Capacity analysis & performance comparison of SISO, SIMO, MISO & MIMO systems

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Abstract. Today trade wireless communication systems are wanted to equip reliable communication and bigger data rates. Two considerable challenges in system design are the restricted fading and spectrum due to multipath components in the wireless system. Multiple transmission and reception can be used to form (MIMO) multiple input multiple output channels to raise the data rate and capacity. The advantages of utilizing multiple antennas are to get reliable performance and a higher data rate. In this paper, an attempt is made to design and simulate SISO, SIMO, MISO and MIMO systems. We have analyzed and compared the performance of these systems based on SNR and channel capacity in a different number of an antenna. The effect of the number of an antenna (4, 8, and 16) on the channel capacity over a range of SNR (0-30db) for the systems is examined. The system performance is simulated in Matlab. The results of the simulation show that as significant improvement in the capacity of systems reached dramatically to 214 (bits / Hz / Sec) when SNR =30 and (16X16) MIMO is used.

1. Introduction
The requirements for channel capacity which depending on (power and spectrum efficiency modulation technique, less interference, high-efficiency antennas, reduced effect of multipath propagation, Doppler shift, less delay time, etc.) are rising day by day in wireless communication technology [1]. The design of a transceiver system is so important, where a comparison between multiple types of systems (SISO, SIMO, MISO & MIMO) has been investigated in this paper. The system used MIMO technique offer high capacity and data rate with compare to the system using other techniques, due to a large number of antennas and multipath is present, so if fading occurs in one of
these paths will be not effected on other paths \[2\][3], antennas of MIMO system not require more power and spectral bandwidth for transmit to give increasing incapacity of channel.

2. System model
There are four schemes for transmission in wireless communication SISO, SIMO, MISO and MIMO depending No. of transceiving antennas as follow [4]:

2.1. SINGLE INPUT SINGLE OUTPUT technique (SISO)

The SISO technique is more easy and simple, it uses one antenna to transmit and receive signals [5]. If we have T as transmit signal, has channel then R receive signal is given by:

\[ R = T + n \text{(noise)} \]  

\[ \text{Figure 1. SISO Diagram} \]

The capacity of the channel is few with comparison to other systems[6].

\[ \text{Cap}(\text{SISO}) = B \log_2(1 + s/n) \]  

\[ (2) \]

Where Cap is channel capacity, B is signal bandwidth and s/n mean ratio of signal to noise[7].

2.2. SINGLE INPUT MULTIPLE OUTPUT technique (SIMO)

SIMO is a familiar technique with one antenna on the transmission aspect and multiple antennas on the reception side. Let we have two signals R1 and R2 are received with not equal coefficient for channel fading h1 and h2 respectively and have Tx. signal T, then relation system of SIMO given by:

\[ R_1 = h_1 T + n_1 \text{(noise1)} \]  

\[ R_2 = h_2 T + n_2 \text{(noise2)} \]  

\[ \text{Figure 2. SIMO Diagram} \]

Multiple antennas in reception can give us robust signal during diversity. The capacity of the channel not increased and given by:

\[ \text{Cap}(\text{SIMO}) = M_r B \log_2(1 + s/n) \]  

\[ (5) \]

Where Cap is the capacity of the channel, \( M_r \) is the number used of antennas in the reception side, B is bandwidth and s/n mean ratio of signal to noise.

2.3. MULTIPLE INPUT SINGLE OUTPUT technique (MISO)

The description of the MISO system that has more than one antenna in the side of the transmission and one antenna only in the side of receiving. If we assume that have two signals as transmission 'T1' and 'T2' with the varying coefficient of fading channel 'h1' and 'h2', then receiving signal 'R' given by:

\[ R = h_1 T_1 + h_2 T_2 + n \]  

(6)
Figure 3. MISO Diagram

Channel capacity in MISO not increased because we need time 2 to transmit two of signals, capacity is given by:

\[ \text{Cap(MISO)} = Mt \log_2(1+s/n) \]  \hspace{1cm} (7)

Where Cap is the channel capacity, Mt the number used of antennas in transmission side, B is bandwidth and s/n mean ratio of signal to noise.

2.4. MULTIPLE INPUT MULTIPLE OUTPUT technique (MIMO)

MIMO is a method uses multiple antennas for transmission and reception aspects, therefor has more capacity and big data rate [8]. If stream used for a one user, this state called (SU-MIMO) single-user MIMO while, if stream used for multiple users, this state called (MU-MIMO) multi-user MIMO [9][10]. The relation between output and input signal in the MIMO model is [11]:

\[ R = HT + n \]  \hspace{1cm} (8)

Where R is vector of received signal, T is a vector of Tx. signal, n is the a complex of white Gaussian noise and H is a channel matrix.

Figure 4. MIMO Diagram

The capacity is higher compared to other techniques of wireless communications (SISO, SIMO, and MISO), to increase this capacity without change bandwidth and power of transmission signal must use several antennas in the transmission side and reception.

The model of Rayleigh has been used which means the channel is random. The matrix used is complex has independent and identically inputs distributed with variance unit and zero, that means used to rounding a channel where the domain of frequency [12].

\[ \text{Cap(MIMO)} = Mt \times Mr \times \log_2(1+s/n) \]  \hspace{1cm} (9)

Where Cap is capacity of the channel, Mt and Mr Special with antennas number for transmission and reception, B is the bandwidth of the signal and s/n mean ratio of signal to noise.

3. Simulation result

The results in this paper are compared for parameters SNR and channel capacity, as well as the channel capacity and a number of antennas, using the Matlab simulation.
Figure 5. Capacity vs. the No. of antennas in case SNR=0.

Fig. (5) shows a comparison between MIMO(16X16), SIMO(1X16), MISO(16X1), and SISO(1X1) in the case of signal-to-noise ratio (SNR) =0, where the lowest value of the capacity in MISO then SISO is approximately less than 1 (bits/sec/Hz), In SIMO, growth in capacity varies from 1 to 4 (bits/sec/Hz), as for MIMO is less than 14 (bits/sec/Hz). We note from the above data that the noise ratio is very high so that there is a strong fading for the transmission and reception.

Figure 6. Capacity vs. the No. of antennas in case SNR=10.

Fig. (6) Where SNR =10, the largest value of the capacity in MIMO74 (bits/sec/Hz), either in SIMO the growth in the channel capacity is approximate to 9 (bits/sec/Hz), at MISO & SISO have been a low rise are 5 and 4.5 respectively. We note there is a slight improvement in channel capacity due to an increase in SNR to 10.
Figure 7. Capacity vs. the No. of antennas in case SNR=20.

In the case of Fig. (7), we can observe a linearly increase in channel capacity for the MIMO system where it reaches 135 (bits/sec/Hz) due to an increase in SNR to 20. We can be seen that the capacity of the SIMO, MISO & SISO remains low as the number of antennas increases were 14, 10 and 9 (bits/sec/Hz) respectively, due to restrictions on transmissions.

Figure 8. Capacity vs. the No. antennas in case SNR=30.

Fig. (8) In SNR 30, observed the capacity value of MIMO has linearly reached dramatically to 214 (bits/sec/Hz) and this high capacity compared with the above cases. At the same time, there is no significant improvement in the capacity of systems (SIMO, MISO & SISO) whereas 20,17.5 & 20 (bits/sec/Hz) respectively due to the number of antennas (M), as signal assembly takes a long time, therefore, time is one of the main factors in the design of communication systems.
Figure 9.1. Capacity vs. SNR for M=4.

Figure 9.2. Capacity vs. SNR for M=8.

Figure 9.3. Capacity vs. SNR for M=16.
Table 1. Comparison between capacity (Bits/S/Hz) & SNR (dB).

|       | M=1   | M=4   | M=8   | M=16  |
|-------|-------|-------|-------|-------|
| SNR   |       |       |       |       |
| 0     | 0.8626| 2.2007| 0.9562| 3.3557|
| 10    | 4.2833| 6.7458| 4.7834| 15.9796|
| 20    | 8.9884| 11.6326| 9.637 | 34.2953|
| 30    | 13.8947| 16.5422| 14.5403| 53.8171|

Figures (9-1,2,3) and Table (1) shows the capacity of SISO, MISO, SIMO & MIMO systems when we change SNR values from 0 to 30 dB with 4, 8 & 16M(no. of the antenna). In the case of SISO, the capacity value ranges from (0.8626 to 13.8947 Bits/S/Hz) it is a low value and increases at a pace very low when SNR increases due to limited transmission system. In MISO, we see from Table 1 that there is no significant difference in capacity (about 0.2) with M increasing, due to the use of a single antenna for receiving which increases the transmission time. In SIMO, a capacity rise of (approximately 1) as M increasing, and this small grow in capacity consequent the increase in the number of receiving antennas and the increase of SNR in each time. Finally in the MIMO system observe has been the large difference in capacity when increasing the number of antennas & SNR, where the heightened of capacity value in MIMO (4x4) (3.3557 - 53.8171), in MIMO (8x8) (6.7026 - 106.9724) & highest capacity in the case of MIMO (16x16) (13.397 - 213.2394) which is excellent result comparison with previous systems.

4. Conclusion

In this paper study and simulation for (SISO, MISO SIMO & MIMO) systems are present for transceiver data, where the result of comparison to these techniques obtained by rising SNR which have been assured the fact that the channel capacity directly Proportional with SNR, whenever larger SNR value (30 dB) applied will give a higher data transfer rate and remarkable stability in performance of system, especially in MIMO system satisfy 80% over than other systems, in contrast, the result to change antennas number as M = 4,8,16 has been documented by synchronizing with change of SNR value 0-30 dB for the systems, a robust stability satisfied of the MIMO system when the number of antennas M = 16 with the improvement of the SNR parameter. We are concluded that possible to make a qualitative leap in the 4G & 5G wireless communication systems by placing arrays of antennas on both sides of the system.

5. References

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