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MIMO System Performance Evaluation for High Data Rate Wireless Networks using Space Time Block Codes with Orthogonal Structure

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Abstract: *Space–time block coding is used for data communication in fading channels by multiple transmit antennas. Message data is encoded by applying a space–time block code and after the encoding the data is break into 'n' streams of simultaneously transmitted strings through n transmit antennas. The received signal at the receiver end is the superposition of the n transmitted signals distorted due to noise .For data recovery maximum likelihood decoding scheme is applied through decoupling of the signals transmitted from different antennas instead of joint detection. The maximum likelihood decoding scheme applies the orthogonal structure of the space–time block code (OSTBC) and gives a maximum-likelihood decoding algorithm based on linear processing at the receiver. In this paper orthogonal space–time block codes based model is developed using Matlab/Simulink to get the maximum diversity order for a given number of transmit and receive antennas subject with a simple decoding algorithm.*
The simulink block of orthogonal space coding block with space–time block codes is applied with and without gray coding. The OSTBC codes gives the maximum possible transmission rate for any number of transmit antennas using any arbitrary real constellation such of M-PSK array. For different complex constellation of M- PSK space–time block codes are applied that achieve 1/2 and 3/4 of the maximum possible transmission rate for MIMO transmit antennas using different complex constellations.
Keywords: *Transmit diversity, Multipath channels, Multiple input multiple output, Wireless communication and OSTBC.*

I. Introduction

Due to fading in a multipath wireless channels makes it becomes very tough for the receiver antenna to differentiate the transmitted signal if the receiver is adjusted with some specific type of diversity having some less-faded replica of the signal transmitted by sending end antenna. In today's many applications one of the popular practical way of achieving diversity is multiplication of number of the antenna at the transmitter and may also be on the receiver additionally. But there is a desired need that receivers should be of small size. Hence under this consideration it may not be practical to use multiple receiving side antennas at the mobile remote station. This justifies the consideration of mainly transmit side diversity.

Transmit diversity is treated as a method of removing data errors in wireless fading channels [2]. It is very popular due to its simplicity of design and the reliability of multiple antennas at the base station. In terms of the cost of multiple transmit chains at the base can be applied over numerous users. Space–time trellis coding [10] is a new coding scheme that combines signal processing at the receiver with coding techniques appropriate to multiple transmit antennas. Specific space–time trellis codes designed for 2–4 transmit antennas perform extremely well in slow-fading environments (typical of indoor transmission) and come close to the outage capacity computed by Telatar [3] and independently by Foschini and Gans [4]. However, when the number of transmit antennas is fixed, the decoding complexity of space–time trellis codes (measured by the number of trellis states in the decoder) increases exponentially with transmission rate. In reference to the matter of the complexity in decoding recently a remarkable scheme is proposed for transmission using only two transmit antennas. This scheme is simplicity on compared with the space–time trellis coding for two transmit antennas but a loss in performance is found as compared to space–time trellis codes. Despite this loss of performance, Alamouti's scheme [1] is applying in many places due to its simplicity and performance and it motivated researchers of all the world for discovering similar schemes using more than or equal to two transmit antennas based communication systems.

II. RELATED WORK

In this paper we have applied the theory of orthogonal designs to create simulation model of Alamouti scheme, of space–time block coding for more than or equal to two transmit antennas. The study of orthogonal designs is a field of mathematics which has been investigated by several great number researchers including Radon and Hurwitz. The work of Geramita and Seberry [5] is an excellent document to understand the significance of orthogonal designs. A classical result in this area is provided by Radon. In his work they determined the set of required dimensions for which an orthogonal design exists [8].

Their analysis results only considers with real square orthogonal designs. In this work, we have applied an extended form of nonsquare and complex orthogonal designs related to the theory of generalized orthogonal designs. Using this concept, we have used orthogonal structure space–time block codes for multiple transmit antennas. Since our approach is related to the theory of orthogonal designs from a communications perspective hence our simulated design model corresponds to combined coding and linear processing at the transmitter.

We have simulated the concept of the orthogonal designs and develop a model based on of generalized orthogonal designs. Using this mathematical theory, we applied a coding schemes for multiple number of transmit antennas. These schemes is providing a full diversity order that can be utilized by the transmitting and receiving antennas. In most of the works very simple maximum likelihood decoding algorithms based only on linear processing at the receiver are applied. It provides a maximum possible transmission rate using totally real constellations as established in the theory of space–time coding [7]. We have also considered the complex orthogonal designs and their properties. Our model restores the scheme given by Alamouti [1], though it is found that generalization to more than two transmit antennas is not possible. We then develop our model related to theory of complex generalized orthogonal designs. These designs exist multiple transmit antennas and again have remarkably simple maximum-likelihood decoding algorithms based only on linear processing at the receiver. In many works full spatial diversity and of the maximum possible rate (as established previously in the theory of space–time coding) using complex constellations are also provided. For complex constellations and for the specific cases of two, three, and four transmit antennas, these diversity schemes are improved to provide, respectively all and of maximum possible transmission rate.

III. SPACE-TIME (MIMO) SYSTEMS

Digital communication using multiple-input-multiple output (MIMO) wireless link is now a day's emerged as one of the most popular technical application in modern communications. This method focuses mainly on the list of recent technical advances with a chance of solving the problems of traffic capacity for future Internet related wireless networks. In a starting years of invention of this technology it seems that it is has entered in large-scale standards-driven commercial wireless products and networks like broadband wireless systems, wireless LAN, third-generation networks and beyond.

MIMO systems can be defined simply as an arbitrary wireless communication system having a link for which the transmitting side and also the receiving side is equipped with multiple antenna devices (Fig. 1).In the MIMO the signals on the transmit (TX) antennas at one end and the receive (RX) antennas at the other end are "combined" in such a way that the quality (bit-error rate or BER) or the data rate (bits/sec) of the communication for each MIMO user are enhanced. Such benefits are used to improve both the network's quality of service and the operator's revenues significantly. The main process in MIMO systems is space–time signal processing in which time (the natural dimension of digital communication data) is complemented with the spatial dimension inherent in the use of multiple spatially distributed antennas. In this way the MIMO systems can be considered as an extension of the new terminology called as smart antennas, a popular technology using antenna arrays for improving wireless transmission dating back several decades.

We have developed our simulation model by considering the multiple antenna system (Fig. 1). A digital source data in the form of a binary stream is provided to a transmitting block containing the functions of error control coding and (possibly joined with) mapping to complex modulation symbols (M phase-shift keying (MPSK), M-QAM, etc.). This produces multiple separate symbol streams which range from independent to partially redundant to fully redundant. Each symbol stream is then mapped onto one of the multiple TX antennas. Mapping includes either linear spatial weighting of the antenna elements or linear antenna space–time pre coding. After upward frequency conversion, filtering and amplification, the signals are launched into the wireless channel. At the receiver, the signals are captured by possibly multiple antennas and demodulation and demapping operations are performed to recover the message. The level of intelligence, complexity, and a priori channel knowledge used in selecting the coding and antenna mapping algorithms can vary a great deal depending on the application. This determines the class and performance of the multiantenna solution that is implemented.

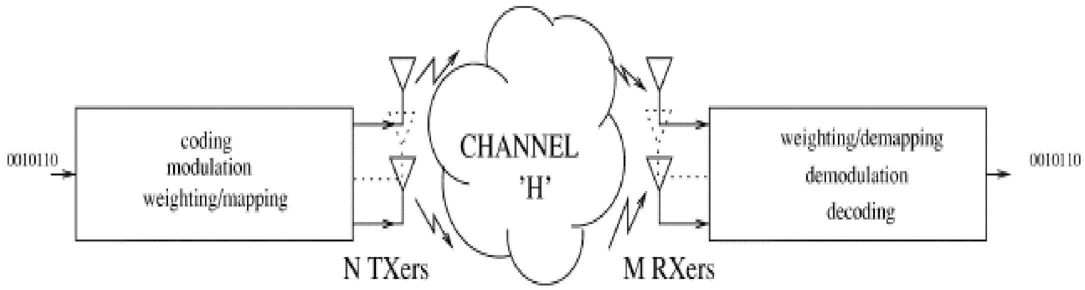

Fig 1: MIMO wireless transmission system with transmitter and receiver are with multiple antenna elements.

In the conventional smart antenna terminology, only the transmitter or the receiver is actually equipped with more than one element, being typically the base station (BTS), where the extra cost and space have so far been perceived as more easily affordable than on a small phone handset. Traditionally, the intelligence of the multi antenna system is located in the weight selection algorithm rather than in the coding side although the development of space–time codes (STCs) is transforming this view.

Simple linear antenna array combining can offer a more reliable communications link in the presence of adverse propagation conditions such as multipath fading and interference. A key concept in smart antennas is that of beam forming by which one increases the average signal-to-noise ratio (SNR) through focusing energy into desired directions, in either transmit or receiver. Indeed, if one estimates the response of each antenna element to a given desired signal, and possibly to interference signal(s), one can optimally combine the elements with weights selected as a function of each element response. One can then maximize the average desired signal level or minimize the level of other components whether noise or co-channel interference.

Another powerful effect of smart antennas lies in the concept of spatial diversity. In the presence of random fading caused by multipath propagation, the probability of losing the signal vanishes exponentially with the number of decorrelated antenna elements being used. A key concept here is that of diversity order which is defined by the number of decorrelated spatial branches available at the transmitter or receiver. When combined together, leverages of smart antennas are shown to improve the coverage range versus quality tradeoff offered to the wireless user [6].

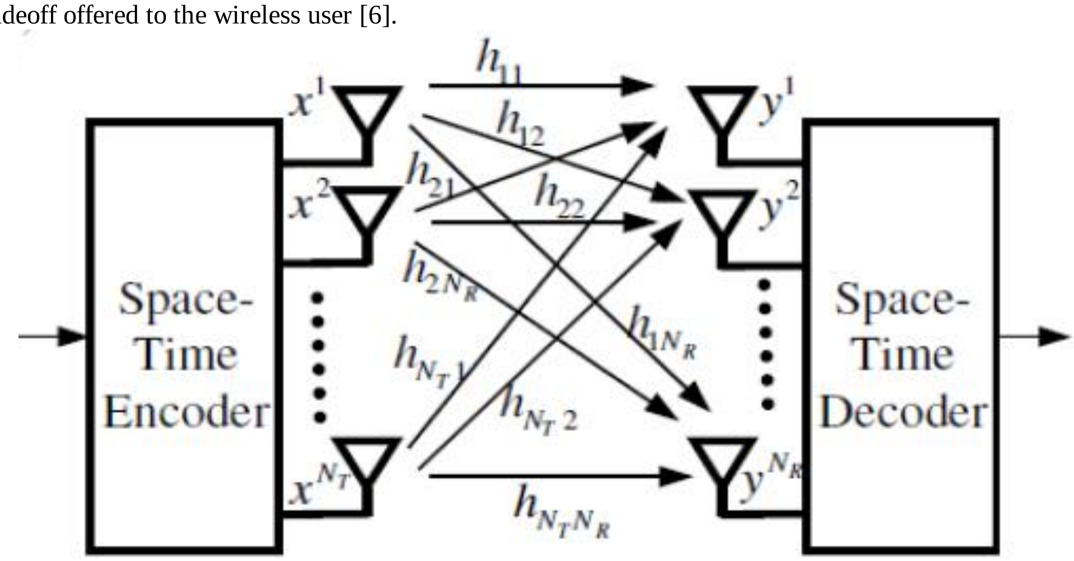

Fig 2: MIMO System Model.

As subscriber units (SU) are gradually evolving to become sophisticated wireless Internet access devices rather than just pocket telephones, the stringent size and complexity constraints are becoming somewhat more relaxed. This makes multiple antenna elements transceivers a possibility at both sides of the link, even though pushing much of the processing and cost to the network's side (i.e., BTS) still makes engineering sense. Clearly, in a MIMO link, the benefits of conventional smart antennas are retained since the optimization of the multi antenna signals is carried out in a larger space, thus providing additional degrees of freedom. In particular, MIMO systems can provide a joint transmit-receive diversity gain, as well as an array gain upon coherent combining of the antenna elements (assuming prior channel estimation). In fact, the advantages of MIMO are far more fundamental. The underlying mathematical nature of MIMO, where data is transmitted over a matrix rather than a vector channel, creates new and enormous opportunities beyond just the added diversity or array gain benefits.

IV. DESIGN RESULTS

In this section we will describe the simulation data design for performance analysis of SISO and MIMO system using MATLAB SIMULINK. Here have 3 design types for explaining the model design and responses in terms of scatter plot and bit error rate (BER).For step wise analysis there are 3 different model are design named as (1) SISO model,(2) MIMO ½ - 3 Tx and 2 Rx model ar rate 1/2 and (3) MIMO 3/4 - 3 Tx and 2 Rx model at rate 3/4. For each model we have applied 4 different modulation technique known as BPSK,QPSK,8PSK,16PSK. For each modulation scheme we have used data transmission without and with gray coding. The transmitted data is passed through the Rayleigh fading channel having maximum Doppler shift of 3hz. We have changed channel SNR by using a AWGN channel simulink block to calculate the BER at different SNR for a particular design used condensation of different modulation coding schemes.

The response are expressed in the form of scatter plot and bit error rate at different SNR varying from 1to 25db.As the SNR is increased the scattering of the signal constellations decreases due to increase in the signal power. The BER is the parameter that is directly proportional to the channel noise i.e. higher the noise higher will be the BER.The BER is calculated by the ratio of number of error bit upon the total number of bits. We have obtained the BER values on running each simulation design for 10 sec in the simulink environment and noted down the BER values in the tabulated form for different value of SNR. In the next sections BER going to explain and discuss the our simulation model results one by one.

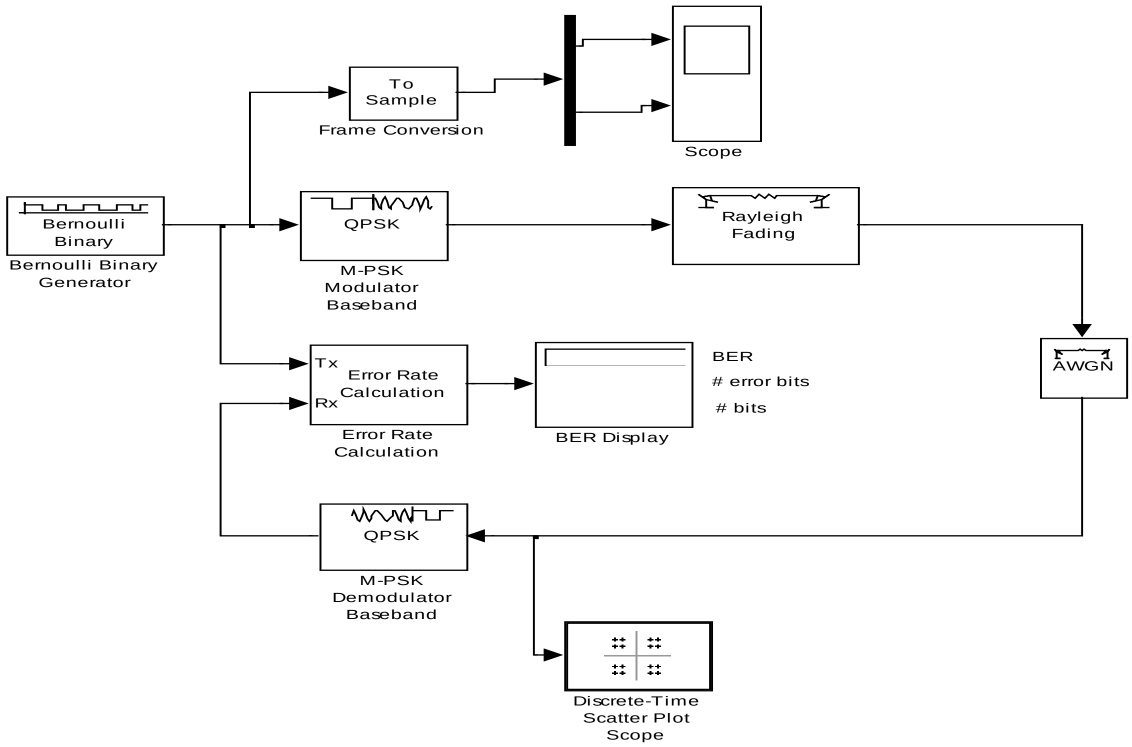

Fig 3: Simulink Model of SISO System

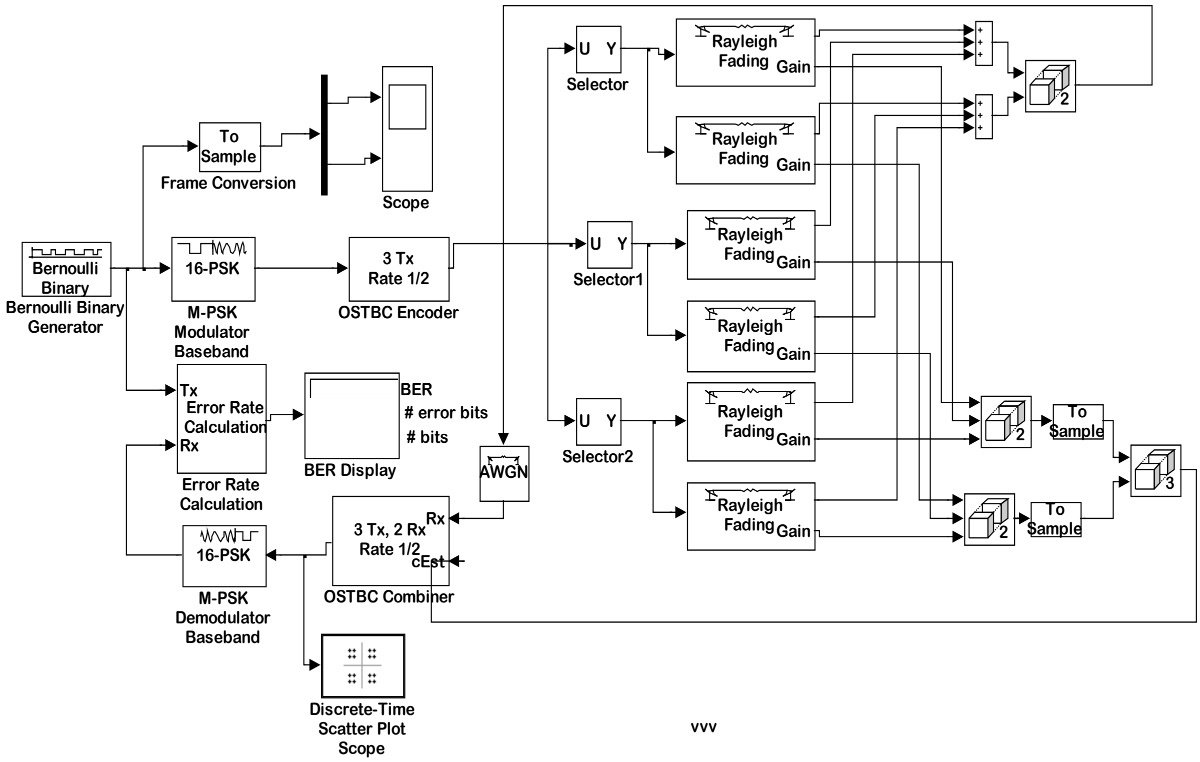

Fig 4: Simulink Model of MIMO1/2 System

Table 1: Performance results of SISO model design.

SNR	1	5	10	15	20	25
Bpsk(B)	0.505	0.4994	0.498	0.501	0.5004	0.5005
BPSK(G)	0.505	0.4994	0.4983	0.501	0.5004	0.5005
Qpsk(B)	0.493	0.4853	0.472	0.4602	0.4575	0.4562
Qpsk(G)	0.4958	0.4953	0.4903	0.4846	0.4862	0.4875
8psk(B)	0.4956	0.4861	0.4879	0.4893	0.4884	0.485
8psk(G)	0.4947	0.4877	0.4781	0.4747	0.4736	0.4742
16psk(B)	0.4964	0.4962	0.4926	0.4857	0.4869	0.4827
16psk(G)	0.4917	0.4927	0.489	0.4892	0.4886	0.488

Table 1,2 And 3 represents the BER values of our SISO model (figure 3), MIMO1/2 (figure 4) and MIMO3/4 design where B indicate binary coding and G indicate gray coding for each row in the table used under different modulation. Each columns shows the bit error rate for different SNR varying in db. It can be observed that in table 1 BER value are varying in between 0.48 to 0.505 under different coding and modulation schemes. Hence this table indicates that there is no variation of BER in the SISO model by using different coding and modulation schemes.

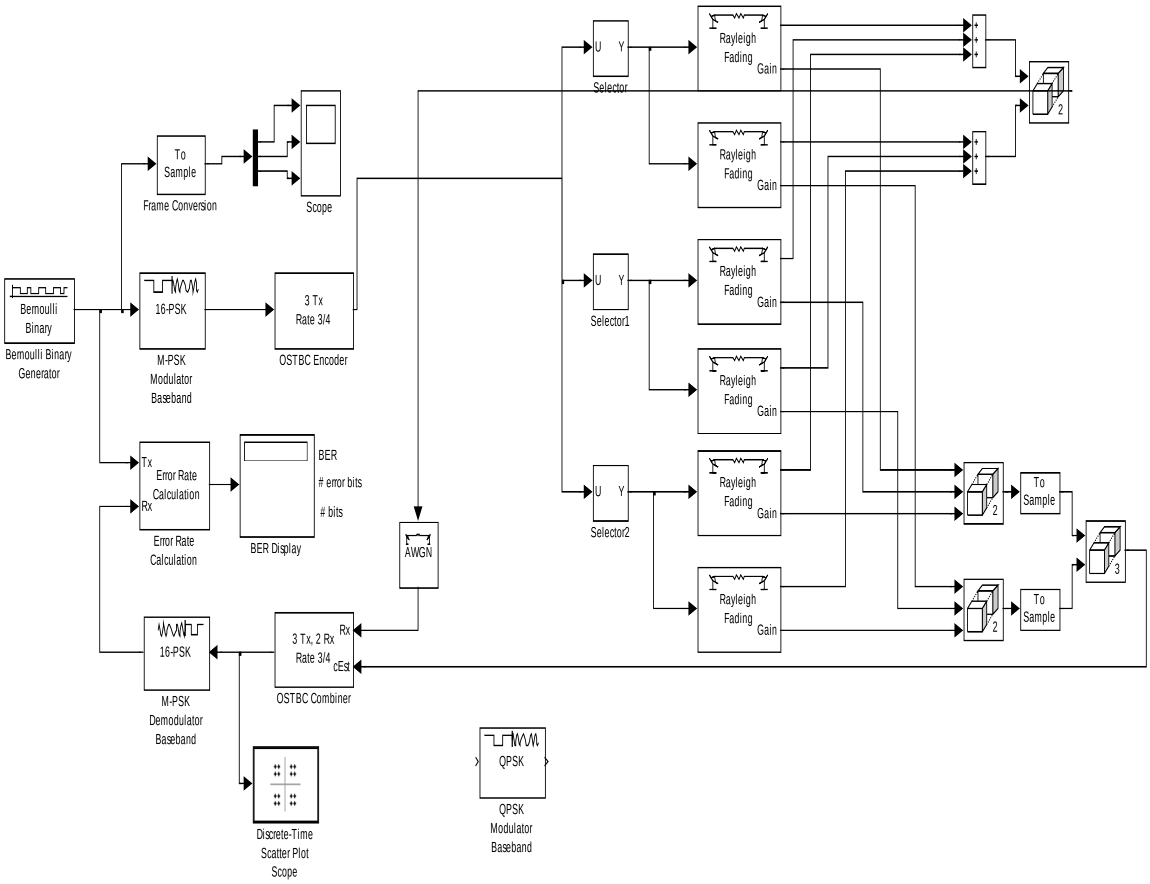

Fig 5: Simulink Model of MIMO3/4 System.

Table 2: Mimo Model ¾ Design Result

SNR	1	5	10	15	20	25
Bpsk(B)	**0.01075**	**0.0002**	0	0	0	0
BPSK(G)	**0.01075**	**0.0002**	0	0	0	0
Qpsk(B)	0.5165	0.01011	0	0	0	0
Qpsk(G)	0.04464	0.006198	0	0	0	0
8psk(B)	**0.1809**	0.7153	**0.006899**	0	0	0
8psk(G)	0.1126	0.04468	**0.004599**	0	0	0
16psk(B)	0.3607	0.2778	0.09028	**0.0112**	0.**0003997**	0
16psk(G)	**0.2155**	0.1168	**0.03788**	**0.006095**	**0.0001998**	0

Table 3: MIMO Model 1/2 Design Result

SNR	1	5	10	15	20	25
Bpsk(B)	0.01191	0.000799	0	0	0	0
BPSK(G)	0.01191	0.0007998	0	0	0	0
Qpsk(B)	0.04337	0.008258	0.0003332	0	0	0
Qpsk(G)	0.03754	0.005998	0.000288	0	0	0
8psk(B)	0.1916	0.00535	0.007164	0.0003999	0	0
8psk(G)	0.1111	0.03667	0.005199	0.0003333	0	0
16psk(B)	0.2551	0.1977	0.0546	0.01562	0.001132	0.0001332
16psk(G)	0.2315	0.11ter26	0.03791	0.007985	0.0007327	0

V. CONCLUSION

We Multiple input multiple output (MIMO) technology proves itself that it can need the demands by increasing spectral efficiency using spatial multiple path gain and its also improves the reability by considering antenna diversity gain in our design algorithm.We have investigated an analyzed various problem in the area of MIMO wireless communication related to the literature describing theoretical perspective and hard ward implementation perspective. It has been observed that MIMO technology has reached the level where we can used it for practical system. In this paper we have investigated the problem that exist to it MIMO system i.e. high bit error rate due to channel fadings. We have designed to different MIMO model based on1/2 and ¾ MIMO transmitter receiver antenna and included the effect of gray coding in the effect of gray coding in the signal trial to the modulation. It has been observed that in the SISO system mode BER is very large for any kind modulation scheme even at the small noise power mirror. Due to fading channel BER is never reduced below 0.4. But in the case of ½ and ¾ designing results BER has reached to zero level at SNR over than 25 for any type of modulation scheme. In the case of MIMO ½ design BER for BPSK modulation are negeable an almost same for binary and gray coding. In the case of BPSK, QPSK, 8PSK and 16PSK the BER after gray coding is found lower than the BER due to binary coding. Similarly in the case of MIMO ¾ model BER is reduced for due the modulation scheme on using gray coding. In this way we can conclude that gray coding helps in improving data transmission efficiency for both ½ and ¾ MIMO systems.

We have also compared our MIMO ½ and ¾ system and it has been found that for BPSK modulation ½ model is giving lower BER at all the SNR. For the case of QPSK ¾ MIMO design is better than ½ MIMO design but for the case of 8 and 16PSK schemes our MIMO ½ design is lower bit error rate as compared to MIMO ¾ specially at the SNR above or equal to 10db. In this way in maximum cases that we have considered MIMO ½ channel design has performed better than MIMO ¾ channel design.

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