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Study the Performance of Capacity for SISO, SIMO, MISO and MIMO in Wireless Communication

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Abstract: Due to the rapid development of the wireless communication system, it is highly required a reliable system which can provide higher channel capacity and higher data transmission rates for the users. These are obtained by the Multiple Input Multiple Output (MIMO) systems because the MIMO systems allow the spatial diversity and spatial multiplexing technique due to its multiple antennas at both transmitter and receiver side. The aim of this paper is to discuss and show the capacity performance between SISO, SIMO, MISO and MIMO systems. In this paper, we will mainly be focused on the MIMO system due to its higher capacity and higher data transmission rates properties. For these properties of the MIMO systems, it will be perfectly suitable for modern communication technology.

Keywords: Channel capacity, MIMO system, MISO system, SIMO system, SISO system, Wireless communication.

I. Introduction

Generally, wireless communication is a type of data communication approach where the communication is performed without any kind of wires, cables or any other forms of electrical conductors. Wireless communication starting with 1G, 2G, 3G and now 4G and this development will be done in recent decades [1]. For the rapid development of communication systems with a large number of mobile users in the world, we need an efficient communication system with high data transfer rates and higher channel capacity [2].

The Multiple Input Multiple Output (MIMO) system will be produced higher data transmission rate and higher channel capacity compared with the other different antenna configuration system such as-Single Input Single Output (SISO), Single Input Multiple Output (SIMO) and Multiple Input Single Output (MISO) [3]. The MIMO system increases the reliability of MIMO channel capacity which is obtained through diversity techniques [4] [5] and this is done by using the MIMO systems multiple number of transmit and receive antennas. Due to multiple antennas on both sides if anyone path is faded the other path is worked for transmitting a signal from transmitter to receiver. The other advantage is the higher data transmission rate that is obtained through spatial multiplexing techniques [1] [6]. MIMO wireless communication system is an IEEE 802.11n standard in worldwide communication [7].

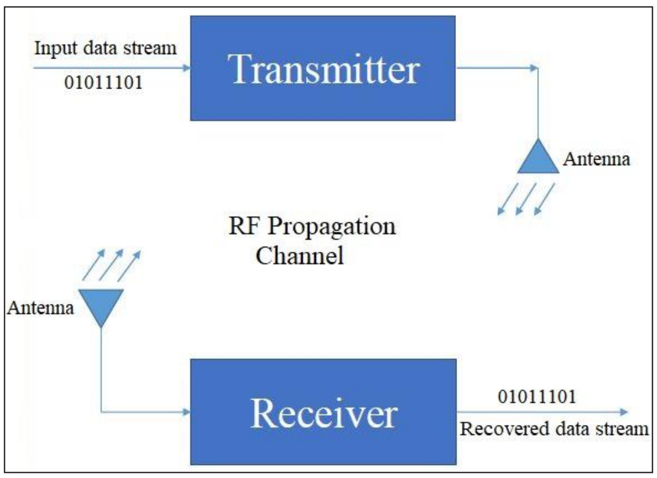

Fig. 1: Basic Block Diagram of Wireless Communication System

Now, we will discuss the capacity performance of SISO, SIMO, MISO and MIMO systems with the simulation diagram. All the simulations are performed by using MATLAB R2016a software.

In this paper, the theoretical information about SISO, SIMO, MISO and MIMO systems as well as the simulation results are discussed in Section II, III, IV, V and VI respectively. And finally, the conclusion is depicted in Section VII.

II. SISO System

SISO stands for Single Input Single Output and this communication system was introduced on the eve of the beginning of wireless communication technology. It is the most less complex and easiest wireless communication system as compared to the other systems. The SISO system has only one antenna at both the transmitter and receiver side. Due to the single antenna at both sides, it is easy to use and implementation and cheap also because there is no additional processing required at the transmitter and receiver side. SISO systems are now found in Wi-Fi, TV, radio broadcasting communication technology [3] [8]. A typical SISO system model illustrated in Fig. 2.

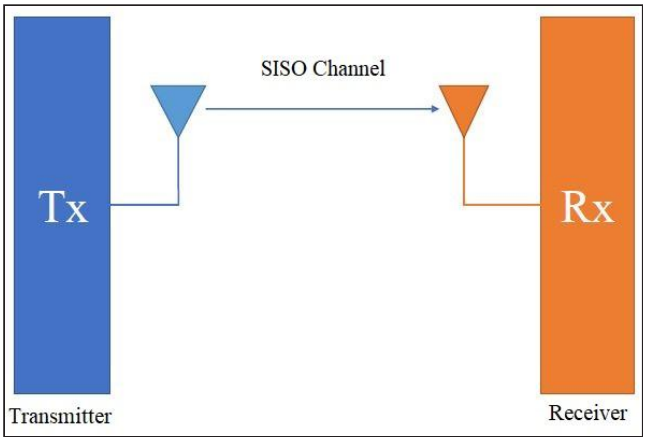

Fig. 2: SISO System Model

A SISO (Single Input Single Output) system capacity is given by [8],

$$C_{SISO} = \log_2(1 + \rho|h|^2)\ bps/Hz \tag{1}$$

Where ρ is Signal to Noise Ratio (SNR) at receiver antenna and h is the normalized complex gain of the channel.

III. SIMO System

In a data transmission scheme, SISO system contains a single antenna at the transmitter side and multiple antennas at the receiver side. This system is also known as receiving diversity. The capacity of the SIMO system is better than the SISO system. Although the system is relatively easy to implement, the processing is required at the receiver end [9]. The SIMO system is simply used in many applications, but where the receiver is situated in a mobile device like a mobile handset, the balance of processing may be narrow by size, cost and battery liquidate. There are two types of SIMO systems that we use in communication systems. Firstly, Switched Diversity SIMO and secondly, Maximum Ratio Combining SIMO [10]. A typical SIMO system model is illustrated in Fig. 3.

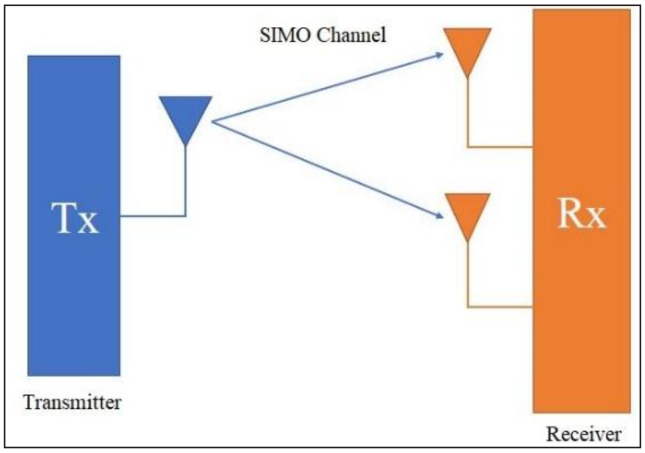

Fig. 3: SIMO System Model

For the N_R number of antennas at receiver R_X, the capacity of the SIMO system is expressed by [3],

$$C_{SIMO} = \log_2\left(1 + \rho \sum_{m=1}^{N_R} |h_m|^2\right)\ bps/Hz \tag{2}$$

Where ρ is Signal to Noise Ratio (SNR) at receiver antenna and h_m is the gain for m^{th} R_X antenna.

IV. MISO System

MISO system refers to the data transmission scheme which contains multiple antennas at transmitter and single antenna at the receiver end. MISO is also known as transmit diversity. During the data transmission, the same data is transmitted redundantly from the two transmitter antennas. This system is required processing at the transmitter end so that the system requires less power and processing at the receiver end. The capacity of the MISO system is lower than the SIMO system [9] [10]. A typical MISO system model is illustrated in Fig. 4.

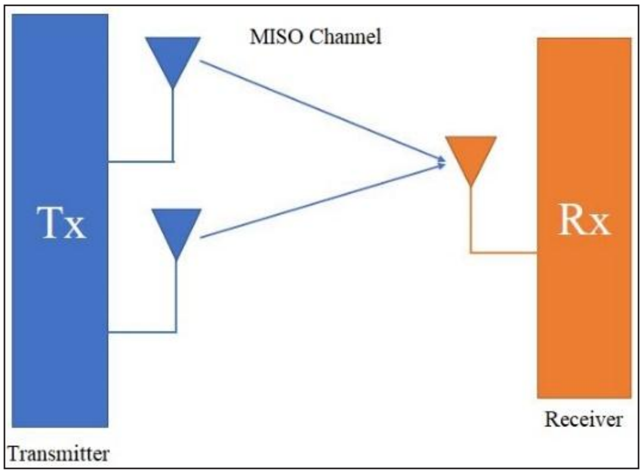

Fig. 4: MISO System Model

For the N_T number of antennas at transmitter T_X, the capacity of the MISO system is expressed by [3],

$$C_{MISO} = \log_2\left(1 + \frac{\rho}{N_T}\sum_{n=1}^{N_T}|h_n|^2\right) \ bps/Hz \quad (3)$$

Where ρ is Signal to Noise Ratio (SNR) at the receiver end and h_n is the gain for the n^{th} T_X antenna.

V. MIMO System

MIMO system refers to the data transmission scheme which contains multiple antennas at both transmitter and receiver end. This system is also known as transmit and receive diversity. The MIMO system provides higher capacity, spectral efficiency and higher data transmission rates than any other data transmission scheme. This system is more reliable due to its multipath in the transmitter to the receiver. Although in MIMO system processing is required at both transmitter and receiver, it will provide channel robustness and data throughput capacity [8] [11] [12] [13] [15].

Consider a MIMO system with N_T transmit and N_R receive antennas as illustrated in Fig-5. For getting transmit and receive a signal in both sides indiscriminately, let the antennas be omnidirectional.

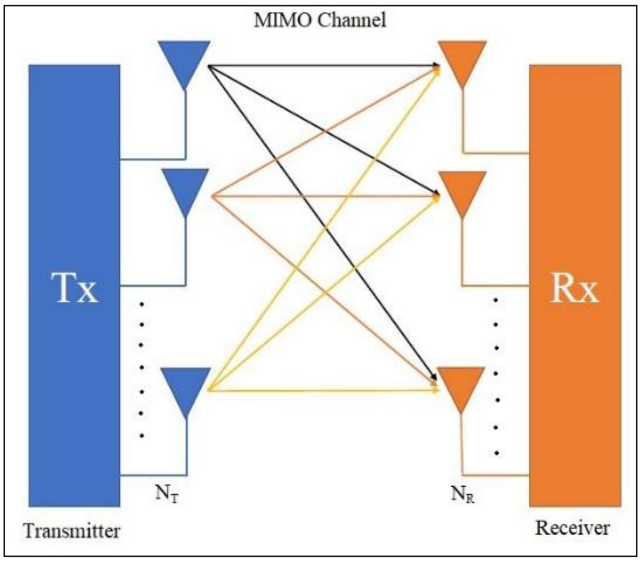

Fig. 5: N_T x N_R MIMO System Model

The linear link model between the transmit and receive antennas can be represented in the vector notation as-

$$y = Hx + n \quad (4)$$

Where y is the N_R x 1 receive signal vector and x is the N_T x 1 transmitted signal vector, n is the N_R x 1 complex Gaussian noise vector and H is the N_R x N_T normalized channel matrix which can be represented as-

$$H = \begin{pmatrix} h_{11} & h_{12} & \cdots\cdots & h_{1N_T} \\ h_{21} & h_{22} & & \\ \vdots & \vdots & \cdots\cdots & h_{2N_T} \\ \vdots & \vdots & & \\ h_{N_R1} & h_{N_R2} & \cdots\cdots & h_{N_RN_T} \end{pmatrix} \quad (5)$$

Each element h_{mn} represents the complex gains between n^{th} transmit and m^{th} receive antennas.

For the number of N_T and N_R in transmit T_X and receive R_X antennas respectively, the capacity of the MIMO system is expressed as [3] [8] [15] [16] [17]-

$$C_{MIMO} = \log_2\left[det\left(I + \frac{\rho}{N_T}HH^{\dagger}\right)\right] \ bps/Hz \quad (6)$$

Where *det*(.) denotes the determinant of a matrix, I is an N_R x N_T identity matrix, ρ is the average received Signal to Noise Ratio (SNR) and $HH^{\dagger}$ is the complex conjugate transpose of H.

VI. System Simulation Results and Discussion

For the simulation result to plot Capacity vs SNR consider the capacity and SNR values at y-axis and x-axis respectively where the SNR value limit is -5 dB to 30 dB. The number of antennas at transmitter and receiver end are considered for the SISO, SIMO, MISO and MIMO system simulation which are shown in the following Table I:

Table I: Antenna Configuration for SISO, SIMO, MISO and MIMO System

Name of the System	Number of Transmitter Antenna	Number of Receiver Antenna
SISO	1	1
SIMO	1	2
MISO	2	1
MIMO	2	2

A. Capacity of the SISO System

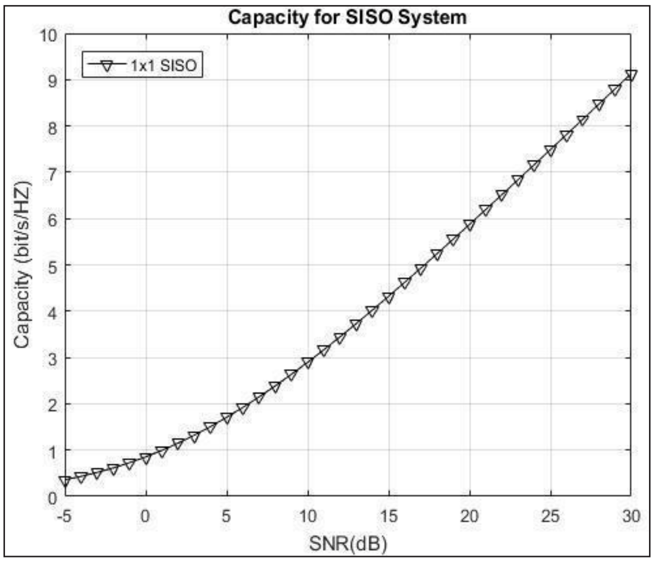

Fig. 6: Capacity of the SISO System

Fig. 6 shows the simulation result of the SISO system with a single antenna at both transmitter and receiver i.e. only one communication channel between transmitter and receiver. The channel capacity of the SISO system is very low and also the implementation of the system is very easy and low cost for the 2G wireless communication system [8].

B. Capacity Comparison of the SISO and SIMO System

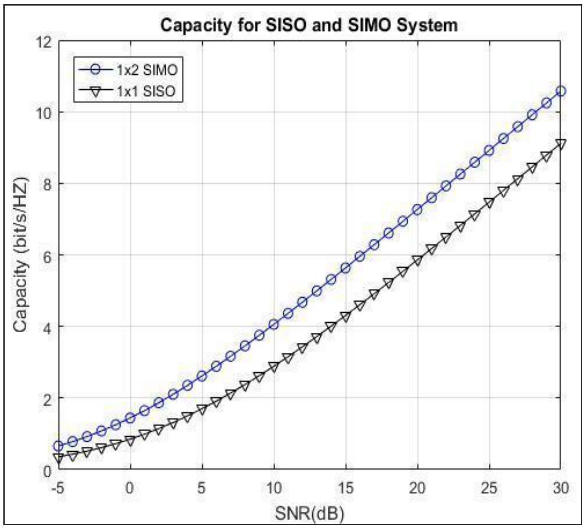

Fig. 7: Capacity Comparison between SISO and SIMO System

Fig. 7 depicted the simulation result for the comparison between SISO and SIMO system capacity. From the simulation result, it will be concluded that the capacity of the SIMO system will be much better than the SISO system [9].

C. Capacity Comparison between SISO, SIMO and MISO System

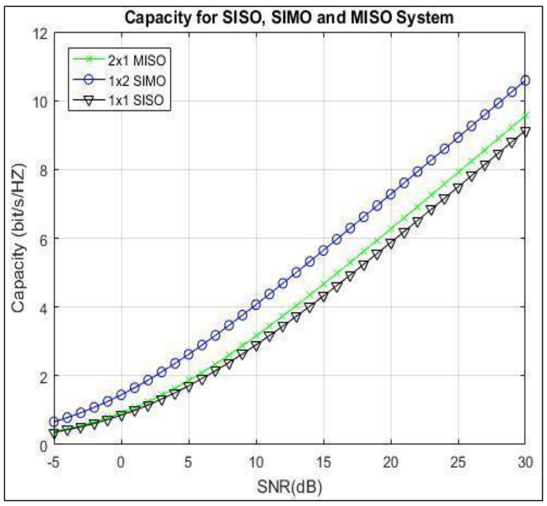

Fig. 8: Capacity Comparison between SISO, SIMO and MISO System

Fig. 8 plotted the simulation result for the comparison between SISO, SIMO and MISO system capacity. From Fig. 8, it will be shown that the capacity curve of the MISO system is approximately the same for the low SNR values and when the SNR is increasing there is a little difference between SISO and MISO capacity performance curves. The performance of the MISO system will be significantly lower than the SIMO system. From the comparison, it will be concluded that a data transmission system can achieve a better capacity performance for the multiple antenna at the receiver end [8] [9].

D. Capacity Comparison between SISO, SIMO, MISO and MIMO System

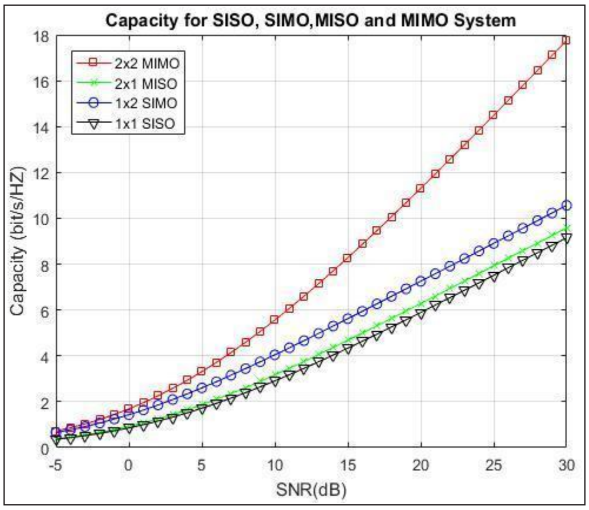

Fig. 9: Capacity Comparison between SISO, SIMO, MISO and MIMO System

Fig. 9 shows the simulation graph for the capacity comparison between SISO, SIMO, MISO and MIMO systems. From Fig. 9, it will be shown that there is a significant difference of capacity performance of the MIMO system as compared to the others i.e. the MIMO system produced the best capacity performance among the others [12]. For a MIMO system, it will be expressed that the capacity of the MIMO system will be increased tremendously during the increasing the values of SNR. Due to the multiple antennas at both transmitter and receiver end, the MIMO system produced higher channel capacity.

From Fig. 10 of Capacity comparison between SISO and various antenna configurations of MIMO systems, it will be shown that when increasing the number of antennas at both transmitter and receiver end for the MIMO system the capacity of the system will be dramatically increased. The capacity of the SISO system is lower than any other systems. In this above figure, 3x3, 4x4, 6x6 and 8x8 antenna configurations will be considered for the MIMO system. In the following Table II, the capacity of the 1x1 SISO, 1x2 SIMO, 2x1 MISO and 2x2 MIMO system with respect to their particular SNR are given.

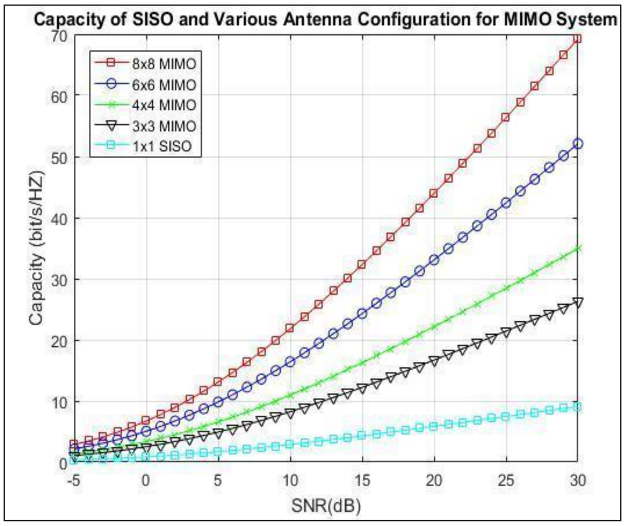

Fig. 10: Capacity Comparison between SISO and Various Antenna Configuration of MIMO System

TABLE II: CAPACITY OF THE 1x1 SISO, 1x2 SIMO, 2x1 MISO AND 2x2 MIMO SYSTEM

Sr. No.	SNR dB	Capacity (bit/s/Hz)			
		1x1 SISO	1x2 SIMO	2x1 MISO	2x2 MIMO
1	-5	0.3568	0.6631	0.3775	0.7186
2	-4	0.4302	0.7869	0.4572	0.8638
3	-3	0.5155	0.9271	0.5503	1.0315
4	-2	0.6136	1.0839	0.6581	1.2233
5	-1	0.7253	1.2575	0.7813	1.4405
6	0	0.8514	1.4478	0.9209	1.6839
7	1	0.9923	1.6540	1.0772	1.9541
8	2	1.1482	1.8756	1.2502	2.2514
9	3	1.3191	2.1116	1.4399	2.5757
10	4	1.5047	2.3607	1.6458	2.9266
11	5	1.7047	2.6218	1.8670	3.3036
12	6	1.9185	2.8937	2.1026	3.7058
13	7	2.1453	3.1751	2.3515	4.1322
14	8	2.3842	3.4647	2.6124	4.5817
15	9	2.6344	3.7615	2.8841	5.0530
16	10	2.8949	4.0644	3.1654	5.5448
17	11	3.1648	4.3724	3.4549	6.0557
18	12	3.4430	4.6848	3.7516	6.5843
19	13	3.7287	5.0009	4.0544	7.1291
20	14	4.0209	5.3199	4.3625	7.6887
21	15	4.3191	5.6415	4.6749	8.2617
22	16	4.6221	5.9651	4.9909	8.8467
23	17	4.9297	6.2903	5.3100	9.4425
24	18	5.2410	6.6169	5.6316	10.0478
25	19	5.5556	6.9447	5.9552	10.6614
26	20	5.8729	7.2733	6.2805	11.2825
27	21	6.1926	7.6026	6.6071	11.9099
28	22	6.5143	7.9325	6.9348	12.5429
29	23	6.8378	8.2629	7.2634	13.1808
30	24	7.1627	8.5936	7.5927	13.8228
31	25	7.4888	8.9246	7.9226	14.4683
32	26	7.8159	9.2558	8.2529	15.1169
33	27	8.1439	9.5873	8.5837	15.7679
34	28	8.4725	9.9189	8.9147	16.4213
35	29	8.8018	10.2506	9.2459	17.0764
36	30	9.1316	10.5824	9.5774	17.7331

VII. CONCLUSION

This paper has attempted to demonstrate the proper information of SISO, SIMO, MISO and MIMO systems as well as depicted the capacity performance of those systems with the comparison. From the simulation results, it will be concluded that the capacity of the SISO system is lower than the other system and the capacity of the SIMO system is better than the SISO and MISO system and the capacity of the MISO system stays between the SIMO and SISO system. This paper will also be mentioned that the MIMO system will produce higher capacity and higher data transmission rates as compared to the other system due to its multiple antennas at both the transmitter and receiver side. With increasing the number of antennas in the MIMO system the capacity will also be increased significantly. MIMO systems will be integrated into 3G, 4G, WLAN, LTE etc. technology due to its tremendous performance.

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