17]. It assumes that the power of a signal passes through a transmission medium will vary randomly which is modeled as Rayleigh distribution. It is a reasonable model for troposphere and ionosphere signal propagation as well as the effect of heavily built-up urban environment on radio signals. This channel is most applicable when there is no line-of-sight between the transmitter and receiver.

III. CHANNEL CODING TECHNIQUES

The channel code encodes the information sent over a communication channel in such a way that channel noise, errors can be detected and corrected. In this paper, two channel coding techniques are implemented. They are low-density parity-check codes (LDPC) and Turbo coding. LDPC and Turbo codes are used as outer coding techniques. Meanwhile, convolutional coding is used as inner coding technique in the forward error correction (FEC) channel.

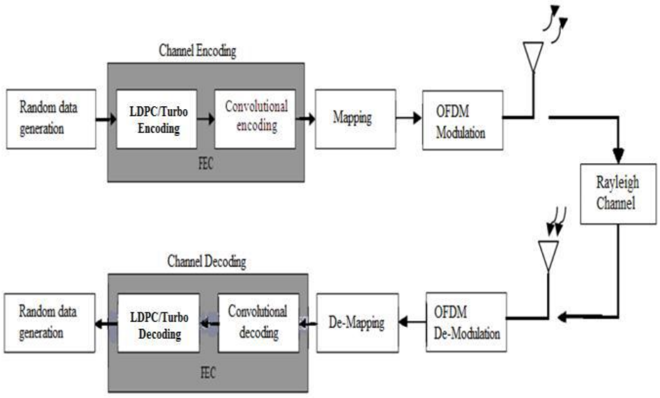

Figure 2: Model of mobile-WiMAX system with LDPC/Turbo coding

1. LDPC Coding

This is the class of error-correcting codes. Low-density parity-check (LDPC) codes have recently attracted tremendous research interest because of their excellent error-correcting performance and highly parallel decoding scheme. Invented by Gallager in 1962, LDPC codes have been largely neglected by the scientific community for several decades until the remarkable success of Turbo codes that invoked the rediscovery of LDPC codes, pioneered by MacKay, Neal and Wiberg. The past few years experienced significant improvement in LDPC code construction and performance analysis.

LDPC codes have been lately selected by the digital video broadcasting (DVB) standard and are being seriously considered in various real-life applications such as magnetic storage, Ethernet and high-throughput wireless local area network (LAN).

It is possible to decode LDPC codes on a relatively low-powered microprocessor by the use of lookup tables [7]. It is also possible to pre-calculate the output bit based upon predetermined input bits. The disadvantage is that its BER performance is low.

2. Turbo Coding

Turbo codes are basically convolutional codes concatenated in series or in parallel and are generally known as convolutional turbo codes (CTC). The advantages of Turbo code are modulation schemes becomes feasible even at low SNR levels, high data rate, low path loss and BER is less compared to other coding techniques [7]. Turbo codes are powerful error-correcting codes. The basic idea of turbo codes is to use two convolutional codes in parallel with some kind of interleaving in between them. Convolutional codes can be used to encode a continuous stream of data, but in this case it is assumed that data is configured in finite blocks corresponding to the interleaver size. The frames can be terminated i.e. the encoders are forced to a known state after the information block. The terminated tail is then appended to the encoded information and is used in the decoder.

The received analog signal is sampled and assigned integers indicating how likely it is that a bit is 0 or 1. Each decoder takes the noisy data, respective parity information and computes each decoded bit. Then the output is converted back to binary digits.

The main disadvantage is the complexity in design. It takes more time and needs a powerful processor.

IV. SPACE TIME CODING TECHNIQUES

Another way to enhance link capacity and spectral efficiency is the application of MIMO in wireless systems. Multiple-input multiple-output (MIMO) systems are today regarded as one of the most promising research areas of wireless communications. This is due to the fact that a MIMO channel can offer a significant capacity gain over a traditional single-input single-output (SISO) channel.

The increase in spectral efficiency offered by MIMO systems is based on utilization of space (or antenna) diversity at both the transmitter and the receiver. Due to the utilization of space diversity, MIMO systems are also referred to as multiple-element antenna systems (MEAs). STBC (Space Time Block Codes) first introduced by Alamouti is a simple orthogonal code which allows for simple single-symbol maximum likelihood detection in flat fading conditions.

The combination of OFDM and MIMO enables the frequency selective MIMO channel to be separated into many flat fading channels and is considered to be suitable for mobile WiMAX. It supports a full range of smart antenna technologies, including STBC, spatial multiplexing and beamforming techniques. Multiple antenna systems can be classified into three main categories.

First, multiple antenna at the transmitter side are usually applicable for beamforming purposes. Frequency and space diversity schemes are realized by using multiple antennas at the transmitter or receiver side constitutes second type. The third category includes systems with multiple transmitter and receiver antennas realizing spatial multiplexing also known as MIMO.

The model of MIMO-mobile WiMAX system is shown in figure 3.

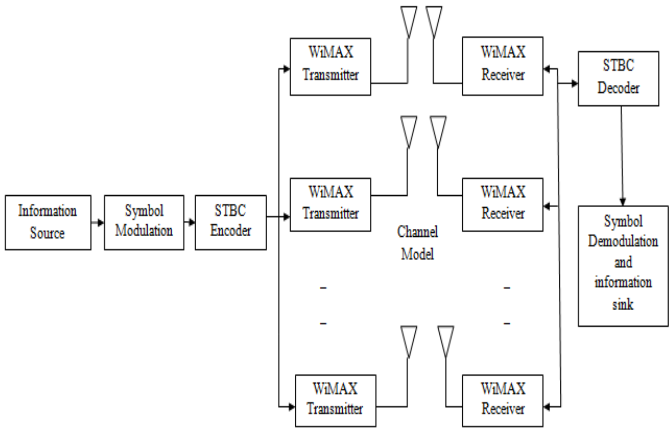

Figure 3: Model of MIMO-mobile WiMAX system

1. STBC (Space Time Block Codes)

STBC is one type space-time coding (STC) technique used as diversity technique and STBC is capable of creating diversity at the receiver to improve the performance of wireless systems [15]. STBC utilizes N transmit antennas separated far apart to ensure independent fades. At a given symbol period, N signals are transmitted simultaneously from N different antennas. The signal transmitted from each antenna has a unique structure that allows the signal to get reproduced in its original form at the receiver. STBC [9] is the generalized version of Alamouti scheme, but have the same key features. These codes have orthogonal properties and can achieve better transmit diversity specified by the number of transmit antennas.

Space-time block code is a complex version of Alamouti's space-time code, in which the encoding and decoding schemes are the same as there in the Alamouti space-time code. The data is constructed as a matrix which has columns equal to the number of transmit antennas and rows equal to the number of time slots required to transmit the required data. At the receiver side, signals received are combined and then sent to maximum likelihood detector where decision rules are applied. Space-time block code is designed to achieve maximum diversity order for given number of transmit and receive antenna. Space-time block codes operate on a block of input symbols producing a matrix output over antennas and time. Unlike traditional single-antenna AWGN block codes, full rate space-time block codes do not provide coding gain. Their key feature is the provision of full diversity with extremely low encoder/decoder complexity.

2. STTC (Space Time Trellis Codes)

The second type of space time coding technique is STTC that can be described by a trellis tree. Compared with STBC, STTC system combines space diversity and coding gain. Bbit-interleave coded modulation (BICM) based STC can be optimally decoded by the Viterbi algorithm without resorting to sub-optimal iterative algorithms. In STTC, N transmit antennas are utilized and the transmit antennas are separated far apart to ensure independent channels. At a given symbol period, N signals are transmitted simultaneously from N different antennas. The signal transmitted from each antenna has a unique structure with inherent error-correction capability allowing signal to be recovered and corrected at the receiver.

Like traditional TCM (trellis coded modulation) for the single-antenna channel, space-time trellis codes provide coding gain [11]. Since they also provide full diversity gain, their key advantage over space-time block codes is the provision of coding gain. However, they are extremely difficult to design and require an expensive encoder and decoder.

V. SIMULATION RESULTS AND ANALYSIS

WiMAX OFDM physical layer model is simulated. The obtained result is compared with theoretical result. Mobile WiMAX system using LDPC coding is simulated initially. QAM and PSK modulation schemes are employed. The channel used is Rayleigh channel. Bit-error rate performance of mobile WiMAX system is determined using LDPC coding and compared for QAM and PSK modulation schemes. Turbo coding is used as second channel coding technique. BER performance of mobile WiMAX system is compared between LDPC and Turbo coding techniques. Further, BER analysis of mobile WiMAX system using MIMO model with STBC and STTC is calculated and compared between different antenna configurations.

1. BER Analysis of WiMAX OFDM Physical Layer

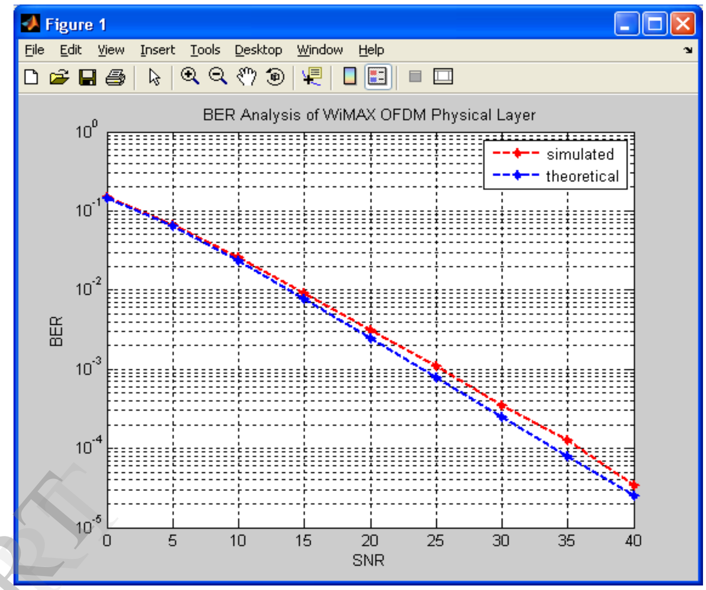

Figure 4: WiMAX OFDM physical layer simulation under Rayleigh channel

It is inferred through figure 4 that, simulation result of WiMAX OFDM physical layer has BER almost comparable with that of theoretical results at 40dB SNR under Rayleigh channel. The bit-error rate is almost near to 10^{-5} at 40dB theoretically and nearly $10^{-4.5}$ as per simulation results.

2. BER Analysis using LDPC Coding under Rayleigh Channel. Comparison between QAM and PSK Modulation Schemes

It is inferred from figure 5 that mobile WiMAX system using LDPC coding under Rayleigh channel has BER of less than $10^{-0.8}$ at 5dB SNR for QAM modulation scheme and BER of $10^{-0.8}$ for PSK modulation scheme.

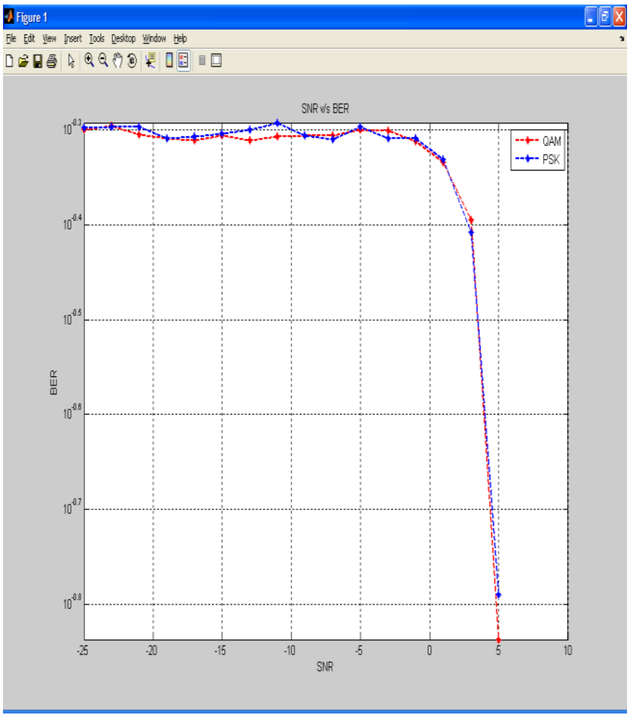

Figure 5: LDPC coding under Rayleigh channel

3. BER Analysis of mobile-WiMAX system using LDPC and Turbo Coding under Rayleigh Channel

The simulation results shown in figure 6 infers that mobile WiMAX system using Turbo coding provides less bit-error rate as compared to LDPC coding under Rayleigh channel.

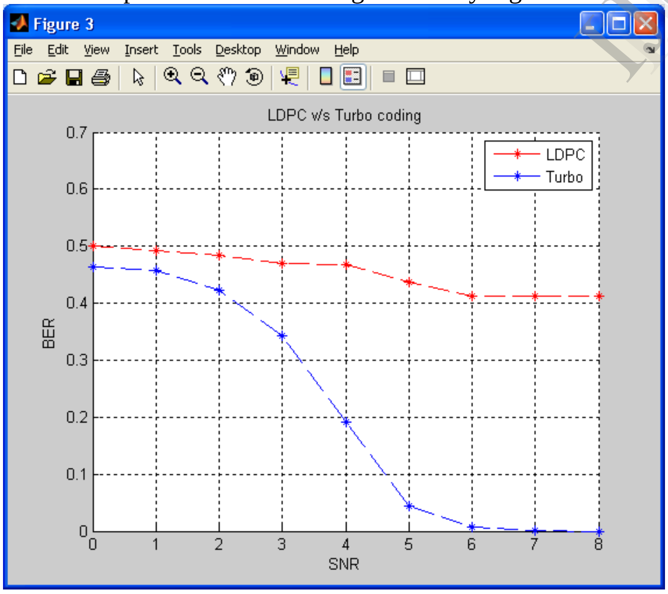

Figure 6: LDPC v/s Turbo coding under Rayleigh channel

4. BER Analysis of MIMO-mobile WiMAX system using STBC technique

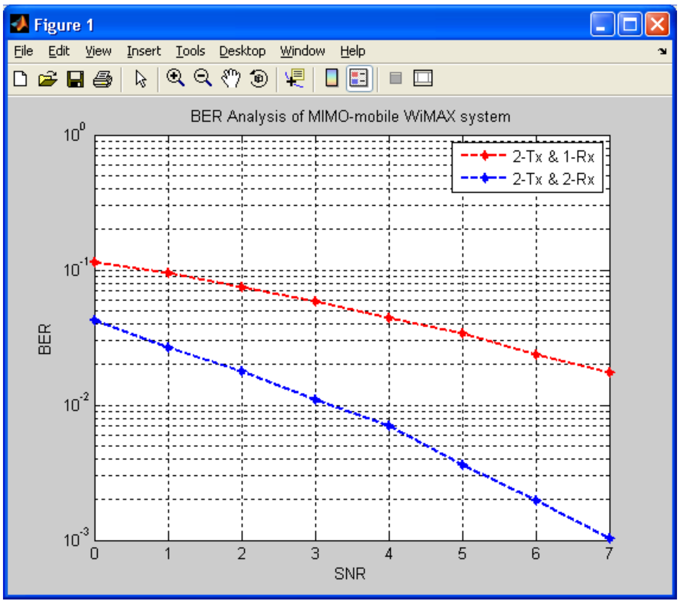

Figure 7: BER analysis of MIMO-mobile WiMAX system using STBC technique

The performance of MIMO-mobile WiMAX system is better for 2x2 configuration. BER is 10^{-3} at 7dB SNR for 2x2 configuration, while BER is nearly 10^{-2} at 7dB for 2x1 configuration.

5. BER Analysis of MIMO-mobile WiMAX system using STTC technique for 2x1 configuration

It is observed through simulation results shown in figure 8 that BER is almost 10^{-3} at 16dB for 2x1 STTC configuration.

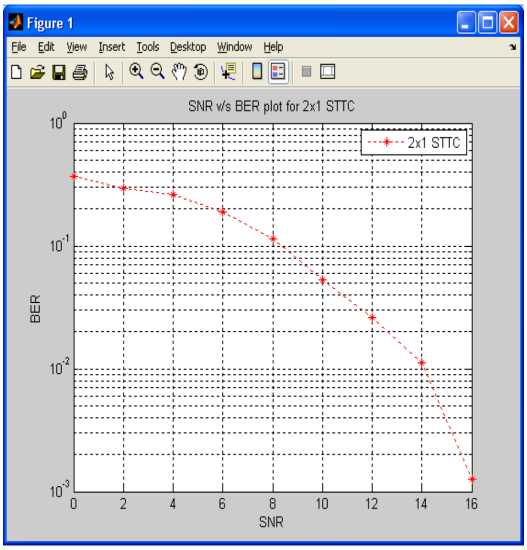

Figure 8: BER analysis using 2x1 STTC technique

6. BER Analysis of MIMO-mobile WiMAX system using STTC technique for 2x2 configuration

We can infer through simulation results shown in figure 9 that BER is less than 10^{-3} at 16dB for 2x2 STTC configuration. Performance is better as compared to 2x1 STTC configuration.

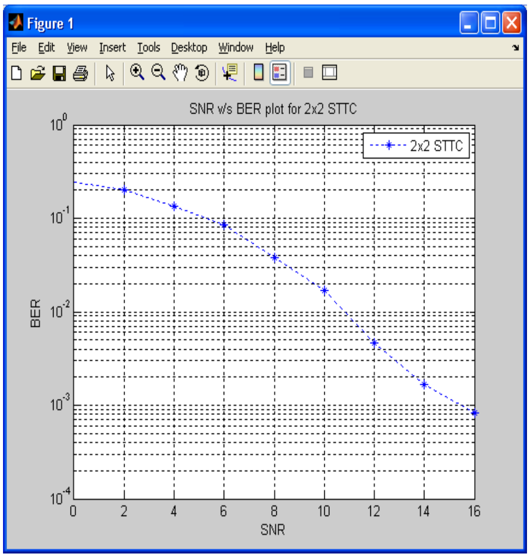

Figure 9: BER analysis using 2x2 STTC technique

VI. CONCLUSION

Mobile WiMAX system using LDPC and Turbo coding for different modulation schemes under Rayleigh channel is simulated. QAM and PSK modulation techniques were used for analysis. From simulation results, it is concluded that Turbo code gives better BER performance than LDPC codes. MIMO-mobile WiMAX system was also simulated. STBC and STTC techniques were implemented. 2x2 configuration provided better results than 2x1 configuration.

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