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SPATIAL DIVERSITY TECHNIQUES FOR WIRELESS COMMUNICATION - A COMPARATIVE ANALYSIS

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Abstract- Wireless communication has highest growth-rate in last decade[1]. Today, due to different coding and encryption techniques, security is not so much major issue for wireless communication. But modern communication systems are capacity limited[2][3], not interference or coverage limited. Spatial diversity techniques like SISO, SIMO, MISO and MIMO gives improved spectral efficiency and better capacity and coverage to cellular communication with limited bandwidth. BER is used as a tool to compare all of these four techniques and MIMO found to be best among four[4],[5],[6]. Advanced digital communication systems or modern wireless communication systems like 4G uses MIMO to obtain all benefits over 3G.
Keywords – Spatial Diversity, MIMO, LTE, 4G, BER

1. INTRODUCTION

Modern wireless communication demands constant improved spectral efficiency. More number of users is needed to be accommodated in a given bandwidth with high quality standards for communication. Different diversity techniques are used for it. Spatial diversity deals with multiple number of transmitting and receiving antenna at transmitter and receiver respectively. When same signal is transmitted or received via multiple devices, spatial diversity is formed. There are main four types of spatial diversity:

SISO (Single Input Single Output -- No diversity)
SIMO (Single Input Multiple Output)
MISO (Multiple Input Single Output)
MIMO (Multiple Input Multiple output)

So, different number of antenna at transmitting end (Input side) and receiving end (Output side) forms spatial diversity systems. These systems are discussed and analyzed mathematically. MIMO, combined with OFDM is used for Long Term Evolution (LTE)[7,8] standards and makes 4G more reliable, fast and efficient. MATLAB 17 software has been used to evaluate different techniques graphically.

The rest of the paper is organized as follows. Proposed algorithm's results and graphs for these diversity techniques are explained in section II. Analysis of experimental results is presented in section III. And concluding remarks are given in section IV.

2. PROPOSED CODES

2.1 SISO - Single Input Single Output

This case is actually considered as no diversity at all. Single input antenna at the transmitting end and single output antenna at the receiving end forms SISO system as shown in figure 1. Bit Error Rate (BER)[9] vs. Eb/N0 plot for SISO is shown in figure 2. As no diversity is applicable in SISO case, multipath fading[9] is a prominent issue in this category of communication[10-12]. The channel capacity for SISO is given as equation (1).

CSISO = B log2 (1 + S/N) ………………………….. (1)

Where, C is the capacity, B is the Bandwidth of the information signal and S/N is the signal to noise ratio of given wireless environment. SISO has a benefit of its design simplicity and economically cheap.

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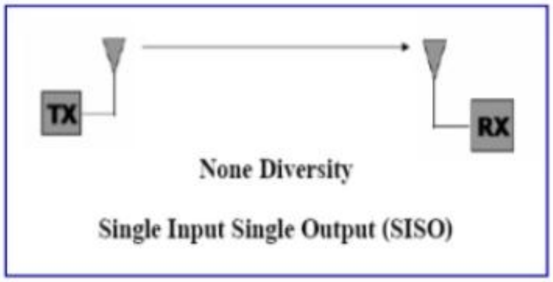

Figure 1. SISO model for wireless communication

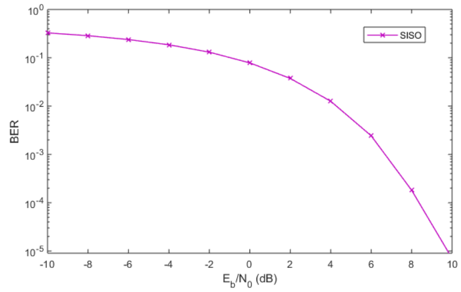

Figure 2. BER vs. Eb/N0 for SISO

SISO system, similar to other diversity systems, is affected by multipath fading. But as no diversity is applied in this case, multipath degradation increases BER drastically improves for multipath SISO as shown in figure 3.

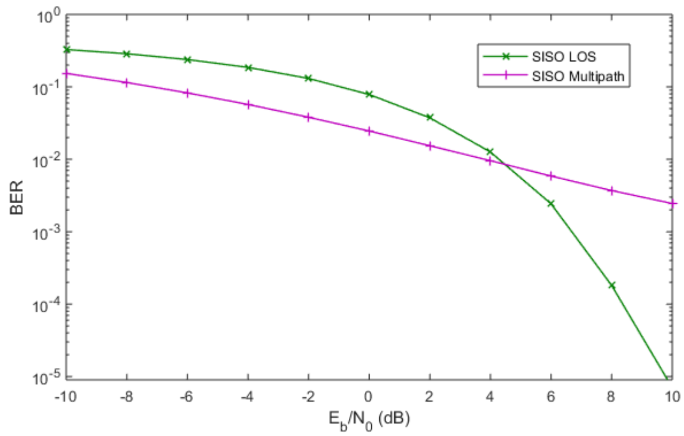

Figure 3. SISO - LOS and Multipath comparison

2.2 SIMO - Single InputMultiple Output

In this case, transmitter side single antenna works while receiving side multiple antenna is implemented as shown in figure 4. As number of receiving antenna increases, multipath fading effect is reduced. SIMO improves receiving diversity but channel capacity is not enhanced as such. Bit Error Rate (BER) vs. Eb/N0 plot for SIMO is shown in figure 5. The channel capacity[13] for SIMO, based on basic Shannon's channel capacity equation is given as equation (2).

CSIMO = MR B log2 (1 + S/N) …………………………. (2)

Where, MR is the number of antennas used at receiver side, C is the capacity, B is the Bandwidth of the information signal and S/N is the signal to noise ratio of given wireless environment. SIMO is comparably simple [14]with reference to MIMO. Better BER is produced using SIMO as it gives better diversity.

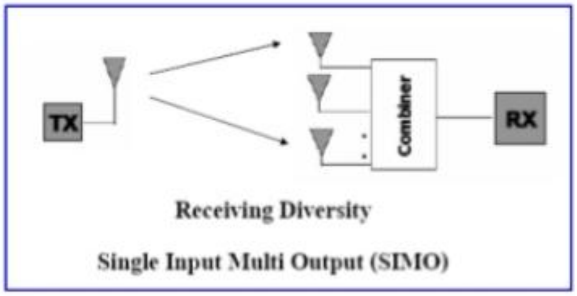

Figure 4. SIMO model for wireless communication

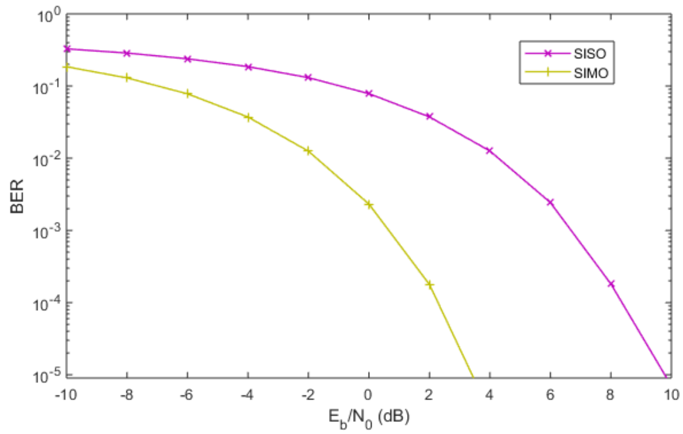

Figure 5. BER vs. Eb/N0 for SISO, SIMO

2.3 MISO – Multiple Input Single Output

In this case, transmitter side multiple antennas are used while, reception is done by single antenna as shown in figure 6. As number of transmitting antenna increases, different sources of communication takes place but there is only one receiver. Fading effect is decreased but channel capacity is not so improved in MISO. Bit Error Rate (BER) vs. Eb/N0 plot for MISO is shown in figure 7. The channel capacity for MISO, is given as equation (3).

CMISO = Mt B log2 (1 + S/N) …………………………. (3)

Where, Mt is the number of antennas used at transmitting end, C is the capacity, B is the Bandwidth of the information signal and S/N is the signal to noise ratio of given wireless environment. MISO is similar to SIMO and both are comparably simple with reference to MIMO[15]. Better BER is produced using MISO w.r.t. SISO as it gives better diversity at least at transmitting end [16].

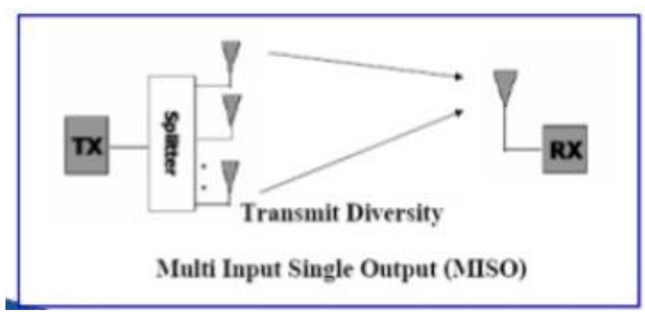

Figure 6. MISO model for wireless communication

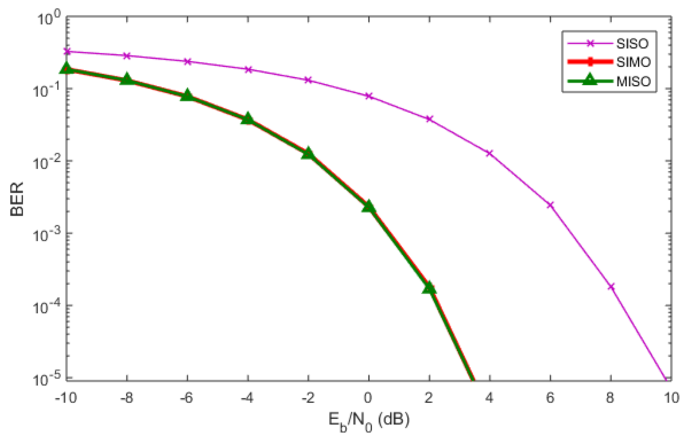

Figure 7. . BER vs. Eb/N0 for SISO, SIMO and MISO

2.4 MIMO – Multiple InputMultiple Output

In this case, Both transmitter and receiver sides are implemented with multiple antennas as shown in figure 8. This diversity technique gives maximum channel capacity[17][18] at minimum BER. As number of transmitting and receiving antennas are increased, fading effect is decreased measurably. Channel capacity is maximum for MIMO so, it is used in so many modern wireless communication systems like LAN, MAN, 3G, 4G with OFDM etc. Bit Error Rate (BER) vs. Eb/N0 plot for MIMO is shown in figure 9. The channel capacity for MIMO[19], is given as equation (4).

CMIMO = NM B log2 (1 + S/N) ………………………… (4)

Where, N is the number of antennas used at transmitting end, M is the number of antennas used at receiver, C is the capacity, B is the Bandwidth of the information signal and S/N is the signal to noise ratio of given wireless environment. MIMO is far better than SISO but implementation cost is highest among all other spatial diversity techniques.

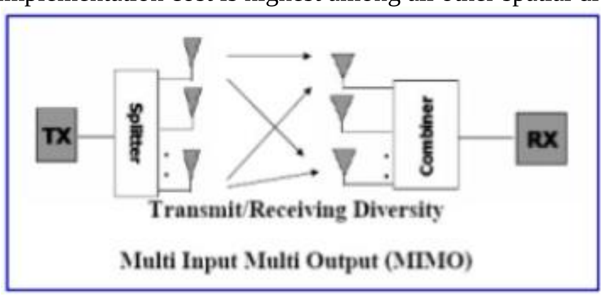

Figure 8. MIMO model for wireless communication

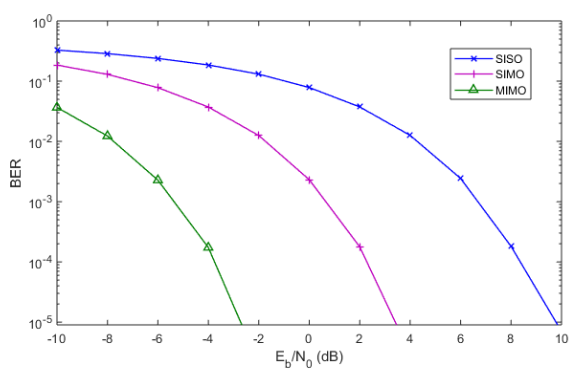

Figure 9. . BER vs. Eb/N0 for SISO, SIMO, MIMO

2.5 Experimental analysis and Results

Practically, SISO, SIMO, MISO and MIMO is compared for BER and SNR. Results clearly shows that the MIMO gives least BER at any given SNR. Choice of diversity technique needed to be implemented is dependent on few parameters like – affordable cost of cellular communication, Coverage and capacity issues of environment, required throughput of system, and spectral efficiency required from system. Matlab17.0 software platform is used to perform the experiment.

Table -1 Experiment's results for SISO, SIMO, MISO and MIMO

	BER			
SNR	SISO	SIMO	MISO	MIMO
0	0.139	0.0838	0.080	0.04
2	0.106	0.0493	0.042	0.18
4	0.071	0.0303	0.0262	0.007
6	0.057	0.0149	0.0130	0.002
8	0.0024	0.007	0.007	0.0005
10	0.0116	0.0019	0.003	0.00015

Table 1 shows the peak signal to noise ratio (SNR) based BER readings for different values of SNR. MIMO performance is best among all for any given SNR is clearly identified from the results obtained.
Different parameter wise comparison for SISO, SIMO, MISO and MIMO is tabulated in table 2.

Table -2 Parametric comparison results for SISO, SIMO, MISO and MIMO

Parameter Name	SISO	SIMO	MISO	MIMO
Quality of Signal at receiver	Poor / Weak	Multiple antennas so, best reception is selected	Improved quality due to multiple transmission	Best quality
BER	Maximum	Medium	Medium	Minimum
Throughput	Very less	Better than SISO	Slightly better than SIMO	Best throughput
Complexity of design	Simplest	Moderate design	Moderate design	complex

3. CONCLUSION

Different diversity techniques can be implemented for spatial diversity. Technical comparison of these techniques is required to implement any of them into real time technology or standards. From above comparison and analysis, we come across the fact that MIMO is best capacity system among all and it is maximum costly for obvious reasons of multiple antenna systems at transmitting and receiving ends.

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