



## Channel Estimation of Various Communication System with Different Modulation Technique

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**Abstract**—In this paper, we have measured channel capacity for various communication system such as SISO, SIMO, MIMO with different modulation technique like BPSK, QPSK, 16-QAM and 64-QAM. In the proposed algorithm the Bit Error Rate (BER) is less compared to conventional algorithm. The proposed algorithm is suitable for fast speed traffic that is when the speed of the mobile is very high. We have measured the channel variation and based on that bit error rate is calculated. Here, in this paper we have applied the Maximum Ratio Combining technique.

**Keywords**—Bit Error Rate(BER), Maximum Ratio Combining(MRC), Multiple Input Multiple Output(MIMO), Multiple Input Single Output(MISO), Single Input Multiple Output(SIMO), Single Input Single Output(SISO), Signal to Noise Ratio(SNR), Binary phase shift key( BPSK), Quadrature phase shift key(QPSK), 16-ary Quadrature Amplitude Modulation( 16-QAM), 64-ary Quadrature Amplitude Modulation( 64-QAM),

### I. INTRODUCTION

Communicating data from one location to another requires some form of pathway or medium. This medium is called communication channel. Channel use two types of media: Cable (Twisted pair wire, cable, fiber optic) and Broadcast(microwave, Satellite, radio, Infrared). Channel Capacity is the tightest upper bound on the rate of information that can be reliably transmitted over a communication channel.

Let X and Y be the random variables representing the input and output of the channel respectively. Let  $Y/X(y/x)$  be the conditional distribution function of Y given X, which is an inherent fixed property of the communication channel. Then the choice of the marginal distribution  $P_X(x)$  completely determine the joint distribution [11]

$$P_{X,Y}(x,y)=P_{Y/X}(y/x)P_X(x) \quad (1)$$

Which in turn, induces a mutual information  $I(X;Y)$ . The channel capacity is defined as

$$C = \sup_{P_X(x)} I(X;Y) \quad (2)$$

Where the Supremum is taken over all possible choices of  $P_X(x)$  [11]

In wireless communication, fading is deviation of the attenuation affecting a signal over certain propagation media. The fading may vary with time, geographical position or radio frequency. and is often modeled as a random process. In wireless system, fading may either be due to multipath propagation, referred to as multipath induced fading, or due to shadowing from obstacles affecting the wave propagation, sometimes referred to as shadow fading. The presence of reflectors surrounding a transmitter and receiver create multiple paths that a transmitted signal can traverse. As a result, the receiver sees the superposition of multiple copies of the transmitted signal, each traversing different paths. Each signal copy will experience differences in attenuation, delay and phase shift while travelling from the source to the receiver. This can result in either constructive or destructive interference, amplifying or attenuating a signal power seen at the receiver. Strong destructive interference is frequently referred to as a deep fade and may result in temporary failure of communication due to a severe drop in the channel signal to noise ratio. So, Diversity is a way to protect against deep fades.

Diversity combats fading by providing the receiver with multiple uncorrelated replicas of the same information bearing signal. In this paper, we have used space diversity. Techniques applied to combine the multiple received signals of a diversity reception device in to a single improved signal is Selection combining(SC), Feedback or Scanning combining(FC or SC), Maximum ratio combining(MRC), Equal gain combining(EGC), Zero forcing(ZF), Minimum mean square error(MMSE). Here MRC is used as a combining method to improve performance in a noise limited communication system where AWGN and fading are independent among the diversity branches.

In MRC, all paths are cophased and summed with optimal weighting to maximize combiner output SNR. A means of combining the signals from all receiver branches so that signals with a higher received power have a larger influence on the final output. In MRC, combining technique needs summing circuits, weighting and co-phasing. The signal from different diversity branches are co-phased and weighting before summing or combining. The weights have to be chosen as proportional to the respective signals level for maximizing the combined carrier to noise ratio(CNR). The applied weighting to the diversity branches has to be adjusted according to the SNR. For maximizing theSNR and minimizing the probability of error at the output combiner, signal of  $d^{\text{th}}$  diversity branch is weighted before making sum with others by a factor  $C_d^*/\sigma_{nd}^2$ . Where  $\sigma_{nd}^2$  is noise variation of diversity branch  $d^{\text{th}}$  and  $C_d^*$  complex conjugate of channel gain. As a result the phase shifts are compensated in the diversity channels and the signals coming from strong diversity branches which have low level noise are weighted more comparing to the signals from the weak branches with high level of noise. The term  $\sigma_{nd}^2$  in weighting can be neglected conditioning that  $\sigma_{nd}^2$  has equal value for all  $d$ . then realization of the combiner needs the estimation of gain in complex channel and it does not need any estimation of the power of noise.

## II. TYPES OF COMMUNICATION TECHNIQUE

The simplest form of radio link can be defined in MIMO terms as SISO - Single Input Single Output. This is effectively a standard radio channel - this transmitter operates with one antenna as does the receiver. There is no diversity and no additional processing required. The advantage of a SISO system is its simplicity. SISO requires no processing in terms of the various forms of diversity that may be used. However the SISO channel is limited in its performance. Interference and fading will impact the system more than a MIMO system using some form of diversity, and the channel bandwidth is limited by Shannon's law - the throughput being dependent upon the channel bandwidth and the signal to noise ratio [6].

The SIMO or Single Input Multiple Output version of MIMO occurs where the transmitter has a single antenna and the receiver has multiple antennas. This is also known as receive diversity. It is often used to enable a receiver system that receives signals from a number of independent sources to combat the effects of fading. It has been used for many years with short wave listening / receiving stations to combat the effects of ionospheric fading and interference. SIMO has the advantage that it is relatively easy to implement although it does have some disadvantages in that the processing is required in the receiver. The use of SIMO may be quite acceptable in many applications, but where the receiver is located in a mobile device such as a cell phone handset, the levels of processing may be limited by size, cost and battery drain [6].

MISO is also termed transmit diversity. In this case, the same data is transmitted redundantly from the two transmitter antennas. The receiver is then able to receive the optimum signal which it can then use to receive extract the required data. The advantage of using MISO is that the multiple antennas and the redundancy coding / processing is moved from the receiver to the transmitter. In instances such as cell phone UEs, this can be a significant advantage in terms of space for the antennas and reducing the level of processing required in the receiver for the redundancy coding. This has a positive impact on size, cost and battery life as the lower level of processing requires less battery consumption [6].

MIMO (pronounced my-moh by some and me-moh by others), is the use of multiple antennas at both the transmitter and receiver to improve communication performance. It is one of the several forms of smart antenna technology. Note the terms input and output refer to the radio channel carrying the signal, not the devices having antennas [6]. MIMO technology has attracted attention in wireless communication 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 [6].

## III. DIVERSITY COMBINING TECHNIQUE

The capacity of wireless system in a multipath environment can be increased by diversity techniques, such as selection combining (SC), Maximum ratio combining (MRC), Equal gain combining (EGC).

### A. Maximum Ratio Combining

MRC is the most optimal linear combining technique; it is seldom implemented in a multipath fading channel because the receiver complexity for MRC is directly proportional to the number of resolvable paths (i.e. branch signals) available at the receiver.[6]

### B. Selection combining

The selection combining technique is similar to the switched combining technique except that  $N$  receivers are required to monitor instantaneous SNR at all branches. The branch with the highest SNR is selected as the output signal.[6]

### C. Equal Gain Combining

EGC is often used in practice as it offers performance comparable to the optimal MRC with much greater simplicity than MRC, thus making it hardware feasible and cost reliable. EGC applies equal weight to the receiver channels; hence no knowledge (measurement) of average channel signal to noise ratio is needed. This diversity technique is commonly used for non-coherent modulation, and is considered a good candidate for wireless applications as well.[6]

IV. MRC APPROACHED ON PROPOSED CHANNEL CAPACITY

Maximum Ratio Combining

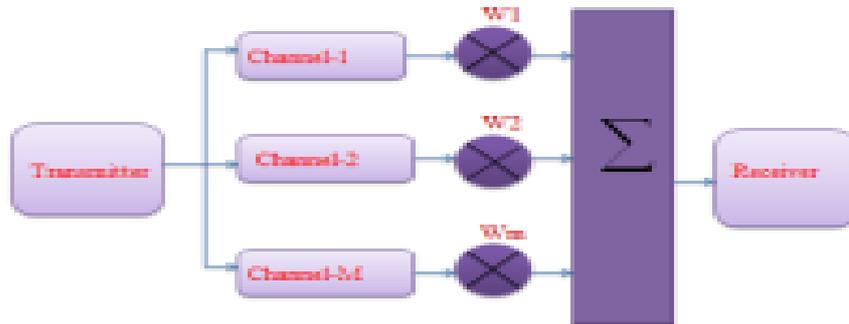


Fig. 1 Block Diagram of MRC Technique

A. AWGN channel

If the average received power is  $\bar{p}[W]$  and the noise power spectral density is  $N_0 [W/Hz]$ , the AWGN channel capacity is [10]

$$C_{avgn} = W \log \left( 1 + \frac{\bar{p}}{N_0 W} \right)_{[bits/s]} \tag{3}$$

$\frac{\bar{p}}{N_0 W}$  is the received signal to noise ratio (SNR). This result is known as the Shannon Hartley theorem.

When the SNR is large (SNR  $\gg$  0dB), the capacity  $C_{avgn} \approx W \log_2 \left( \frac{\bar{p}}{N_0 W} \right)_{[bits/s]}$  is logarithmic in power & approximately linear in bandwidth. This is called bandwidth limited regime[10].

When the SNR is small (SNR  $\ll$  0dB), the capacity  $C_{avgn} \approx \frac{\bar{p}}{N_0} \log_2 e$  is linear in power but insensitive to bandwidth. This is called the power limited regime[10].

B. Rician channel

The Rician fading channel can be described by two parameters:  $k$  and  $\Omega$  [13].

$k$  is the ratio between the power in the direct path and the power in the other, scattered, paths[14].

$\Omega$  is the total power from both paths ( $\Omega = \nu^2 + 2\sigma^2$ ), and acts as a scaling factor to the distribution.

The received signal amplitude (not the received signal power)  $R$  is then rice distributed with parameters

$\nu^2 = \frac{k}{1+k} \Omega$  and  $\sigma^2 = \frac{\Omega}{2(1+k)}$  [15]. The resulting PDF is

$$f(x) = \frac{2(k+1)x}{\Omega} \exp\left(-k - \frac{(k+1)x^2}{\Omega}\right) I_0\left(2\sqrt{\frac{k(k+1)}{\Omega}}x\right) \tag{4}$$

Where,  $I_0(\cdot)$  is the 0<sup>th</sup> order modified Bessel function of the first kind.

C. Rayleigh channel

Rayleigh fading is a reasonable model when there are many objects in the environment that scatter the radio signal before it arrives at the receiver. The central limit theorem holds that, if there is sufficiently much scatter, the channel impulse response will be well modeled as a Gaussian process irrespective of the distribution of the individual components. If there is no dominant component to the scatter, then such a process will have zero mean and phase evenly distributed between 0 to  $2\pi$  radians. The environment of the channel response will therefore be Rayleigh distributed[12]. Calling this random variable  $R$ , it will have a probability density function[12],

$$P_R(r) = \frac{2r}{\Omega} e^{-r^2/\Omega}, r \geq 0 \quad (5)$$

Where,  $\Omega = E(R^2)$

Often the gain and phase elements of a channel's distribution are conveniently represented as a complex number. In this case, Rayleigh fading is exhibited by the assumption that the real and imaginary parts of the response are modeled by dependent and identically distributed zero mean Gaussian process so that the amplitude of the response is the sum of two such processes[12]. The requirement that there be many scatters present means that Rayleigh fading can be a useful model in heavily built-up city centers where there is no line of sight between transmitter and receiver and many buildings and other objects attenuate, reflect, refract and diffract the signal[12].

#### D. Maximum ratio combining

MRC is a method of diversity combining in which:

The signals from each channel are added together. The gain of each channel is made proportional to the rms signal level and inversely proportional to the mean square noise level in that channel. Different proportionality constants are used for each channel. It is also known as ratio-squared combining and pre-detection combining. MRC is the optimum combiner for independent AWGN channels. MRC can restore a signal to its original shape.

Here, we assume that the channel is a flat fading Rayleigh multipath channel and the modulation is BPSK.

- 1) We have N receive antenna and one transmit antenna.
- 2) The channel is flat fading, it means that the multipath channel has only one tap. So, the convolution operation reduces to a simple multiplication.[7]
- 3) The channel experienced by each receive antenna is randomly varying in time. For the  $i^{\text{th}}$  receive antenna, each transmitted symbol gets multiplied by a randomly varying complex number  $h_i$ . As the channel under consideration is Rayleigh channel, the real and imaginary parts of  $h_i$  are Gaussian distributed having mean  $\mu_{h_i} = 0$  and variance

$$\sigma^2_{h_i} = \frac{1}{2}. [7]$$

- 4) The channel experience by each receive antenna is independent from the channel experienced by other receive antennas.[7]

i. On each receive antenna, the noise  $n$  has the Gaussian probability density function with

$$p(n) = \frac{1}{\sqrt{2\pi\sigma^2}} e^{-\frac{(n-\mu)^2}{2\sigma^2}} \text{ with } \mu = 0 \text{ and } \sigma^2 = \frac{N_0}{2}. \quad (6)$$

The noise on each receive antenna is independent from the noise on the other receive antenna.[7]

- 5) At each receive antenna, the channel  $h_i$  known at the receiver.[7]

- 6) In the presence of channel  $h_i$ , the instantaneous bit energy to noise ratio at  $i^{\text{th}}$  receive antenna is  $\frac{|h_i|^2 E_b}{N_0}$  for rotational convenience, let us define,

$$\gamma_i = \frac{|h_i|^2 E_b}{N_0} \quad (7)$$

Here, on the receiver antenna, the received signal is,

$$y_i = h_i x + n_i \quad (8)$$

$y_i$  = received symbol on the  $i^{\text{th}}$  receive antenna

$h_i$  = channel on the  $i^{\text{th}}$  receive antenna

$x$  = transmitted symbol

$n_i$  = noise on  $i^{\text{th}}$  receive antenna

Expressing it in matrix form, the received signal is,  $y = hx + n$  where,

$y = [y_1 y_2 \dots y_N]^T$  is the received symbol from all the received antenna.

$h = [h_1 h_2 \dots h_N]^T$  is the channel on all the receive antenna

$n = [n_1 n_2 \dots n_N]^T$  is the noise on all the receive antenna

$x$  = is transmitted symbol

The equalized symbol is,

$$\hat{x} = \frac{h^H y}{h^H h} = \frac{h^H h_x}{h^H h} + \frac{h^H n}{h^H h} = x + \frac{h^H n}{h^H h} \quad (9)$$

It is intuitive to note that the term,  $h^H = \sum_{i=1}^N |h_i|^2$  i.e. sum of the channel powers across all the receive antennas.[7]

#### E. Effective $E_b / N_0$ with MRC

In the presence of channel  $h_i$  the instantaneous bit energy to noise ratio at  $i^{\text{th}}$  receive antenna is

$$\gamma_i = \frac{|h_i|^2 E_b}{N_0} \quad (10)$$

Given that we are equalizing the channel with  $h^H$ , with the N receive antenna case, the effective bit energy to

$$\gamma_i = \sum_{i=1}^N \frac{|h_i|^2 E_b}{N_0} \quad (11)$$

$$\gamma = N\gamma_i \quad (12)$$

Effective bit energy to noise ratio in a N receive antenna case is N times the bit energy to noise ratio for single antenna case[8].

#### F. Bit Error Rate with MRC

We know that, if  $h_i$  is a Rayleigh distributed random variable then  $h_i^2$  is a chi-squared random variable with two degrees of freedom. The pdf of  $\gamma_i$  is

$$p(\gamma_i) = \frac{1}{(E_b/N_0)} e^{\frac{-\gamma_i}{(E_b/N_0)}} \quad (13)$$

Since the effective bit energy to noise ratio  $\gamma$  is the sum of N such random variables, the PDF of  $\gamma$  is a chi-squared random variable with 2N degrees of freedom. The pdf of  $\gamma$  is

$$p(\gamma) = \frac{1}{(N-1)(E_b/N_0)^N} \gamma^{N-1} e^{\frac{-\gamma}{(E_b/N_0)}}, \gamma \geq 0 \quad (14)$$

BER computation in AWGN, with bit energy to noise ratio of  $\frac{E_b}{N_0}$ , the bit error rate for BPSK in AWGN derived as,

$$P_b = \frac{1}{2} \operatorname{erfc} \left( \sqrt{\frac{E_b}{N_0}} \right) \quad (15)$$

Given that the effective bit energy to noise ratio with MRC is  $\gamma$ , the total bit error rate is the integral of the conditional BER integrated over all possible values of  $\gamma$  [8].

$$P_e = \int_0^{\infty} \frac{1}{2} \operatorname{erfc}(\sqrt{\gamma}) p(\gamma) d\gamma \quad (16)$$

$$P_e = \int_0^{\infty} \frac{1}{2} \operatorname{erfc}(\sqrt{\gamma}) \frac{1}{(N-1)(E_b/N_0)^N} \gamma^{N-1} e^{\frac{-\gamma}{(E_b/N_0)}} d\gamma \quad (17)$$

This equation reduces to

$$P_e = p^N \sum_{k=0}^{N-1} (N-1+k)(1-p)^k \quad (18)$$

$$P_e = \frac{1}{2} - \frac{1}{2} \left( 1 + \frac{1}{(E_b/N_0)} \right)^{-\frac{1}{2}} \quad (19)$$

## V. SIMULATION RESULTS

### A. BER V/S SNR for SISO and SIMO system with BPSK Modulation Technique

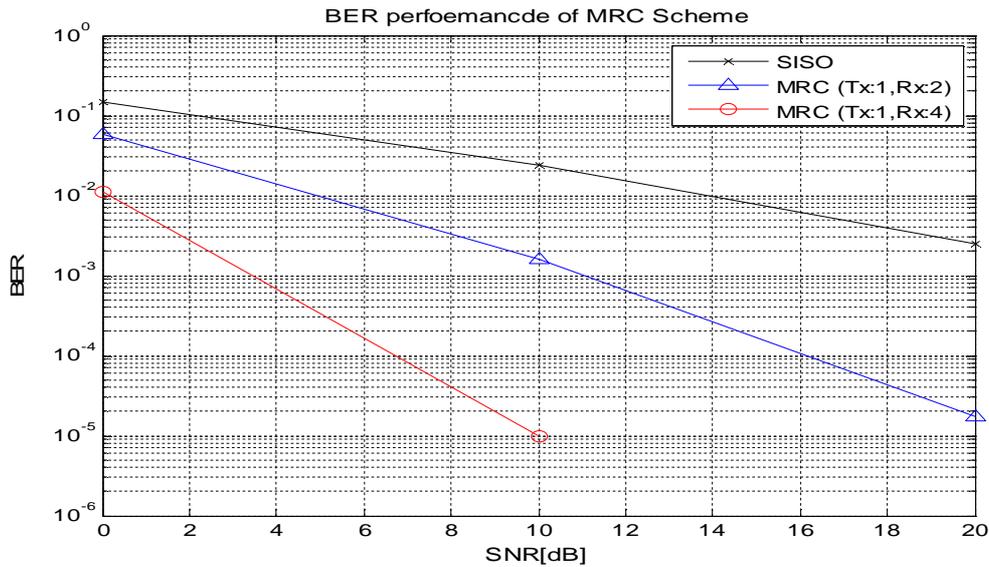


Fig. 2 BER V/S SNR for SISO and SIMO with BPSK Modulation Technique

Figure 2 shows the bit error rate performance of SISO and SIMO system with BPSK modulation technique. From figure 2, it is seen that at SNR 10 dB, the value of BER for SISO system is around  $10^{-2}$  and for SIMO (one transmitter antenna and two receiver antenna) system BER is around  $10^{-3}$  and  $10^{-5}$  for SIMO with one transmitter antenna and four receiver antenna.

So, from figure 2, we say that as the number of antenna is increased the BER is reduced and performance of the overall system is better.

### B. BER V/S SNR for SISO and SIMO system with QPSK Modulation Technique

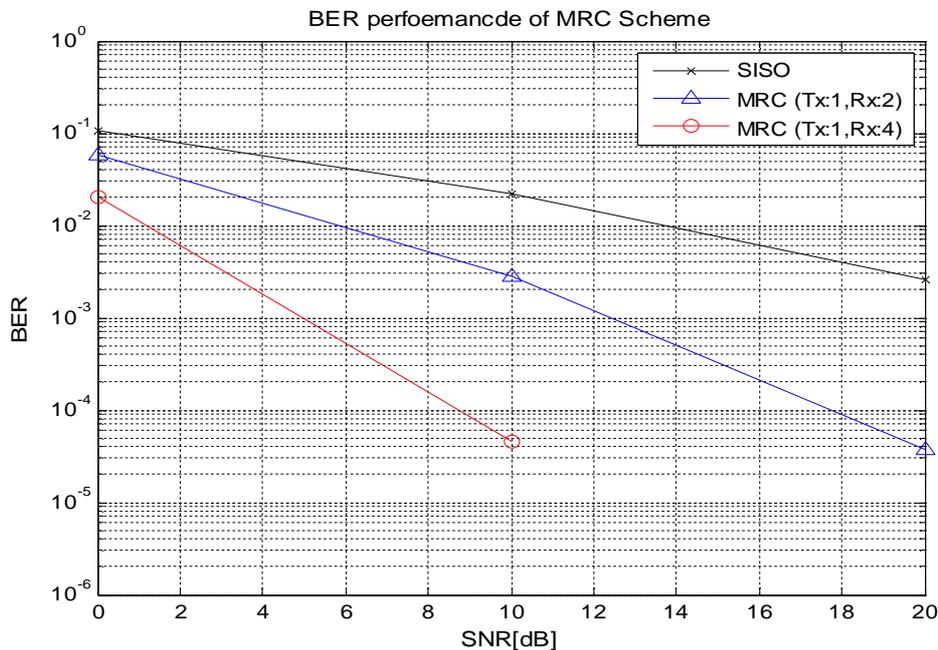


Fig. 3 BER V/S SNR for SISO and SIMO with QPSK Modulation Technique

Figure 3 shows the bit error rate performance of SISO and SIMO system with QPSK modulation technique. From figure 3, it is seen that at SNR 10 dB, the value of BER for SISO system is around  $10^{-2}$  and for SIMO (one transmitter antenna and two receiver antenna) system BER is around  $10^{-3}$  and  $10^{-5}$  for SIMO with one transmitter antenna and four receiver antenna.

So, from figure 3, we say that as the number of antenna is increased the BER is reduced and performance of the overall system is better.

### C. BER V/S SNR for SISO and SIMO system with 16-QAM Modulation Technique

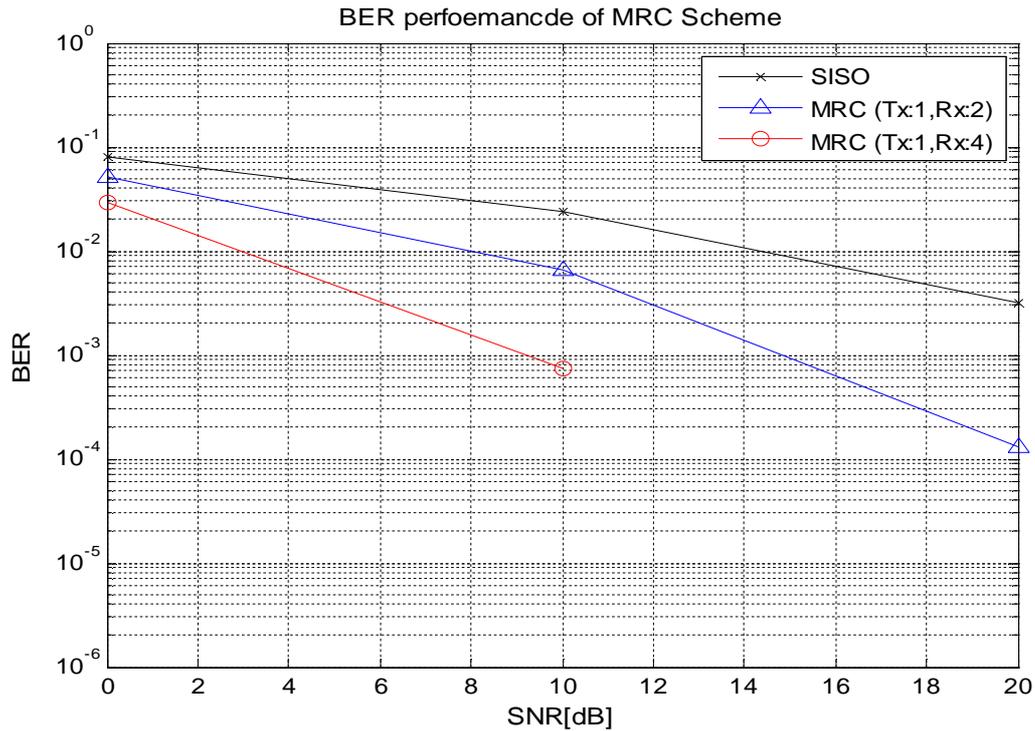


Fig. 4 BER V/S SNR for SISO and SIMO with 16-QAM Modulation Technique

Figure 4 shows the bit error rate performance of SISO and SIMO system with 16-QAM modulation technique. From figure 4, it is seen that at SNR 10 dB, the value of BER for SISO system is around  $10^{-1}$  and for SIMO (one transmitter antenna and two receiver antenna) system BER is around  $10^{-2}$  and  $10^{-3}$  for SIMO with one transmitter antenna and four receiver antenna. So, from figure 4, we say that as the number of antenna is increased the BER is reduced and performance of the overall system is better. Compared to figure 2 (BPSK) and figure 3 (QPSK) bit error rate in figure 4 (for 16-QAM) is high because as M-ary number increased bit error rate is also increased.

D. BER V/S SNR for SISO and SIMO system with 64-QAM Modulation Technique

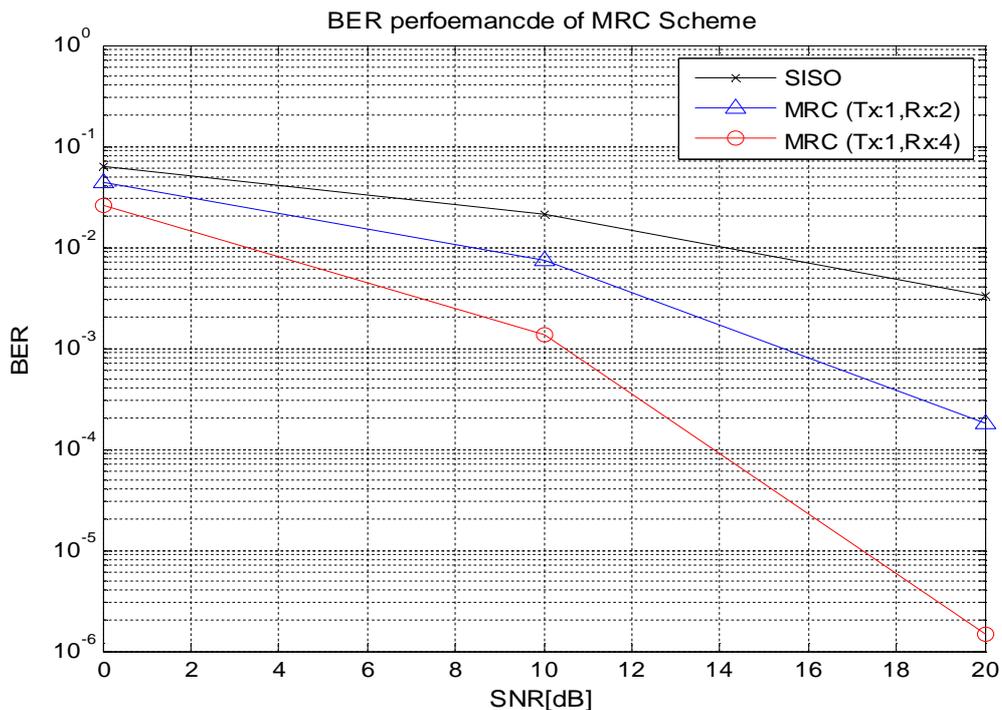


Fig. 5 BER V/S SNR for SISO and SIMO with 64-QAM Modulation Technique

Figure 5 shows the bit error rate performance of SISO and SIMO system with 64-QAM modulation technique. From figure 5, it is seen that at SNR 10 dB, the value of BER for SISO system is around  $10^{-1}$  and for SIMO (one transmitter antenna and two receiver antenna) system BER is around  $10^{-2}$  and  $10^{-3}$  for SIMO with one transmitter antenna and four receiver antenna. So, from figure 4, we say that as the number of antenna is increased the BER is reduced and performance of the overall system is better. Compared to figure 2 (BPSK) and figure 3 (QPSK) bit error rate in figure 5 (for 64-QAM) is high because as M-ary number increased bit error rate is also increased.

E. BER V/S SNR for MIMO system with 8-transmitter and 12-receiver antenna

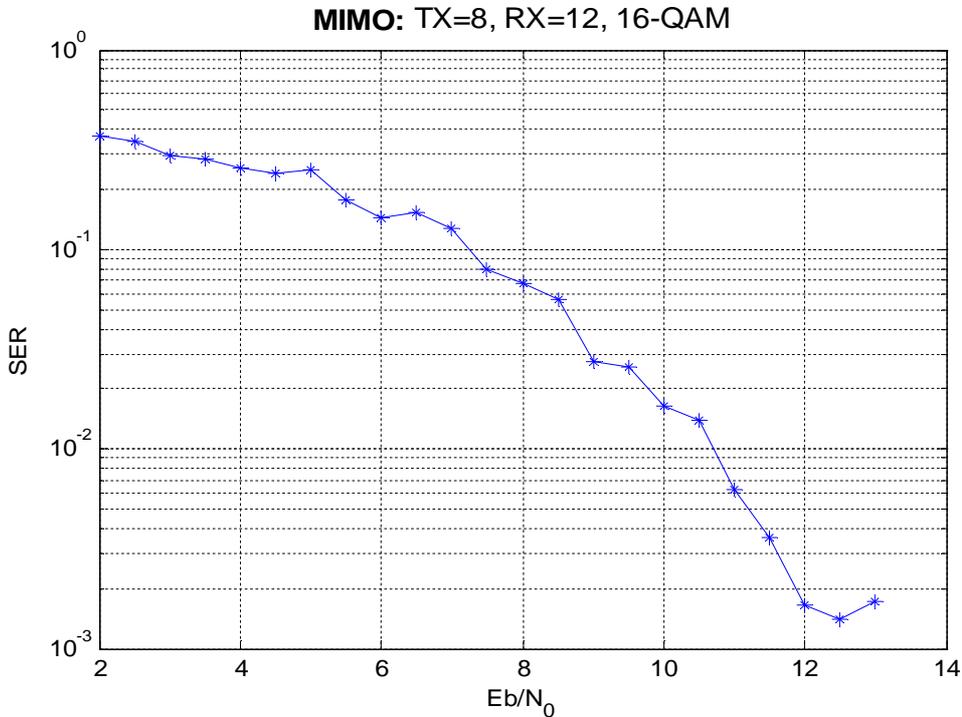


Fig. 6 SER (Symbol Error Rate) V/S SNR for MIMO with 8-transmitter and 12-receiver antenna

From figure 6, it is seen that as the SNR increased SER decreased. In figure 6, we have taken 8-transmitter and 12-receiver antenna. From figure 6, we say that at SNR 10 dB the value of SER is around  $10^{-2}$  and BER is very less.

F. Channel Capacity V/S SNR for MRC Technique

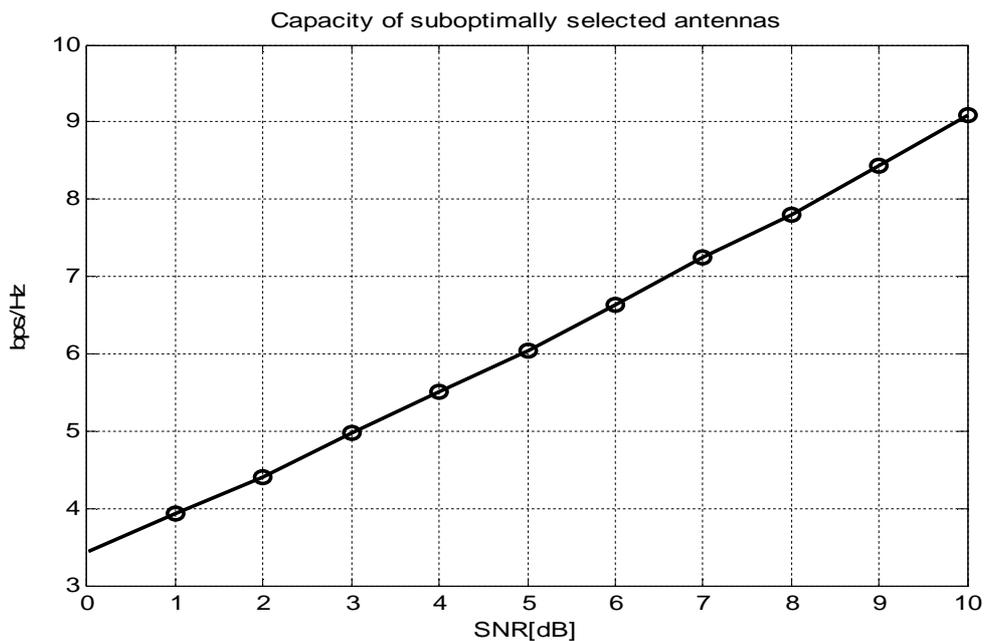


Fig. 7 Channel Capacity V/S SNR for MRC Technique

From figure 7, it is seen that as SNR increased the channel capacity is also increased. As we increased the number of antenna the channel capacity is also increased.

## VI. CONCLUSION

In this paper, we have measured channel capacity for various communication system such as SISO, SIMO, MIMO with different modulation technique like BPSK, QPSK, 16-QAM and 64-QAM. In the proposed algorithm the Bit Error Rate (BER) is less compared to conventional algorithm. As we increased the number of antenna as both transmitter and receiver side the BER is decreased. It is also conclude that as we increased the number of antenna the channel capacity is also increased. The proposed algorithm is suitable for fast moving vehicle as well as for more fading environment.

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