CAPACITY ENHANCEMENT OF MIMO SYSTEM UNDER DIFFERENT FADING CHANNELS

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***Abstract*-- An efficient technique to maximize the channel capacity of MIMO system in case of practical fading channel has been designed for efficient data transmission. Beneath pragmatic fading environment, transmitted signal suffers phase and magnitude deterioration. Hence it becomes imperative to dodge the effect of fading in any communication channel and to make an efficient system. Rayleigh fading is studied and a comparison is being made among BPSK, QPSK and 16 QAM modulation technique in Rayleigh fading environment. An efficient model is created in which data transmission can take place with least fading effect. Moreover channel capacity of MIMO system depends upon number of half wave dipole antenna used in antenna array. At small SNR values capacity increases linearly and channel matrix coefficients are studied to further optimize the channel characteristics. There are many factors which pragmatically decide the channel capacity of MIMO system like number of antenna elements at transmitting and receiving side, power fed at antenna section, channel matrix coefficients etc. In the proposed system it is proved that as number of antenna elements increases there is significant increase in channel capacity.**

***Keywords*– MIMO capacity, fading channel model, antenna array**

1. INTRODUCTION

In wireless technology biggest challenge is to overcome the effect of Rayleigh fading channel. The multipath nature of the channel leads to inter symbol interference (ISI) and as the bandwidth occupied increases, the ISI severity is pronounced. To cope with this problem of multipath channel, various techniques have been and continuously are being proposed by the researchers of system modelling. MIMO is one of the widely used such techniques. MIMO technology has evolved into a pragmatic data transmission technique which can dodge the effect of fading also up to certain percent. MIMO technology involves multiple antennas for data transmission at receiver and at transmitter side. MIMO technology has attracted attention in wireless communications, because it offers significant increases in data throughput and link range without additional bandwidth or increased transmit power. It achieves this goal by spreading the same total transmit power over the antennas to achieve an array gain that improves the spectral efficiency (more bits per second per hertz of bandwidth) and/or to achieve a diversity gain that improves the link reliability (reduced fading). Because of these properties, MIMO is an important part of modern wireless communication standards such as IEEE 802.11 b (Wi-Fi). MIMO system has large potential for maximization of channel capacity and it can perform efficiently under various fading channels. But there are many pragmatic hindrances to the efficient MIMO system. So there is a need to increase the channel capacity of MIMO system and try to formulate the techniques to reduce effect of Rayleigh and other fading [1].

2. CHANNEL MODELLING OF MIMO SYSTEM

A MIMO channel model consist of an antenna array used at transmitter and receiver. Considering the following parameters

No. of Transmitting Antenna = L

No. of receiving Antenna = N

The power radiated by single transmitting antenna= PS (regardless the value of L).

Average power at output of each receiver antenna = S

Noise at receiver is complex N dimensional AWGN with statistically independent power S_n in each of the N receiving antennas. The channel matrix H, is Rayleigh distributed with complex, zero mean and unit variance [2].

$$C=\frac{1}{2}\log_2\left(\det\left(I_n\ \frac{SNR}{L}G.G^G\right)\right) \qquad [1]$$

Where H is the channel matrix

SNR is the signal to noise ratio

L is the no. Of transmitting antenna

G^G is the hermitian transpose of the matrix G

I_N is N * N Identity matrix

For the given MIMO channel model given, using the value of overall channel matrix, the capacity of a MIMO communication system is expressed as a function of the antenna array geometry of the transmitter and receiver. The impact of antenna array geometry is modelled into the expression of the capacity by making channel matrix a function of array manifold vector. The channel matrix here depends upon the structure of the antenna array (no of elements) and the spacing within the antenna elements. The channel at time t is modelled by a nR*nT matrix. The impact of antenna array geometry is modelled into the expression of the capacity by making channel matrix a function of array manifold vector.

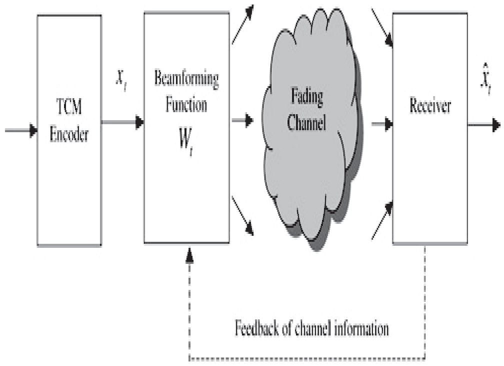

Fig.1 Block diagram a communication system

The transmitted signal vector at time t can be written as

St = W[A] t * X[B] t [2]

Where St is the transmitted vector

A is the beam forming vector

B is the encoded sequence in channel

The channel matrix here depends upon the structure of the antenna array (no. of elements) and the spacing within the antenna elements. The channel at time t is modelled by a nR * nT matrix [16].

$$H_t = \begin{pmatrix} Ht^{1,1} & & Ht^{1,nt} \\ Ht^{2,1} & \cdots & Ht^{2,nt} \\ Ht^{3,1} & & Ht^{3,nt} \\ \vdots & \ddots & \vdots \\ Ht^{nr,1} & \cdots & Ht^{nr,nt} \end{pmatrix} \quad [3]$$

Where $Ht^{j,i}$ is the channel fading coefficient from the transmit antenna i to the receive antenna j at time t.

$$r_t = Ht * s_t + n_t = H_t * w_t x_t + n_t \quad [4]$$

where rt indicates the signal received by the receiver antenna at time t and nt denotes nr* 1.

Generally In Due to multiple numbers of local multi paths fast fading (Rayleigh fading) there will be interference at the receiver, although the received signals from different transmitters will follow different paths to reach receiver but during their travel they superimpose over a dominant signal and causes interference. There will be three cases depending on antenna elements in antenna array [3].

3.ANTENNA ELEMENTS vs CHANNEL CAPACITY

According to Gauss-Markov Model capacity of a MIMO system channel capacity is given by

$$C = \frac{1}{2}\log_2(\det\left(I_n + \frac{SNR}{L} G.G^G\right)) \quad [5]$$

and Gauss-Markov equation can also be written as

C=x + log(1+log(1+SNR)) [6]

where x is an asymptotic parameter.

It is evident from Eq.6 that with increase of SNR values, channel capacity of MIMO system increases. For three different antenna array system is designed to obtain channel capacity apropos Shannon theorem. MIMO system have the capability to obtain higher channel capacity more than what theoretical given by Shannon Hartley theorem [4].

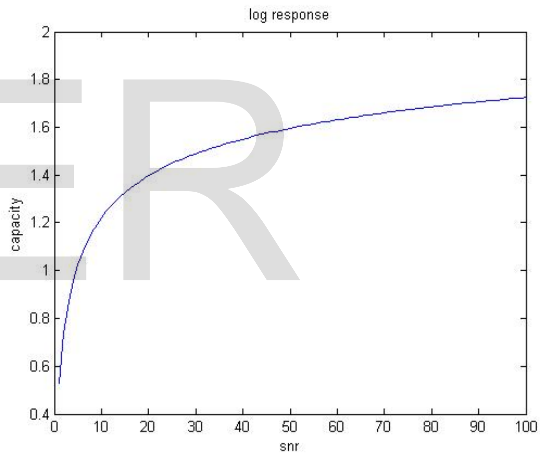

Fig.2 Plot of Gauss-Markov capacity equation showing Capacity variation with SNR.

Capacity linearly increases with increase in SNR (at low values) and logarithmically increases at high SNR.

3.1 Antenna array of 8 element

For 8 antenna elements, putting different values of SNR in Eq.3.3 a curve is obtained for antenna elements and Fig.3 Channel capacity of MIMO system and Shannon capacity for 8 antenna elements. Figure.3 gives channel capacity of MIMO systems, when SNR is varied .This graph also depicts the results for antenna array consisting of 8 half wave dipoles. MIMO system channel capacity at SNR 10 db is 22.5 bits/ Hz whereas theoretical capacity capacity given by Shannon theorem is 4 bits/Hz. This figure also provides information regarding capacity for low SNR and high SNR. At low SNR values capacity increases linearly with SNR values, but at high SNR values capacity increases logarithmically with SNR values. It is also evident that there is stark difference between Shannon`s capacity and and practical MIMO system .SISO system channel capacity might agree with Shannon`s theorem results [5][6].

3.2 Antenna array of 16 element

For 16 antenna elements in an antenna array and putting different values of SNR in eq.5.1 a curve is obtained for channel capacity of MIMO system and a comparison is also made between theoretical channel capacity of frivolous system and practical MIMO system.

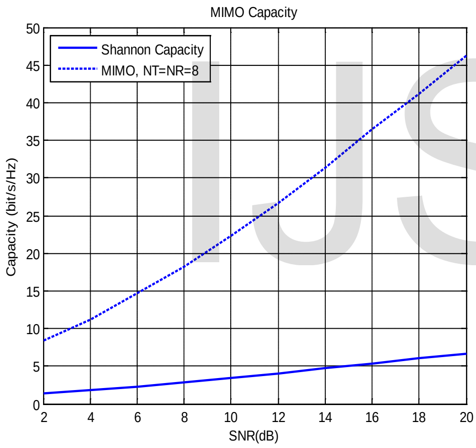

Fig 3 Plot showing Channel capacity of MIMO system and Shannon capacity for 8 antenna elements

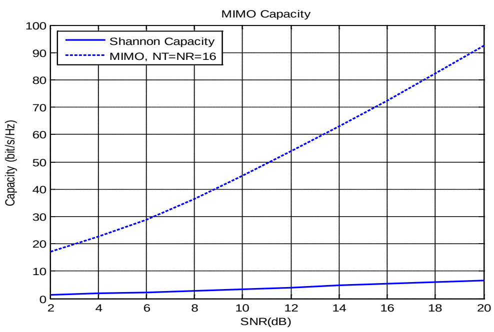

Fig.4 Channel capacity of MIMO system and Shanno capacity for 16 antenna elements.

3.3 Antenna array of 32 elements

For 32 antenna elements in an antenna array and putting different values of SNR in eq.5.1 a curve is obtained for channel capacity of MIMO system and a comparison is also made between theoretical channel capacity of frivolous system and practical MIMO system.

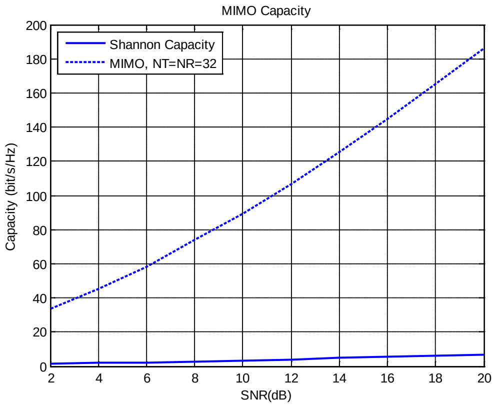

Fig.5 Plot showing Channel capacity of MIMO system and Shannon capacity for 32 antenna elements.

3.4 Comparison of different antenna elements

Referring fig 3, fig 4 and fig 5 it can be concluded that as no. of antenna elements increases , there is stark increase in the channel capacity of MIMO system and when this channel capacity is compared with Shannon`s capacity , it become clear that MIMO system employs such techniques which increases capacity as compared to theoretical values. When the above three figures are plotted in one figure showing the effect of SNR, channel capacity and number of antennas used in each antenna array.

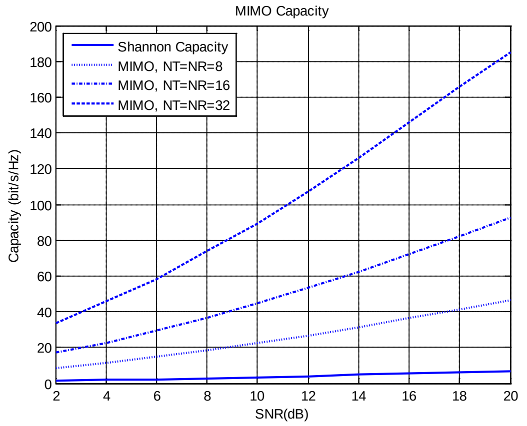

Fig. 6 comparison of various antenna array with Shannon maximum capacity

Figure 6 clearly state that to obtain maximum capacity for a MIMO system maximum number of antenna must be used at receiver and transmitter.

SNR in db	Capacity (bits/s/Hz) 8 antenna elements	Capacity (bits/s/Hz) 16 antenna elements	Capacity (bits/s/Hz) 32 antenna elements
2	9	18	34
4	11	22	45
6	14	30	55
8	18	36	75
10	23	45	90
12	28	53	110
14	32	61	128
16	36	70	148

Table 1 Table showing channel capacity for SNR values for different antenna array.

Above table presents a succinct for the channel capacity of a MIMO system in which three antenna arrays of 8, 16 and 32 half wave dipoles are considered. Referring Figure 6 it is evident that at smaller SNR values, capacity increases linearly but at high SNR values Channel Capacity varies logarithmically. In case of 8 half wave dipoles capacity is 23bits/s/Hz at SNR of 10 db , but in case of 16 half wave dipoles capacity is 45 bits/s/Hz at SNR of 10 db , but in case of 32 half wave dipoles capacity is 90 bits/s/Hz at SNR of 10, proving our results.

CONCLUSION

A study of Rayleigh fading on the transmitted signal in MIMO system is undertaken beneath various modulation technique and a pragmatic model is considered to increase the channel capacity of practical MIMO system in fading environment. It is observed that the channel capacity of MIMO system depends upon SNR of the transmitted signal and number of antenna elements in antenna array. Increasing half wave dipoles in antenna array linearly increases the channel capacity. BPSK modulation technique comes out to be more efficient in Rayleigh. Among Rayleigh, Gaussian and AWGN channel, Rayleigh is the worst case fading. Hence multiple antenna increases channel capacity.

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