International Journal of Wireless Communication and Simulation
ISSN 2231-1254 Volume 9, Number 1 (2017), pp. 1-14

http://www.ripublication.com

Performance and Comparative Analysis of SISO, SIMO, MISO, MIMO

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Abstract

In the present world, due to rapid growth in communication (over broader distance) has increased; therefore there is a need to improve the transmission of the data over wireless media so as to achieve the demand of fast and feasible communication. To meet the above, it is required to have better and improved throughput, data rates, BER and quality of signals received at the receiving end of the system, in the advanced wireless communication. The parameter (like throughput, data rates, BER) mainly depends on the antennas used in transmitting and receiving end of transmitter and also on the external disturbances introduced in the form of noise in the system. The antenna that can attain all the parameters values at optimum level is MIMO antenna. Apart of MIMO we also have SISO, SIMO, MISO antennas available for communication over radio channels. Among all the four mentioned (SISO, SIMO, MISO, MIMO) MIMO gives the best diversity gain of the signals received at the receiving end also it has got the ability to handle the external noise effect in the most appropriate manner than other so as to reconstruct the same signal at the receiving end. In this article we will analyze all the four types of antennas theoretically and practically (with respect to OFDM) to have an clear view regarding how the signals are processed in all the four types and what are the advantages and limitations of using each of them and what all are the limitations in SISO, SIMO and MISO which makes the MIMO technique the most suitable among the four. In this article we have compare all of them practically using BER (comparison parameter) to support the theoretical analysis. Based on the analysis obtained we can derive that MIMO is the best suitable for advanced digital wireless communication.

Keywords: SISO, SIMO, MISO, MIMO, OFDM (Orthogonal Frequency Division Multiplexing), BER, LAN, WAN, MAN

I. INTRODUCTION

During the past few years (especially the last decade), the communication industry has experienced an exponential growth which has led people use this pace of advancement in communication industry at the highest level.

Mobile communication has reached to 4G from 2G, here the data rate for 2G was around 12kbps and then 2Mbps in 3G and followed by 100Mbps downlink speed and 50 Mbps uplink speed in 4G-LTE [2].

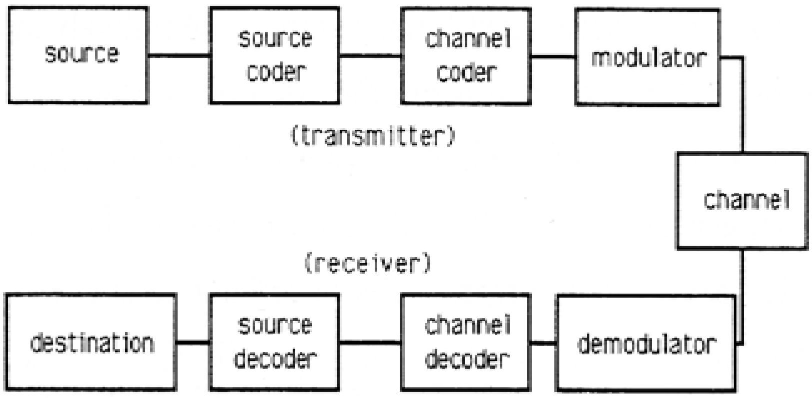

Fig. 1: Block Diagram of wireless digital communication system [2].

The above block diagram indicates how the signals are transmitted and received in radio channels. In the above diagram, the transmitting antenna is located at after the modulator to pass the modulated signal to receiving antenna via radio channels. The quality of the signals received at the receiver end depends on the channel, since many unwanted signals may get introduced in the original signal when the data is getting processed from transmitter end to receiver end. For transmitting of the signals antennas are located at both the ends and the channel capacity is maintained by the different types of antennas used in the system [1].

As of now, there has been a tremendous increase in the wireless communication globally, which has led down an increased demand to have better communication over radio channels in wireless media with minimal or negligible (if possible) data loss, proper SNR value to give fast and effective communication. As it depends mainly on the types of antennas used, we will now study each of them in detail. As discussed earlier we have four types of antennas available viz. SISO, SIMO, MISO and MIMO. The criterion that classifies any antenna in any of the four types is number of antennas at input side and number of antennas at output side.

II. MODULATION TECHNIQUE(S)

There are many types of modulation techniques available which can be used, some of the techniques available are – PSK, BPSK, DPSK, DEPSK, QPSK, MPSK, BFSK, MFSK, QASK / QAM, MSK.

Here we have analyzed all the antennas using BPSK (Binary Phase Shift Keying) since modulating a digital signal is easier in BPSK comparatively with other techniques. In BPSK, when the data is at one level then one of the two phases is fixed while the other phase is at a phase difference of 180 degree [1]. It consists of a bit synchronizer to detect the end of one signal and the start of other so as to change the phase of the system. The BPSK signal transmission in time domain is as shown below.

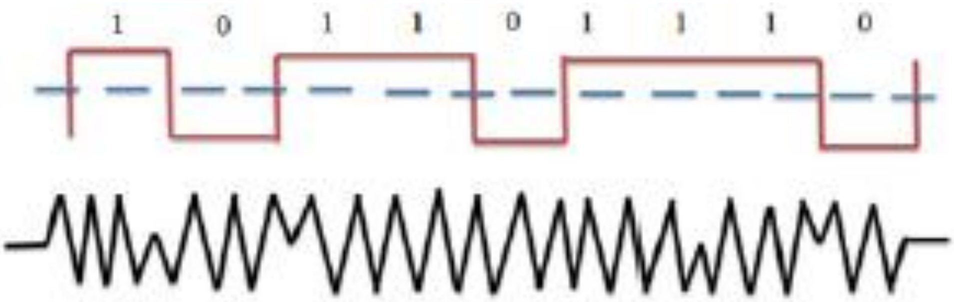

Fig. 2: BPSK signal modulation.

I. TYPES OF ANTENNAS

1. SISO (Single Input Single Output)
2. SIMO (Single Input Multiple Output)
3. MISO (Multiple Input Single Output)
4. MIMO (Multiple Input Multiple Output)

1. SISO (Single Input Single Output)

In SISO type of antenna, there is only one transmitting at the transmitter end and one receiving antenna at the receiver end. This makes SISO the simplest to implement and easiest to design amongst all the four types of antennas available. Following is the block diagram of SISO system.

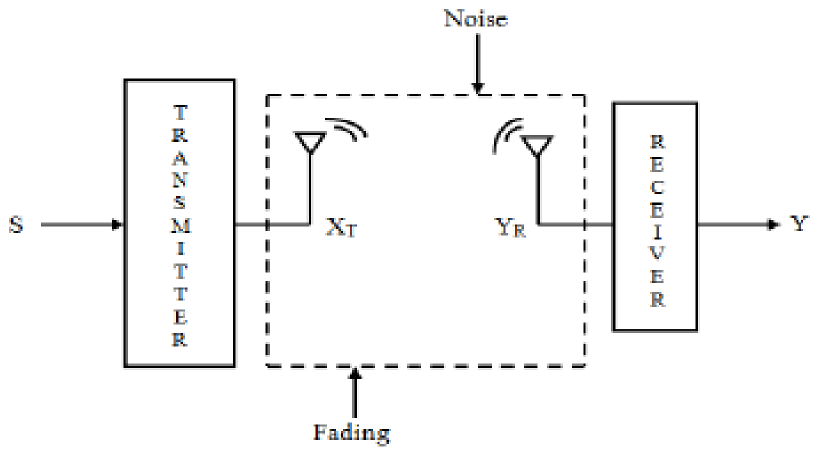

Fig. 3: SISO system.

In the above diagram, S: input, Y: output, X_T: Transmitting antenna, Y_R: Receiving antenna

The noise is introduced in the system when the signal is processing from X_T to Y_R (and the signal fads in this region while it is processed) as shown in diag. above. The channel capacity of the SISO system is given as [1]:

$$C_{(SISO)} = B \log_2\left(1 + \frac{S}{N}\right) \tag{1}$$

Where C is the capacity, B is Bandwidth of the signal and S/N is the signal to noise ratio [1].

The channel bandwidth of SISO is limited by Shannon's law which states that, theoretical maximum rate at which error-free digits can be transmitted over a bandwidth-limited channel in the presence of noise.

The only advantage of using SISO system is that it is very simple in design and cheap that all the other types of systems. SISO system has found out its applications in Wi Fi, TV, radio Broadcasting, etc [2].

2. SIMO (Single Input Multiple Output)

In SIMO technique, there is only one transmitting antenna and multiple receiving antennas at receiving end; this helps to increase the receiving diversity at the receiving end as compared with SISO [2]. Following is the block diagram of SIMO system with one transmitting antenna and two receiving antenna at the receiving end for analysis (in this case only two, more than two also possible).

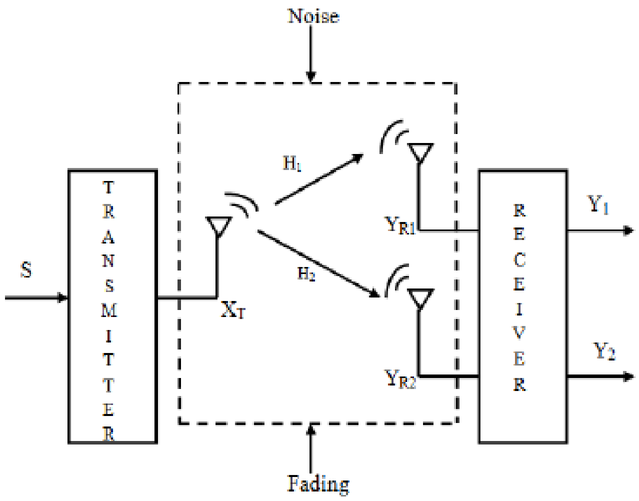

Fig. 4: SIMO system.

In the above diagram, S: input, Y_1 & Y_2: two outputs from two receiving antennas, X_T: Transmitting antenna, Y_{R1} & Y_{R2}: two receiving antenna (both the receiving antennas will have different fading coefficients).

In the receiving scheme of SIMO, since there are multiple receiving antennas many type of signal receiving techniques can be used like RAKE receiver (as discussed above). SIMO helps in improving the receiving diversity of the antenna as it gives stronger diversity than SISO, but there is no increase observer in channel capacity [1]. The channel capacity of the SISO system is given as [1]:

$$C_{(SIMO)} = M_r B \log_2\left(1 + \frac{S}{N}\right) \tag{2}$$

Where C is the capacity, M_r is the number of antennas used at receiver side, B is Bandwidth of the signal and S/N is the signal to noise ratio [1].

SIMO has found out his applications in encountering the effects of ionosphere fading for listening and receiving short waves. The advantage of SIMO over SISO is that it gives improve diversity than SISO and due to this SIMO can give a better BER analysis than SISO we will see this in results section further. In SIMO, the receiving antennas are mostly placed in devices like mobile phone and due to this the performance of the systems will be restricted the some of the physical parameters of the mobile used like battery, shape and size, etc [2].

3. MISO (Multiple Input Single Output)

In MISO, there can be multiple transmitting antennas from which the signal can be sent, and there I only one receiving antenna to receive the signals coming from multiple transmitting antenna, which means there are different sources available but there is only one destination available [2]. Following is the block diagram of MISO system with two (in this case only two, more than two also possible) transmitting antenna and one receiving antenna at the receiving end for analysis.

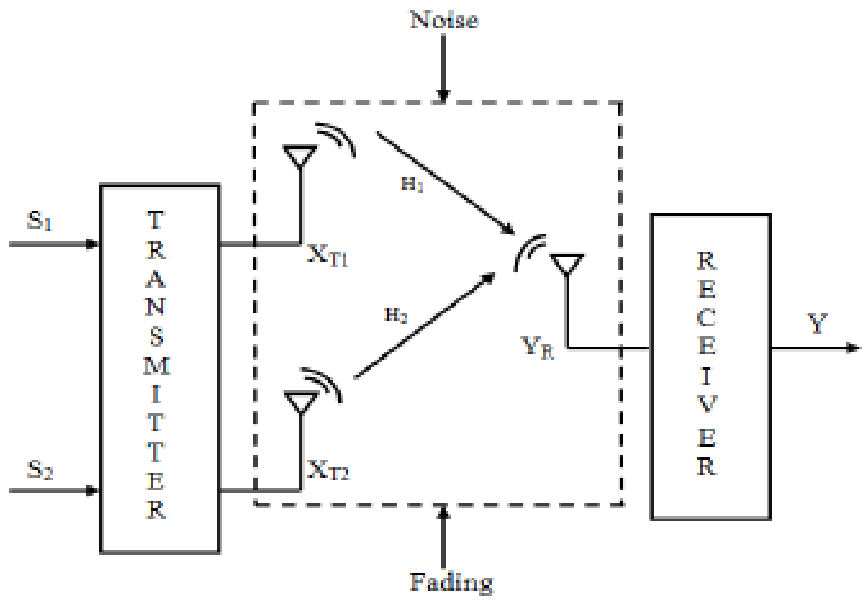

Fig 5: MISO system.

In the above diagram, S1 & S2: two inputs from two transmitting antennas, Y1 & Y2: outputs from, X_{T1} & X_{T2}: two transmitting antenna (both the transmitting antennas will have different fading coefficients), Y_R: two receiving antenna.

This scheme of antenna helps to recover original signal at receiving end with lesser path loss than SISO and SIMO, and also the effect of multipath fading is observed to be less that the above two techniques since there are two antennas at the transmission end [2]. Since two signals needs to be transmitted the channel capacity has still not increased but it is better than the other two (SISO & SIMO), the channel capacity of the SISO system is given as [1].

$$C_{(MISO)} = M_t B \log_2\left(1 + \frac{S}{N}\right) \quad (3)$$

Where C is the capacity, M_t is the number of antennas used at transmitter side, B is

Bandwidth of the signal and S/N is the signal to noise ratio [1].

MISO has got wide range of applications (due to high diversity gain) like W-Lans and Digital TV. The advantage of using MISO over SISO is that if the receiving antenna is placed in mobile phone that multiple signals may get received with different time delay and this can be completely overcome by using MISO since there is only one receiving antenna and therefore a complete signal will be received at the receiver, this is due to the reason that the coding redundancy is moved from receiver to transmitter. Also it does have any impact from the physical parameters of mobiles phones as is it is in SIMO [2].

4. MIMO (Multiple Input Multiple Output)

In MIMO, there can be multiple transmitting antennas from which the signal can be sent, and also there are multiple receiving antennas through which the signal can be received. In MIMO, since there can be multiple transmitting antennas the signal can be transmitted by any antenna and therefore the signal can follow any path to reach to receiving end and this path followed by the signal depends on the position of the antenna i.e. if we move the antenna by small position the path will get change [2]. The fading introduced in the signal from multiple paths can be termed as multipath fading. Following is the block diagram of MIMO system with N(in this case only two considered for practical analysis, more than two also possible) transmitting antenna and M (in this case only two considered for practical analysis, more than two also possible) receiving antenna at the receiving end for analysis.

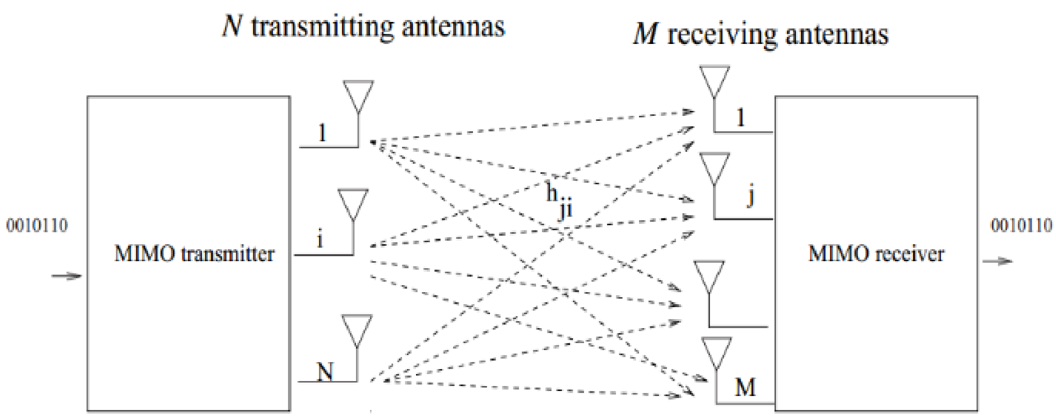

Fig. 6: MIMO System

In the above fig., there is one digital input given at the transmitter of MIMO which goes through multiple path to receiver and at receiver the signal received from all the receiving antennas are combined using RAKE receiver to reconstruct the original signal back at the receive end. The requirement to have better throughput, increased data rates and optimized spectral efficiency can be achieved by using MIMO [1].

In MIMO multiple channels are available, therefore the MMO channel can be represented as a $N \times M$:

$$\begin{bmatrix} h_{11} & h_{12} & \cdots & h_{(1N)} \\ h_{21} & h_{22} & \cdots & h_{(2N)} \\ . & . & & . \\ . & . & & . \\ . & . & & . \\ h_{(M_1)} & h_{(M_2)} & \cdots & h_{(MN)} \end{bmatrix}$$

Let the above matrix be of format H, where h_{11}, h_{12}, etc are the variables of fading gain between the transmitting and receiving antenna [1]. If the data rate has been increased for single user using MIMO then it is called as SU – MMIO (Single User - MIMO) whereas for multiple users it is MU – MIMO (Multiple User - MIMO) [1].

The input and output relation for the MIMO antenna can be given by the equation:

$$output\left[y(t)\right] = \sum^{N}{}_{(j=1)} h_{(NM)} S_{(M)}(t) \tag{4}$$

Here $S_M(t)$ is the signal received at M^{th} antenna which was transmitted by j^{th} antenna [1].

The capacity of MIMO system is given as [1]:

$$C = NMB \log_2\left(1 + \frac{S}{N}\right) \tag{5}$$

Where C is the capacity of MIMO system, N is the number of transmitting antennas, M is the number of receiving antennas and S/N is the signal to noise ratio [1].

As MIMO system gives the best capacity amongst all the four its has got wide range of applications like in MIMO signals can be transmitted via different spatial domains by employing Spatial Multiplexing using MIMO, MIMO is used in almost all the advanced wireless communication systems like LAN, WAM, MAN, 3G (OFDM - CDMA), 4G (OFDM – IDMA / LTE) [2]. The advantage of using MIMO is that it can give the best results when compared with the rest three since it has got the best throughput and efficiency of signals transmissions by the using multiple antennas both at transmitting & receiving end.

III. OFDM (ORTHOGONAL FREQUENCY DIVISION MULTIPLEXING)

In most of the advanced communication methods OFDM is used due to its advantage of using the channel in the most optimized manner as compared with other communication techniques. Here, in this article we have used OFDM system to analysis all the above four types of antennas practically i.e. we will observe the BER plot of OFDM system with all four types of antennas to study the practical aspects of a four of them.

Following is the basic block diagram of OFDM system.

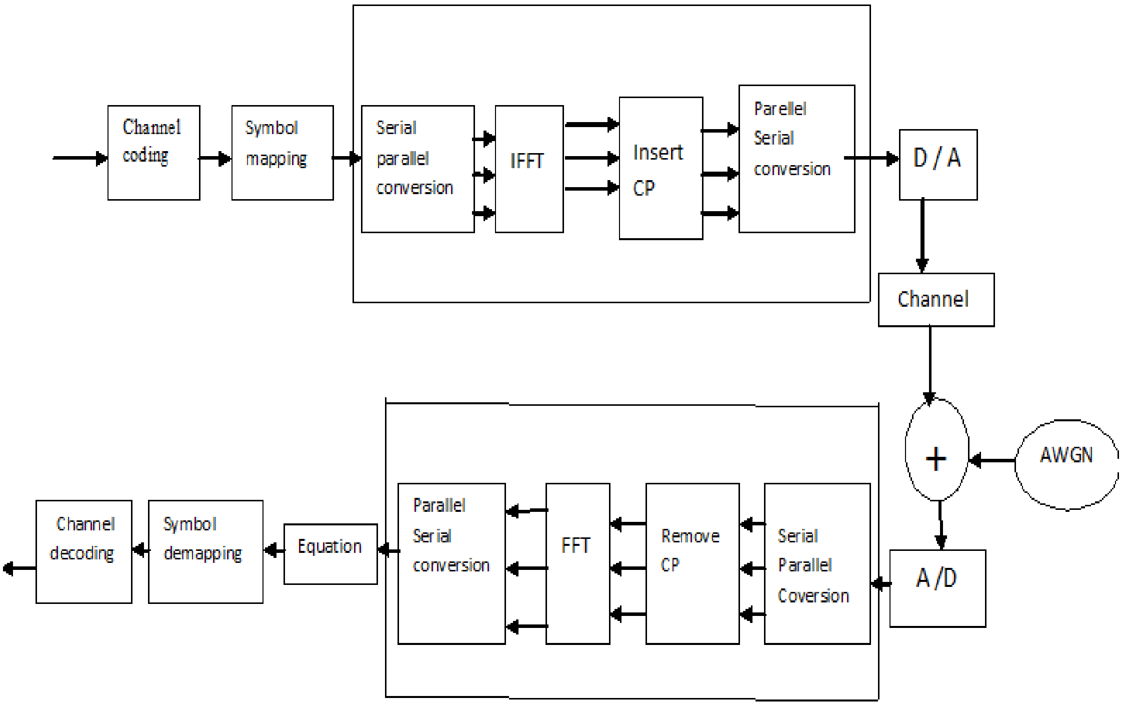

Fig. 7: OFDM System [3]

IV. BER (BIT ERROR RATE)

The BER of any system is defined as the ratio of number of error bits received to the total number of bits transmitted [3]. The error may get introduced by the fading effect while using different types of antennas. Mathematically, BER is given as:

BER = No. of errors / Total number of bits

V. THEORITICAL COMPARISION OF SISO, SIMO, MISO, MIMO

Table 1: Comparison of SISO, SIMO, MISO & MIMO

Sr. No.	Parameters	SISO	SIMO	MISO	MIMO
1	BER	It gives the lowest BER value due to only one antenna.	The value is better than SISO due to multiple antennas at receiving end.	Better than SIMO since loss of signal is less.	Optimized value of BER is observed, due to multiple antennas at both the ends.
2	Throughput	It is observed to be very less than all the others.	Even though there are multiple antennas at receiving end, it is observed to be less due to the complexities at receiver end due having multiple antennas.	Slightly better than MISO since there is only one receiving antenna.	It is observed to have the best capacity amongst all, which allows MIMO to have a wide range of applications.
3	Transmitting (Processing) of signals from Tx to Rx and	Since there is only one antenna at Tx & Rx end, the signal is transmitted from one end and received at another end.	Here, the signals are received by multiple antennas and they are then combined by the technique of Maximum Ratio Combining (MRC) and Equal Gain Combining [4].	The signals are transmitted using transmit beam forge and space time coding, there is only one receiving and multiple transmitting antenna [5].	Here transmit receive diversity is used where multiple antennas are present at both Tx &Rx end.
4	Quality of signal received at the output.	The quality of signal is quite weak as there is only one transmitting & receiving antenna.	It uses the concept of switched diversity (selection diversity) for implementation, where the receiver can choose the stronger antenna for receiving the signal.	It is implemented by Space Time Coding (STC) technique where signal can be transmitted in both time & space i.e. data can be transmitted by multiple antennas; this increases the gain & signal quality [5].	Signal can be transmitted using Spatial Multiplexing which allows the signal to be transmitted across different spatial domain, therefore it gives the best signal quality and diversity gain.

VI. RESULTS, ANALYSIS AND DISCUSSIONS

In this article, we have implemented SISO, SIMO, MISO and MIMO with respect to OFDM. In the above sections we have analytically studied all the four types of antennas and here in this section we have carried out the practical analysis of all four of them to satisfy the above theoretical analysis practically. For practical analysis we have plotted the BER curve against SNR for all the four antennas.

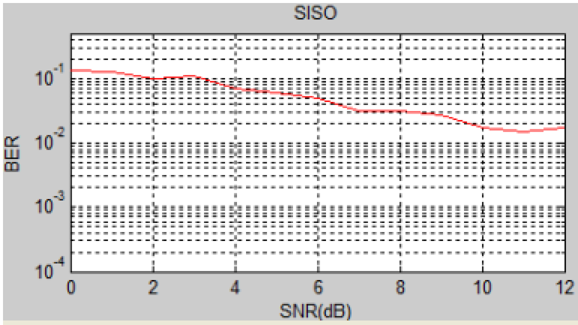

Fig. 8: BER response of SISO System.

In the above curve we can observe that, as the SNR increases the value of BER is decreasing, which shows that SISO system is getting affected the noise signal and the original signal will be faded.

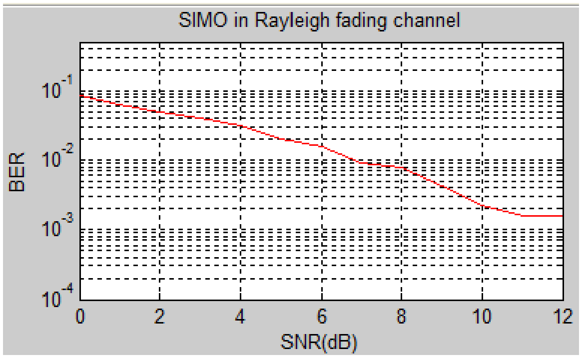

Fig. 9: BER response of SIMO System.

In SIMO, it is observed that the BER value has increased as compared to SISO since there are multiple receiving antennas and it employs techniques like transmit beam forge and space time coding for signal transmission.

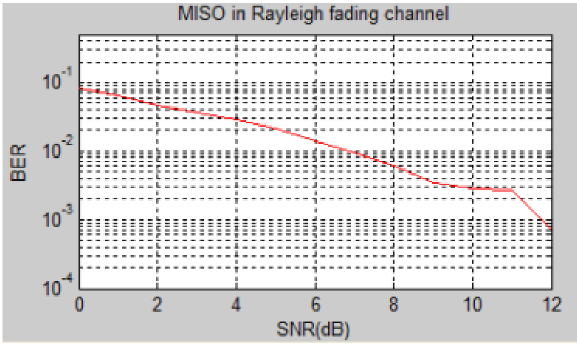

Fig. 10: BER response of MISO System.

Here in MISO, the BER value is a bit better than SIMO. It uses RAKE receiver at the receiver to combines the multiple signal received. In this case, as there is only one receiving antenna and if in a case the number of transmitting antenna increases then the time required by the RAKE receiver will be more, therefore we have gone to MIMO system to overcome the drawbacks all MISO and the above two systems.

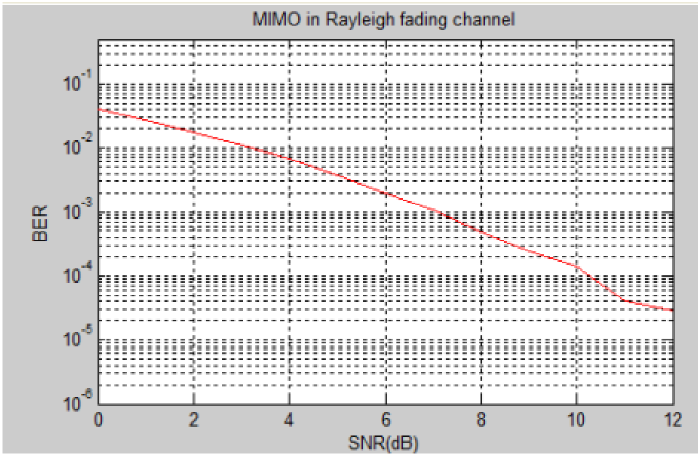

Fig. 11: BER response of MIMO System.

The above curve of MIMO gives the optimum result amongst all the four which and be observed from the above graph.

The following table gives the comparative analysis of BER results obtained for all the above four types of antennas and using the below table we will be able to compare the above graphs on the basis of practical analysis. The practical analysis obtained in the below table also matches the theoretical analysis of for all the four antennas and therefore it can be stated that MIMO gives the best possible output when compared with the other three and also MIMO has found out its applications in higher order digital communication techniques like CDMA, OFMD & IDMA.

Table 2: Practical Comparison of SISO, SIMO, MISO & MIMO.

BER / SNR (In dB)	SISO	SIMO	MISO	MIMO
0	0.145	0.0844	0.081	**0.04048**
2	0.112	0.0499	0.0469	**0.01787**
4	0.077	0.0308	0.0252	**0.006693**
6	0.063	0.0154	0.0136	**0.001984**
8	0.03	0.008	0.006	**0.00049**
10	0.022	0.0023	0.0028	**0.000138**

VII. CONCLUSION

The key idea behind this article was to have a comparison of SISO, SIMO, MISO & MIMO (both theoretically & practically) so that we can reach out to a conclusion that which of the antenna will play an important role in future wireless communication.

Based on the above analysis what we have found out is SIMO is better than SISO, since due to better throughput value it give a good BER value whereas MISO is found to be even better that SIMO sine it avoids there is only one receiving antenna but the time rehired here for combining the signal may get increased in case of more number of transmitting antenna and since we are looking to have such an antenna which can be used in digital communication therefore time is one of the major factor here, so we have reached to MIMO were the signal can be transmitted in Spatial domain and it gives the optimum BER values which is clearly observed from table 2.

Therefore, we can definitely conclude that from all of the analysis done above both theoretical & practical we can make out that MIMO system is the one which can be used in future wireless communication for transmitting the signals with least fading, within optimized time with best throughput and this will led down the transformation in advanced wireless communication giving maximum data rate to all the users.

REFERENCES

[1] Nimay Ch Giri, Anwesha Sahoo, J. R. Swain, P. Kumar, A. Nayak, P. Debogoswami, Lecturer, Department of ECE,B.Tech Scholar, Centurion University of Technology and Management, Odisha, India, Capacity & Performance Comparison of SISO and MIMO System for Next Generation

Network (NGN), International Journal of Advanced Research in Computer Engineering & Technology (IJARCET) Volume 3 Issue 9, September 2014

[2] Kritika Sengar, Nishu Rani, Ankita Singhal, Dolly Sharma, Seema Verma, Tanya Singh, Banasthali University, Newai, India, Amity Institute of Information and Technology University, Noida, India, Study and Capacity Evaluation of SISO, MISO and MIMO RF Wireless Communication Systems, International Journal of Engineering Trends and Technology (IJETT) – Volume 9 Number 9 - Mar 2014

[3] Chirag R. Shah, Department of Electronics &Telecommunication Engineering, University of Mumbai, Performance and Comparative Analysis of OFDM, OFDM–CDMA & OFDM–IDMA Systems, International Journal of Engineering Research & Technology (IJERT),Vol. 5 Issue 04, April-2016

[4] S. Lokya, Diversity Combining Techniques, ELG4179: Wireless communication Fundamentals.

[5] Sissi Xiaoxiao Wuy, Anthony Man-Cho Soz, and Wing-Kin May, Department of Electronic Engineering, The Chinese University of Hong Kong, Hong Kong*z* Department of Sys. Eng. & Eng. Mgmt., The Chinese University of Hong Kong, Hong Kong, Rank-two transmit beamformed alamouti space-time coding for physical-layer multicasting.