Bit Error Rate Analysis in Multicast Multiple Input Multiple Output Systems

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Abstract— At the present time whole information and communication technology industry contributes to the global carbon emission. With the aim of reducing the carbon footprint and the operating cost of wireless networks, overall energy reduction is required in the region of two to three orders of magnitude. Meanwhile, significant increase of the network spectrum efficiency is needed to cope with the exponentially increasing traffic loads. Due to this factors spatial modulation (SM) has recently established itself as promising transmission concept which belongs to single-radio frequency large scale multiple input multiple output (MIMO) wireless system. Spatial modulation MIMO takes advantage of whole antenna array at the transmitter, while using limited number of radio frequency chains. The multiple input multiple output multiplies capacity by transmitting different signals over multiple antennas and orthogonal frequency division multiplexing (OFDM), which divides a radio channel into many closely spaced sub channels to provide more reliable communication at high speeds. The system calculate the bit error rate (BER) for multicast multiple input multiple output system with the spatial modulation (SM) and study the effect of signal to noise ratio on bit error rate. MATLAB software is use to simulate system. The simulation results show that bit error rate decreases as signal to noise ratio increases. System reaches zero bit error rate for the value of signal to noise ratio greater than 18dB. System has provided less bit error rate for large signal to noise ratio which improves system performance.

Keywords-*Spatial modulation, Multiple input multiple output, Orthogonal frequency division multiplexing, Bit error rate Signal to noise ratio*

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I. Introduction

With the aim of reducing the carbon footprint and the operating cost of wireless networks, overall energy reduction is required in the region of two to three orders of magnitude. Meanwhile, significant increase of the network spectrum efficiency is needed to cope with the exponentially increasing traffic loads. Due to those factors spatial modulation (SM) has recently established itself as promising transmission concept which belongs to single-radio frequency (RF) large scale multiple input multiple output (MIMO) wireless system family while exploiting multiple antenna in novel fashion compared to state-of-the-art high complexity and power hungry classic multiple input multiple output system. Spatial modulation type multiple input multiple output takes advantage of whole antenna array at the transmitter, while using limited number of radio frequency chains. The main distinguishing feature of spatial modulation type multiple input multiple output is that they map additional information bits onto “spatial modulation constellation diagram”, where each constellation element is constituted by either one or subset of antenna elements. This unique characteristic facilitates high rate multiple input multiple output implementation to have reduced signal processing and circuitry complexity as well as improved energy efficiency (EE). Spatial modulation multiple input multiple output have inherent potential of outperforming many state-of-the-art multiple input multiple output schemes, provided that sufficiently large number of antenna element is available at transmitter, while just few of them are simultaneously active.

The applications of the multicast system, where a single transmitter sends the common information to multiple receivers have emerged in many wireless communication systems. By exploiting the broadcast nature of radio communications, the multicast transmission provides significant spectral efficiency improvements for group reception. This motivates extensive investigations on the theoretical limits and enhancing techniques for multicast systems using the conventional multiple input multiple output transmission. Recently, due to the increasing interests in green communications and low power transmissions, energy-efficient designs aiming to maximize the energy efficiency have drawn considerable attentions. As the spatial modulation type multiple input multiple output targets to provide a low complexity and high energy efficiency alternative to the conventional multiple input multiple output, we consider it promising candidate for enhancing the multicast systems. Although the spatial modulation type multiple input multiple output and its bit error rate (BER) performance have already been investigated in different environments and fading channels [5] [9], the bit error rate performance of spatial modulation type multiple input multiple output has not been addressed for multicast systems. In this work, bit error rate performance of the spatial modulation type multicast multiple input multiple output system is defined. The work focuses on the investigation of the bit error rate performance for spatial modulation type multiple input multiple output in multicast systems and aims to establish the fundamental properties which potentially benefit future works in designs and implementations.

II. RELATED WORK

Although spatial modulation multiple input multiple output system has received widespread attention from research community only in last four or five years, it is 13-year old technology. During years 2001-2008 various researchers independently developed transmission concepts closely related to spatial modulation multiple input multiple output scheme.

The space modulation principle appeared for first time in 2001, scheme is called space shift keying modulation and it exploits difference in signals received from different transmit antennas (TAs) to discriminate the transmitted information messages. A year later in 2002, Haas et al. proposed multiantenna modulation scheme, where the number of bits that is equal to that of the transmit antenna elements is multiplexed in an orthogonal fashion. A special property of encoding scheme is that only one out of available transmit antennas is active in every channel use. Two years later in 2004, Song et al. proposed modulation scheme termed as channel hopping technique, which is exactly what is known today as spatial modulation multiple input multiple output. It foresees transmission of two information streams, first is explicitly transmitted by using conventional phase shift keying/quadrature amplitude modulation and second is implicitly transmitted by activating single transmit antenna of available antenna array.

In 2005, Mesleh independently proposed same modulation scheme. The main motivation behind is to develop an inter channel interference (ICI) free multiantenna modulation scheme, which is realised by activating one transmit antenna in every channel use and by encoding some information bits using transmit antenna switching process. In 2006, Mesleh further investigated proposed scheme and they used for first time terminology of spatial modulation to identify encoding mechanism. A joint maximum likelihood (ML) detection method was proposed where the transmit antenna index and the transmitted symbol are estimated together providing an optimal detector for spatial modulation. Multiple input multiple output-orthogonal frequency division multiplexing (OFDM) is one of the most sought-after research directions. When spatial modulation confronts an orthogonal frequency division multiplexing system the main challenge lies on the conflict between the constraint of a single radio frequency chain in spatial modulation and the requirement of different streams for orthogonal frequency division multiplexing subcarriers. Furthermore, theoretical work has been done to analyse the performance for spatial modulation in terms of bit error probability [9]. Results show that spatial modulation offers a better performance than many state of the art multiple input multiple output techniques, while achieving a low-complexity implementation.

In 2009, J. Jeganathan, A. Ghrayeb, L. Szczecinski, and A. Ceron introduced space shift keying modulation for multiple input multiple output channels based on spatial modulation (SM) [6]. In space shift keying, antenna index used during transmission passes information rather than transmitted symbols. The absence of symbol information eliminates elements necessary for amplitude phase modulation transmission and detection. Simplicity involved in modulation and reduces detection complexity compared to spatial modulation. Analytical and simulation results show performance gain over amplitude phase modulation system (3dB at bit error rate of 10^{-5}) making space shift keying important for future wireless application.

In 2012, A. Stavridis, S. Sinanovic, M. Di Renzo, H. Haas, and P. Grant evaluate energy efficiency of multiantenna base station (BS) employing spatial modulation (SM) [1]. Taking advantage of single radio frequency (RF) chain configuration of spatial modulation, they show that spatial modulation offer significant total power reduction compared to other multi-radio frequency chain MIMO. For number of transmit antenna larger than two, spatial modulation result in higher ergodic capacity than space-time block-coding (STBC) combined with significant power saving. For base station with eight transmit antenna achieved power saving of spatial modulation can reach upto almost 90%. In 2012, Y. Chang, S. J. Lin, and W. H. Chung proposed energy efficient communication using class of spatial modulation (SM) [12]. Energy efficient modulation design is formulated and minimum achievable average symbol power consumption is derived with rate, performance and hardware constraints. Theoretical optimum is achieved by energy efficient hamming code aided space shift keying (EE-HSSK) that incorporate use of hamming and huffman code techniques in alphabet and bit-mapping design. In 2012, N. Serafimovski, S. Sinanovi´c, M. Di Renzo, and H. Haas study the behaviour of spatial modulation (SM) in multiple access scenarios [11]. Spatial modulation avoids inter channel interference by activating single transmit antenna for any transmission, requires no synchronization between transmit antenna and single radio frequency chain at transmitter. The maximum likelihood detector is proposed which can decode incoming data from multiple simultaneous transmissions. Simulation results show that detectors having knowledge of interference performs better than complexity equivalent multi-user maximum likelihood single input multiple output (ML-SIMO) detectors by at least 3dB at an average bit-error-ratio of 10^{-3}.

In 2013, A. Younis, W. Thompson, M. Di Renzo used first time real world channel measurement to analyze performance of spatial modulation [2]. In this full analysis of average bit-error performance of spatial modulation using measured urban correlated and uncorrelated Rayleigh fading channel is provided. Channel measurements are taken from outdoor urban multiple input multiple output measurement campaign. Average bit error rate (ABER) performance result using simulated Rayleigh fading channel are provided and compared with derived analytical bound for average bit error rate of spatial modulation and average bit error rate results for spatial modulation using measured urban channels. Average bit error rate results using measured urban channels validate derived analytical bound and average bit error rate results using simulated channels. Average bit error rate of spatial modulation is compared with performance of spatial multiplexing (SMX) using measured urban channels for small and large scale multiple input multiple output. It is shown that spatial modulation offers nearly same or slightly better performance than spatial multiplexing for small scale multiple input multiple output. Spatial modulation offers large reduction in bit error rate for large scale multiple input multiple output.

III. METHODOLOGY

A. *Multicast Spatial Modulation type Multiple Input Multiple Output System*

The multicast multiple input multiple output system consisting of a transmitter and K independent receivers. Then transmitter is equipped with N_t transmit antennas and each receiver is equipped with N_r receive antennas. The spatial modulation type multiple input multiple output is employed to convey information in the multicast multiple input multiple output system. As shown in Figure 1, the information bits are processed by the spatial modulator for conversion to the spatial modulation type signals which are transmitted in the next stage. Same spatial modulation type signal is transmitted to all receivers.

Considering the system activating N_a antennas at each time instant the flat-fading baseband multiple input multiple output signal model for receiver k can be expressed as

$$y^k = H^k x_i + n^k, \qquad (1)$$

where,
H^k is the small-scale fading channel matrix for receiver k.
y^k is the complex received signal for receiver k.
x_i is the i th complex transmitted spatial modulation type signal (symbol).
n^k is the complex white gaussian noise for receiver k.

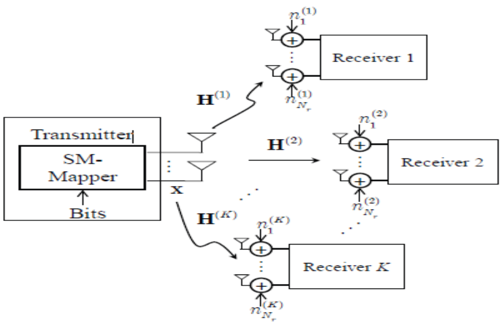

Figure 1. System model of multicast spatial modulation type multiple input multiple output system, adapted [11].

This signal model is generally applicable for most standard types of spatial modulation multiple input multiple output transmission schemes which also include the conventional spatial multiplexing. This model can be easily extended to cover generally all types of spatial modulation multiple input multiple output transmission schemes without time or frequency dispersion.

B. *Spatial Modulation*

Spatial modulation (SM) is a recently established promising transmission technique. The basic idea of spatial modulation is to map a block of information bits into two information carrying units, first a symbol that was chosen from a complex signal-constellation diagram and second a unique transmit antenna index that was chosen from a set of transmit antenna in the antenna-array. The use of the transmit antenna number increases the overall spectral efficiency by the base-two logarithm of the number of transmit antennas. At the receiver, in particular, a maximum likelihood detector is used. According to the maximum likelihood principle, the receiver computes Euclidean distance between received signal and set of possible signals modulated by wireless channel and chooses closest one. In this way all the bits in the transmitted block can be decoded and original bit stream recovered. Here, we apply SM to orthogonal frequency division multiplexing (OFDM) transmission. In general, any number of transmit antennas and any digital modulation scheme can be used.

C. *Orthogonal Frequency Division Multiplexing*

Orthogonal frequency division multiplexing (OFDM) is a special form of multicarrier modulation (MCM) with closely spaced subcarriers with overlapping spectra, thus allowing multiple-access. Multicarrier modulation works on the basis of transmitting data by dividing the stream into several bit streams, each of which has a much lower bit rate and by using these sub-streams to modulate several carriers.

In multicarrier transmission, bandwidth divided in number of subcarriers. In orthogonal frequency division multiplexing, the sub-channels overlap each other to a certain extent, which leads to a more use of the total bandwidth. The information sequence is mapped into symbols and sent over the N sub-channels, one symbol per channel. The carrier frequencies must be chosen carefully according to their orthogonal properties. By using orthogonal carriers, frequency domain can be viewed so as the frequency space between two sub-carriers is given by the distance to their first spectral null.

The data bit stream of orthogonal frequency division multiplexing is divided into N data streams using a rate of with each being parallel to each other i.e., the available spectrum must be divided into several narrow sub-channels. Equalization becomes very simple due to flat fading. Cyclic prefix (CP), which is a copy of last part of the orthogonal frequency division multiplexing symbol, is used to mitigate inter-symbol and inter-carrier interference. Figure 2 shows block diagram of orthogonal frequency division multiplexing transmitter and receiver.

Input

The system used a random bit generator to generate a random bit stream. The output is a 1 dimensional array of bits. Then perform a serial-to-parallel conversion sending the bits on parallel streams each representing a subcarrier.

Modulation

Various modulation schemes used on all the subcarriers and the results have been simulated.

Series to Parallel

This is a simple method to convert a serial data that have been entered to the circuit into parallel one. The series to parallel conversion is done to allocate the bit stream generated in previous step to the various subcarriers.

Inverse Fast Fourier Transform (IFFT)

This perform the inverse fast Fourier transform of all the parallel data streams together ensuring orthogonality between the subcarriers and the conversion of symbols to time domain. Orthogonality between subcarriers means all the subcarriers overlap each other in such a way that they don‘t interfere with each other and ensure minimum bandwidth usage. Inverse fast Fourier transform for a set of N complex data points from N orthogonal parallel streams is given by the formula.

$$x(n) = \frac{1}{N}\sum_{k=0}^{N-1} X(k).e^{j\left(\frac{2\pi}{N}\right)nk} \; ; (n = 0,1, \ldots..N-1) \qquad (2)$$

where,

X(k) is a complex frequency domain data sent on subcarriers of frequency k/N, k=0,1,….,N and k/N term is orthogonal to every other value of k/N

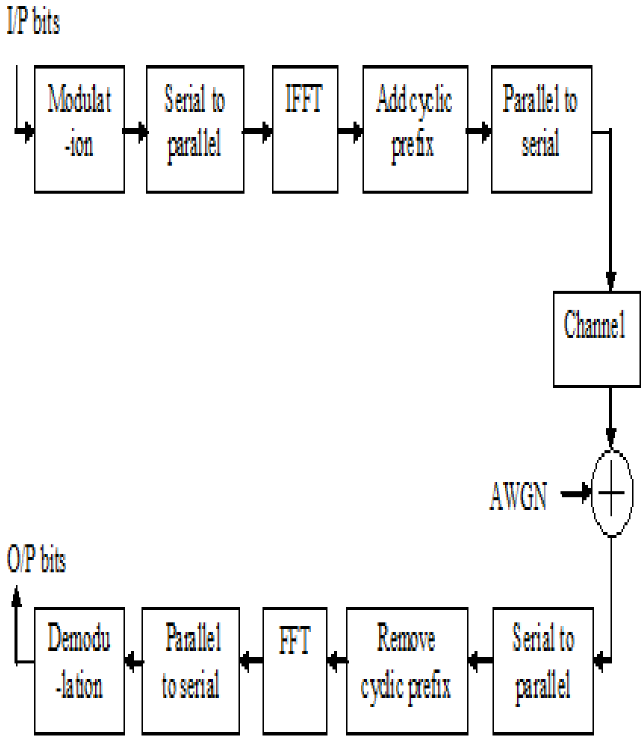

Figure 2. Block diagram of orthogonal frequency division multiplexing transmitter and receiver.

Cyclic prefix

Cyclic prefix addition is the next step of the procedure. The term cyclic prefix refers to the prefixing of a symbol with a repetition of the end. The cyclic prefix serves two purposes

1. It provides guard interval to eliminates the inter symbol interference from the previous symbol.
2. It repeats end of the symbol so linear convolution of a frequency-selective multipath channel can be modeled as circular convolution, which in turn may be transformed to the frequency domain using a discrete Fourier transform.

Parallel to Serial (P/S) conversion

The cyclic prefixed bit stream is now converted back to serial bit stream to be transmitted over the channel.

Channel

The channel used is pure AWGN (Additive White Gaussian Noise) channel. This is a noise channel. This channel effects on the transmitted signals when signals passes through the channel. It adds white Gaussian noise to the input signal. After adding Gaussian noise data is then passed to the receiver

Receiver

The complementary blocks are implemented in the receiver. The cyclic prefix is removed, sub carriers are demodulated via the fast Fourier transform (FFT) and sub-carrier de-mapping is performed. After that channel decoding process is performed.

Serial to parallel (S/P) conversion

The serial bit stream is converted to parallel data and is mapped onto the respective subcarriers.

Remove Cyclic Prefix

The cyclic prefix added at the time of transmission is removed in this step. This is the first step at the receiving end.

Fast Fourier Transform

Fast Fourier Transform is used to convert the signal to Fourier domain to make the analysis easier. Built in functions is used to convert the data stream into Fourier domain.

Parallel to Serial (P/S) conversion

The parallel data is then converted back to serial bit pattern to retrieve the message which is the final output.

Demodulator

In order to retrieve the original or baseband signal, the bit stream demodulated by demodulator. According to the type of modulation used the corresponding demodulation method is applied.

D. Space Time Coding

To improve reliability of data transmission in cellular communications as well as in wireless local area networks, a method called space time code (STC) is employed. Space time coding is performed in both spatial and temporal domain introducing redundancy between signals transmitted from various antennas at various time periods. The space time codes mainly focuses on improving the system performance by using multiple transmit antennas. In general, the design of STC amounts to finding transmit matrices that satisfy certain optimality criteria. Researcher needs to trade-off between three objectives namely simple decoding, minimizing the error probability and maximizing the information rate for constructing STC.

Let us consider a space-time coded communication system with n_t transmit antennas and n_r receive antennas. The transmitted data are encoded by a space-time encoder. At each time slot, a block of binary information symbols

$$c_t = [c_t^1, c_t^2, \dots \dots, c_t^{m-n_t}]^T \qquad (3)$$

are fed into the space-time encoder. The encoder maps the block of m binary data into n_t modulation symbols from a signal set of constellation $M = 2^m$ points. The n_t parallel outputs are simultaneously transmitted by different antennas, the n_t symbols

$$s_t = [s_t^1, s_t^2, \dots \dots, s_t^{n_t}]^T \quad 1 \le t \le N \qquad (4)$$

are transmitted simultaneously during the slot t from n_t transmit antennas. Symbol s_t^i, $1 \le i \le n_t$, is transmitted from antenna i and all transmitted symbols have the same duration of T sec. The vector in equation above is called a space-time symbol and by arranging the transmitted sequence in an array of $n_t \times N$ space-time code-word matrix can be defined as

$$S = [s_1, s_2, \dots, s_N] = \begin{bmatrix} s_1^1 & s_2^1 & \cdots & s_N^1 \\ s_1^2 & s_2^2 & \cdots & s_N^2 \\ \vdots & \vdots & \ddots & \vdots \\ s_1^{n_t} & s_2^{n_t} & \cdots & s_N^{n_t} \end{bmatrix} \qquad (5)$$

The i-th row $s_i=[s_t^1, s_t^1, \dots\dots, s_N^1]^T$ is the data sequence transmitted from the ith transmit antenna and the jth column= $[s_j^1, s_j^2, \dots\dots s_j^{nt}]^T$ is the space-time symbol transmitted at time j,1 to N. The MIMO channel matrix H corresponding to n_t transmit antennas and n_r receive antennas can be represented by an $n_r \times n_t$ matrix

$$H = \begin{bmatrix} h_{1,1}^t & h_{1,2}^t & \cdots & h_{1,n_t}^t \\ h_{2,1}^t & h_{2,2}^t & \cdots & h_{2,n_t}^t \\ \vdots & \vdots & \ddots & \vdots \\ h_{n_r,1}^t & h_{n_r,2}^t & \cdots & h_{n_r,n_t}^t \end{bmatrix}$$
(6)

E. Flowchart

The flowchart for bit error rate calculation in multicast multiple input multiple output system is shown in Figure 3

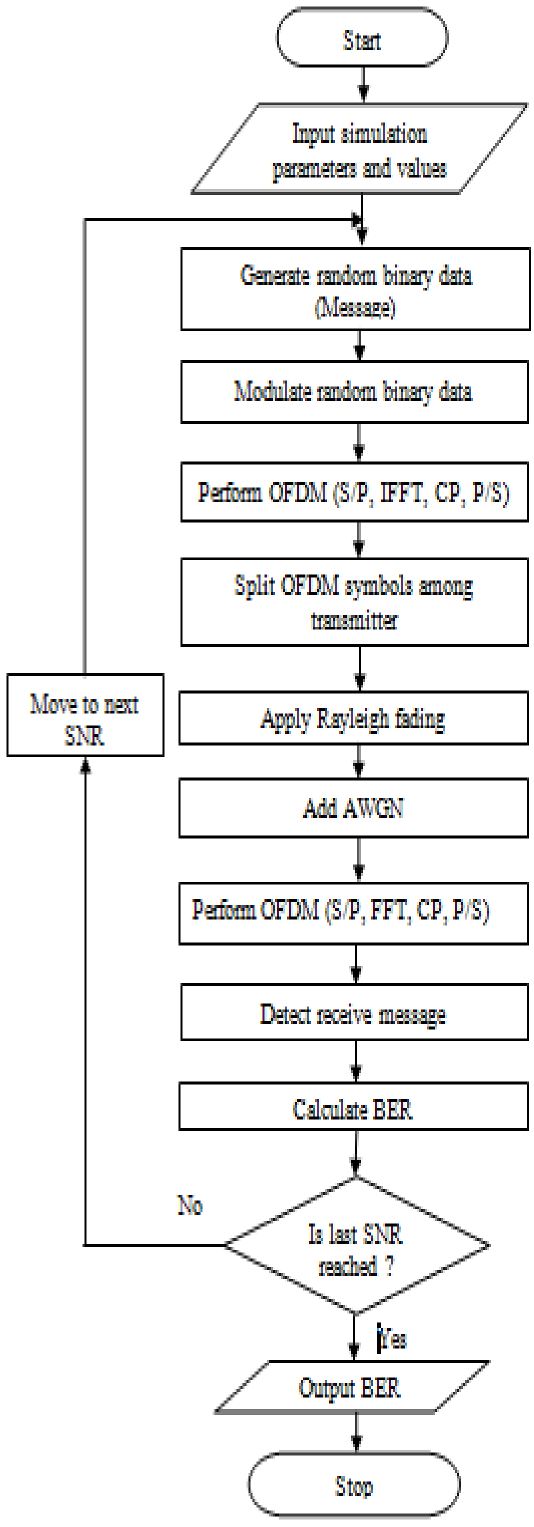

Figure 3. Flowchart for bit error rate calculation in multicast multiple input multiple output system.

First define input simulation parameters like number of transmitter antennas, number of receiver antennas, carrier frequency etc. and their values. After this, generate random binary data. Then encode and modulate generated random binary data. Inserted pilot data in modulated data. After insertion of pilot, perform orthogonal frequency division multiplexing. In orthogonal frequency division multiplexing, perform different operations like serial to parallel, inverse fast Fourier transform, addition of cyclic prefix, parallel to serial. Then use Rayleigh fading channel and add additive white Gaussian noise. Then perform orthogonal frequency division multiplexing at receiver side which includes different operation like serial to parallel, fast Fourier transform, remove cyclic prefix, parallel to serial etc. After this, detect receive message and calculate bit error rate (BER). Repeat this procedure until system reaches last signal-to-noise ratio.

IV. BIT ERROR RATE

The number of bit errors in digital transmission is the number of received bits of a data stream over communication channel that have been changed due to noise, interference, attenuation and distortion. Bit error rate has no unit but it frequently expressed in percentage. The bit error rate or bit error ratio (BER) is the ratio of bit errors to the total number of transferred bits during a studied time interval. The bit error rate is normally expressed as 10 to the negative power. Measuring the bit error rate helps to choose the appropriate forward error correction codes. Since most such codes only bit-flips, but not bit insertions or bit detection, the hamming distance metric is the appropriate way to measure the number of bit errors. The bit error rate can be affected by number of factors. By manipulating the variables that can be controlled it is possible to optimize a system to achieve performance that are required. Normally it is not possible to achieve all the requirements and some trade-offs are required. Bit error rate is defined as the rate at which errors occur during the transmission. The bit error rate can be expressed as

$$BER = \frac{Number\ \ of\ errors}{Total\ number\ \ of\ bits\ sent} \tag{7}$$

The bit error rate will be very small and having no effect on overall system, if the medium between the transmitter and receiver is good and the signal to noise ratio is high. Bit error rate can also be defined in terms of the probability of error (POE). To determine probability of error, three other variables error function (erf), the energy in one bit (E_b) and noise power spectral density (N_0) are used. Different type of modulation has its own value for the error function. This is because each type of modulation performs differently in the presence of noise.

The bit error rate may be better with choosing strong signal strength by using slow and robust modulation system, line coding scheme and by also applying channel coding system. The transmitted bit error rate is the ratio of number of sensed bits that are incorrect before error improvement and total number of transferred bits.

V. SIMULATION RESULTS

A. Simulation Parameters

Table I shows list of simulation parameters with their values used in simulation model.

TABLE I. SIMULATION PARAMETERS

Parameter	Value
Number of transmitter antennas	2
Number of receiver antennas	2
Number of users	4
Number of symbols	8
Carrier frequency (GHz)	5
Number of frames	10
Bandwidth (MHz)	10
Number of subcarriers	1024
FFT length	1024
Sampling frequency(MHz)	15.36

B. Simulation Results for Bit Error Rate Performance

Following are the results that have been simulated using MATLAB. Figure 4 shows bit error rate for multicast multiple input multiple output systems using binary phase shift keying. As shown in plot, bit error rate starts at approximately $10^{-0.8}$ at 0 dB E_b/N_0 and reached to $10^{-4.7}$ at 16 dB E_b/N_0. This proves that bit error rate decreases with increase in E_b/N_0. Figure 5 shows bit error rate versus E_b/N_0 plot for E_b/N_0 values ranges from 0 to 10 dB. Figure 6 shows bit error rate versus E_b/N_0 plot for E_b/N_0 values ranges from 10 to 20 dB.

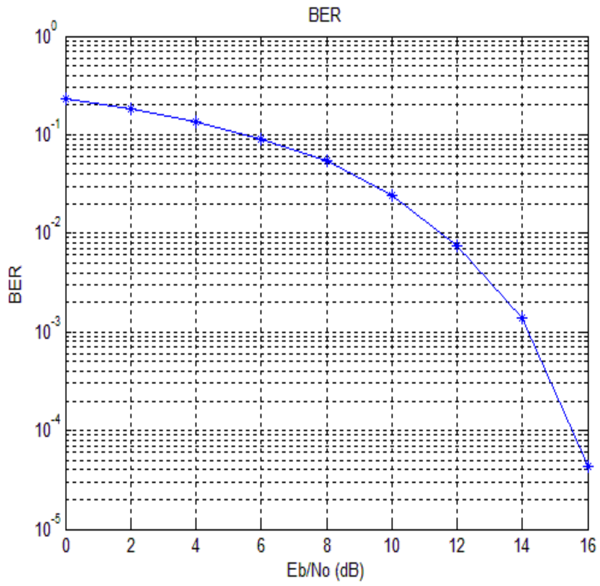

Figure 4. Plot of bit error rate versus E_b/N_0 for E_b/N_0 from 0 to 20 dB using binary phase shift keying.

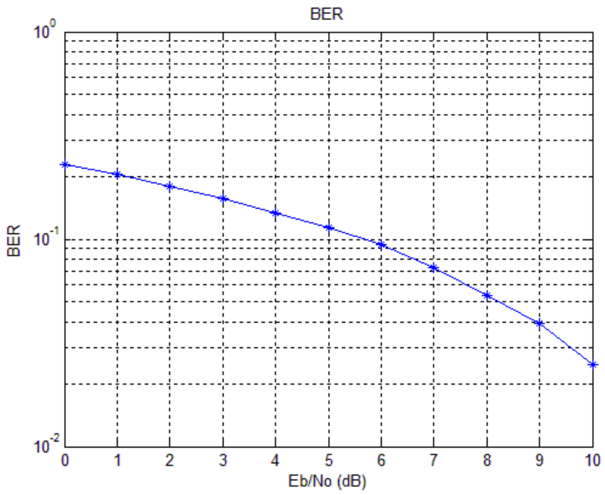

Figure 5. Plot of bit error rate versus E_b/N_0 for E_b/N_0 from 0 to 10 dB using binary phase shift keying.

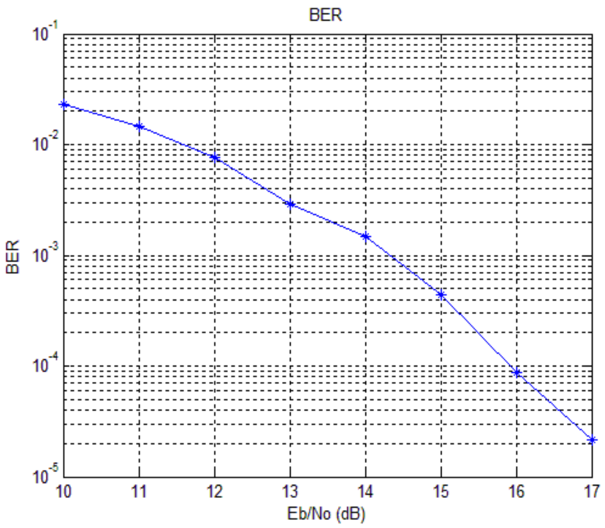

Figure 6. Plot of bit error rate versus E_b/N_0 for E_b/N_0 from 10 to 20 dB using binary phase shift keying.

The following figures show the various output at different stages of system. Figure 7 shows the generated random data. After generation of random data, system performed encoding and modulation on random data. Figure 8 and Figure 9 shows the modulated and encoded bits respectively. The data was modulated by using spatial modulation. Figure 10 shows the pilot data. After insertion of pilot data, orthogonal frequency division multiplexing was performed. In orthogonal frequency division multiplexing, first inverse fast Fourier transform was performed which converts frequency domain to time domain, this maps the complex data symbols to a time domain orthogonal frequency division multiplexing symbol. Then cyclic prefix are added and transmitted data on channel. Figure 11 shows transmitted data. The noise added in transmitted data. Figure 12 shows transmitted data with additive white Gaussian noise. This noisy data received at receiver side. At receiver side, orthogonal frequency division multiplexing was performed means removed cyclic prefix and performed fast Fourier transform. Decoding and demodulation were performed after fast Fourier transform. Figure 13 and Figure 14 shows decoded and demodulated data respectively.

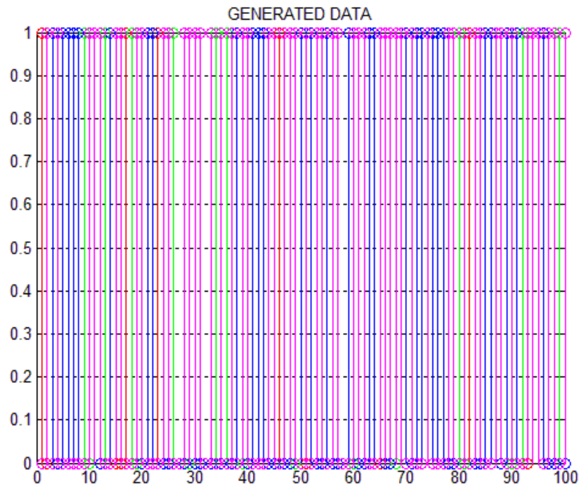

Figure 7. Generated random data.

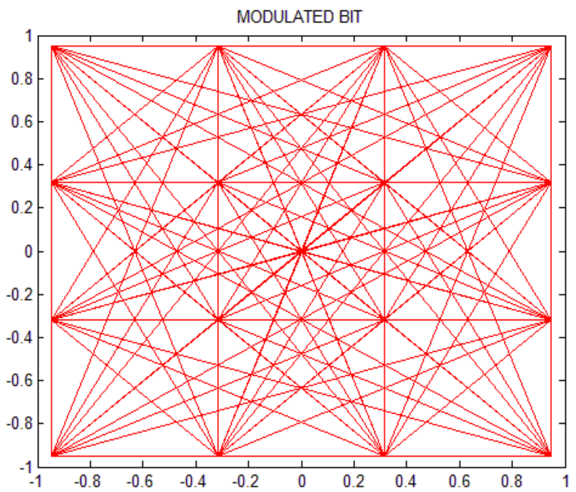

Figure 8. Modulated bits.

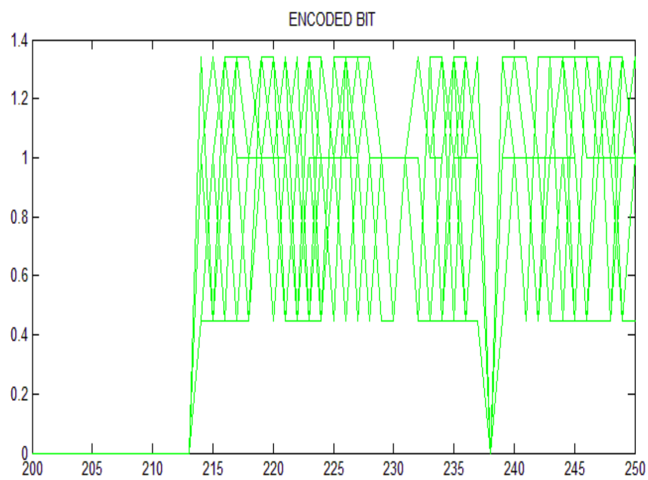

Figure 9. Encoded bits.

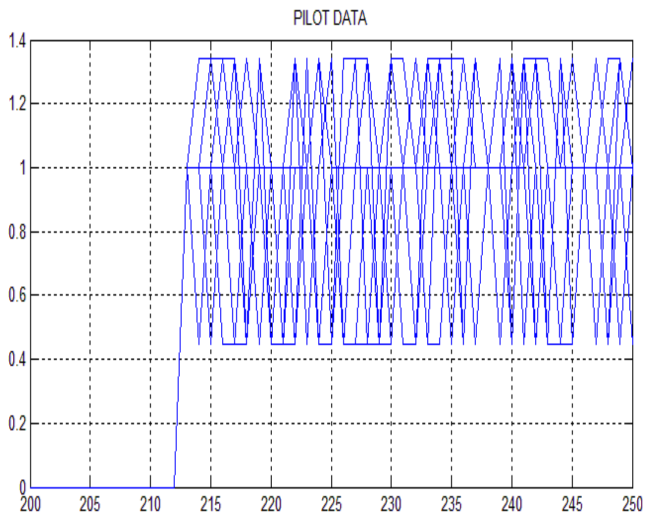

Figure 10. Pilot data.

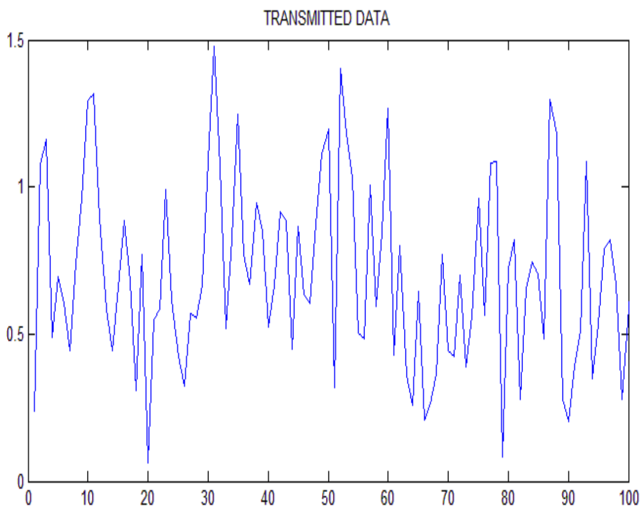

Figure 11. Transmitted data.

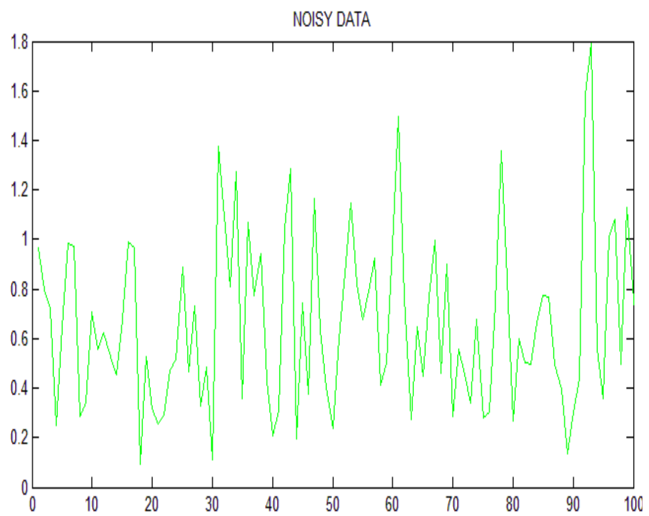

Figure 12. Transmitted data.

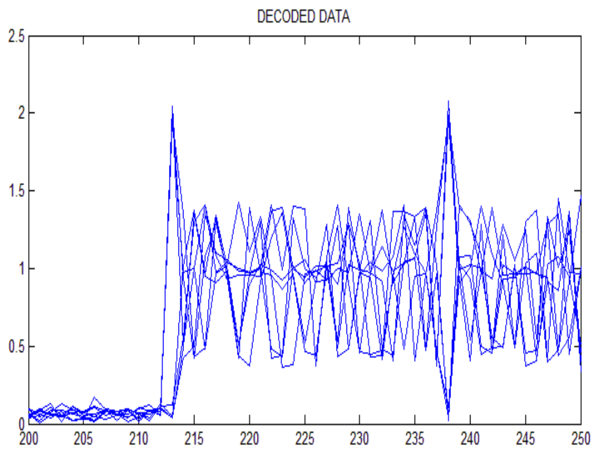

Figure 13. Decoded data.

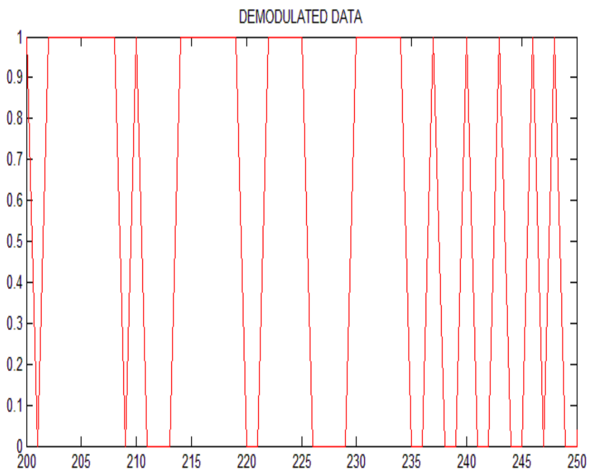

Figure 14. Demodulated data.

Table II shows values of bit error rate for different E_b/N_0 values as shown in Figure 3. It is clear from table that bit error decreases as E_b/N_0 value increase. For E_b/N_0 values greater than 18dB, system reached zero bit error rate. Therefore system performs better for high E_b/N_0 values.

TABLE II. BIT ERROR RATE FOR DIFFERENT E_B/N_0 VALUES

Sr. No.	E_b/N_0 (dB)	Bit Error Rate
1	0	0.22810
2	2	0.18130
3	4	0.13560
4	6	0.09080
5	8	0.05330
6	10	0.02510
7	12	0.00710
8	14	0.00150
9	16	0.00008
10	18	0.00000
11	20	0.00000

VI. CONCLUSION

This system implemented spatial modulation based multicast multiple input multiple output system. The system calculated bit error rate for multicast multiple input multiple output system and studied the effect of E_b/N_0 on the bit error rate. MATLAB software has preferred for the simulation of model because it is adequate for the simulation of different signal processing methods used in wireless networks. After running simulation model at different values of signal to noise ratio (SNR), system got different values of bit error rate (BER). The bit error rate versus E_b/N_0 plot using binary phase shift keying shows that, with increasing the value of E_b/N_0, there is decreasing the value of bit error rate (BER). For large values of E_b/N_0, system got less bit error rate. Therefore, system performance is increases. For the value of E_b/N_0 greater than 18dB, system reaches zero bit error rate. It also improves spectral efficiency and energy efficiency of wireless system. The system shows huge improvement over the previous systems, with better bit error rate results at a wide range of E_b/N_0.

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