# Channel Capacity Comparison of MIMO Systems with Rayleigh Distribution, Rician Distribution, Nakagami-M Distribution and Weilbul Distribution

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***Abstract-* (MIMO) multiple input and multiple output** system have potential to achieve very high capacities, depending on the propagationenvironment.This paper represents the MIMO channel capacity over Rician fading, Rayleigh fading, Nakagamifading,Weibull fading channel.This paper analyses and simulate the behaviour of MIMO system and its capacity of channel under different fading distributions. In order to maximize the channel capacity Waterfilling Model is implemented. For simulation MATLAB software is used.

***Keywords-*** MIMO, fading, Rayleigh distribution, Rician distribution, Nakagami-M distribution, Weibull distribution.

## I. INTRODUCTION

During the past decade, Wireless Communications and especially mobile communication systems have grown considerably. Multiple input multiple output (MIMO) systems specify any wireless communication system where multiple antennas are used at both sides of communication channel. So the systems that use more than one transmit and receive antenna are called as multiple input multiple output (MIMO) systems. This wireless technology enormously enhances the capacity and the range of a wireless communication system. It also reduces the bit error rate. The channel between the transmitter and receiving antenna of MIMO system is defined with a channel matrix. Channel gains among transmitter and receiver antenna combinations are the elements of MIMO channel matrix. Uncertainty in the system is generally increased by multipath environment. Antenna array utilized at the receiver, number of elements in the array, statistical properties and the spacing present between the antenna elements are the factors on which system is dependent. These multiple paths only used to create interference in other systems. MIMO can use these additional paths as an additional advantage. It can be applied to give further robustness to the radio link by battering the SNR (signal to noise ratio), or by enhancing the link data capacity. Fading decrease the performance of arrangement due to error rate but MIMO behave freely over different fading channels. It has latency for the enhancement of channel capacity. This technology has great advantage because of its use in digital television (DTV), wireless local area networks (WLANs), metropolitan area networks (MANs), and mobile communication. MIMO is an essential element of wireless communication standards comprising: IEEE802.11ac(Wi-Fi), IEEE802.11n(Wireless Fidelity), HSPA +(3G) World Wide Interoperability for Microwave Access (4G), and LTE (4G). Home plug AV2 specification and power-line communication for 3wire installations as a part of ITU-G standard are the recent area where it has been used. In adequate MIMO system there are some logical obstructions so it is necessary to enhance the channel capacity between transmitter and receiver of multiple input multiple output system and to develop the techniques to decrease fading effects.

## II. MATHEMATICAL MODEL OF MIMO SYSTEM

The general MIMO system is shown in Fig. 1 with NT transmitter antennas and NR receiver antennas. The signal model represented as:

$$r = Hx + n \qquad (1)$$

where r is (NR x 1) received signal vector, x is (NT x 1) transmitted signal vector, n is (NT x 1) complex additive white Gaussian noise (AWGN) vector with variance σ, and H is the (NR x NT) channel matrix. The channel matrix H represents the effect of the medium on the transmitter –receiver links. The channel matrix H can be represented as,

$$H = \begin{bmatrix} h11 & \cdots & h1NT \\ & & \\ hNR1 & \cdots & hNRNT \end{bmatrix} (2)$$
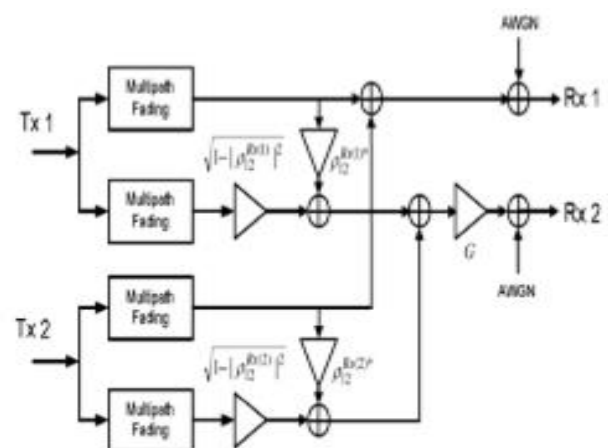


Fig.1: General Diagram of MIMO system

Channel matrix can endeavor K corresponding coordinate auxiliary medium with distinct mean gains, where $K=rank(HH^H)\leq min(NTNR)$         (3)

To determine the consequences of channel matrix H on the capacity, Singular value decomposition (SVD) simplification may be used. So, channel matrix H can be represented as:

$$H=PQR^H \qquad (4)$$

The elements of the unit matrix P (AT x AR) consists of the Eigen vectors of $HH^H$ and the elements of the unitary matrix R (AT x AT) consists of the Eigen vectors of $HH^H$. The diagonal matrix Q (AR x AT) contain elements that are positive and have real value which is known as singular values, equivalent to the Eigen values λ of $HH^H$ square root. Suppose that the channel is familiar at both transmitter and receiver (full or prefect channel sensing information CSI) so the maximal normalized capacity as for bandwidth in terms of b/s/Hz spectrum efficiency of coordinate auxiliary medium equals to :

$$C=\sum_{i=1} \log_2 (1+\lambda_i P_i/\sigma_N^2) \qquad (5)$$

Here pi is the power designate to all sub channel i and can be resolved to enhance the capacity by using water filling theorem so that all sub channel is filled with appropriate level E :

$$1/\lambda_i + P1 +\ldots\ldots+1/\lambda_k + P_k = E \qquad (6)$$

Or

$$P_i= L -1/\lambda i \qquad (7)$$

So that it meets the following specification that the total transmitted power is equal to the addition of all power of sub channels or:

$$\sum_{i=1}^{k} P_i= P_{TX}$$

And if $1/\lambda i > E$ then $P_i$ is set to zero.

A brief overview of random distribution used in this work is as following:

## RICIAN DISTRIBUTION:
This distribution is appropriate to use when there is a direct line of sight(LOS) between transmitter and receiver, thus there will be an LOS signal component in received signal due to multipath. The density function for this distribution is given by:

$$f(x) =\frac{x}{b^2} e^{\left(\frac{((-x^2+s^2)}{2b^2}\right)} I_0\left(\frac{xs}{b^2}\right)$$
                                (9)

The zero order $I_0$ is first type modified Bessel function, s (s ≥ 0) is non-centrality parameter and b (b > 0) is scale parameter. This type of distribution is used to create the channel matrix as well as to calculate the relevant capacity for the system:

$$H_{Rician}= \begin{matrix} \square 11 \ldots & \square 1NT \\ \square NR1 \ldots & \square NRNT \end{matrix} \qquad (10)$$

## RAYLEIGH DISTRIBUTION:
The Rayleigh fading model uses a statistical approach to analyses the propagation, and can be used in a number of environments. In this fading model the signal is fade according to Rayleigh distribution. The received signal envelope distribution where all the components are non-line of sight describes by Rayleigh fading. Rayleigh fading basic model assumes a received multipath signal to subsist of a large number of reflected waves with independent and identicallydistributed in phase and quadrature amplitudes. Rayleigh distribution is a special case of Weibull distribution. The Rayleigh distribution is given by:

$$f(x)= \frac{r}{b^2} e\left(-\frac{x2}{2b2}\right) \qquad (11)$$

The Rayleigh distribution is used to generate the channel capacity and determine the related capacity of the system:

$$HRayleigh = \begin{matrix} h11 \ldots & h1NT \\ hNR1 \ldots & hNRNT \end{matrix} \qquad (12)$$

## NAKAGAMI-M DISTRIBUTION:
Nakagami-m distribution is a probability distribution relevant to gamma distribution.   In the field of wireless communication, to represent statistical fading of the multipath environments, Nakagami-M distribution is other major distribution that is used and that is established through empirical evaluation. The probability density function for Nakagami-m is given by:

$$f(x)=\frac{2m^m x^{2m-1}}{\Gamma(m)\Omega^m} e^{-\frac{mx^2}{\Omega}} =\frac{2x^{2m-1}}{\Gamma(m)}\left(\frac{m}{\Omega}\right)^m e^{-\frac{mx^2}{\Omega}} \qquad (13)$$

Where $\square$ is the second moment and represent the scale parameter, m (m ≥ 0.5) is known as the Nakagami fading parameter or shape parameter, and Γ(.) is the standard Gamma function. The Nakagami-m distribution covers a wide range of fading conditions; when m=0.5 it is a one-sided Gaussian distribution and when m=1, it is a Rayleigh distribution and when m < 1, the Nakagami model applies a fading scenario that is more severe than Rayleigh fading.

The Nakagami-m distribution is used to generate the channel matrix and determine the related capacity for the capacity for the system:

$$HNakagami= \begin{matrix} h11 & h1NT \\ hNR1 & hNRNT \end{matrix} \qquad (14)$$

## WEIBULL DISTRIBUTION:
The Weibull distribution is mainly used in both indoor and outdoor environments. The probability density function for Weibull distribution is given by:

$$f(x) = \frac{k}{\lambda}\left(\frac{x}{\lambda}\right)^{k-1} e^{-\left(\frac{x}{\lambda}\right)^k} \qquad (15)$$

The Weibull distribution is availed to develop the channel matrix and to find out the relevant capacity for the system.

$$\text{HWeilbull} = \begin{matrix} h11 \ldots & h1NT \\ hNR1 \ldots & hNRNT \end{matrix} (16)$$

## III. SIMULATION RESULTS

In this paper, MATLAB m-file is used to verify the model and simulate the effect of various types of distribution(Rician, Rayleigh, Nakagami-M and Weibull) for a MIMO system under flat fading to generate channel matrix.

### A. RICIAN DISTRIBUTION

The capacity of MIMO arrangement in terms of bits/sec/Hz is determined under Rayleigh distribution for eight transmitter and receiver antennas over the range of -10dB to 40dB SNR. The results in the Figure. 2 shows the deviation of capacity with number of antennas used. The capacity of MIMO system is enhancing with the number of antennas used in transmitter and receiver side.
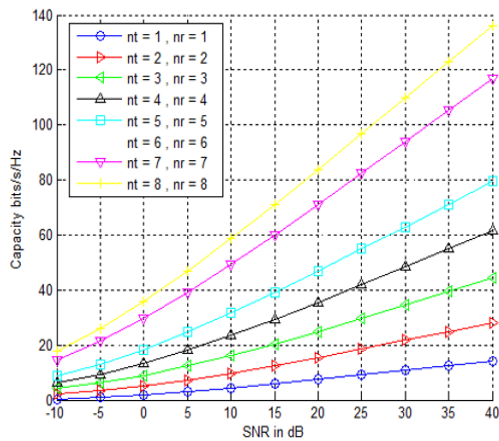


Fig.2: Capacity of MIMO system over Rician distribution

### B. RAYLEIGH DISTRIBUTION:

In terms of bits/sec/Hz the capacity of MIMO system is determined under Rayleigh distribution for eight transmitter and receiver antennas over the range of -10dB to 40dB SNR. The results in the Figure.3 shows the deviation of capacity with number of antennas used. For eight antennas unique marker colors and marker symbols are used.
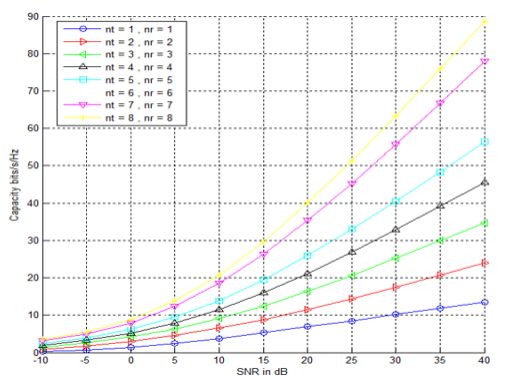


Fig.3: Channel capacity of MIMO system over Rayleigh distribution

Comparing with results in Fig. 2, the capacity with Rayleigh distribution is lower in the value comparing to that with Rician distribution.

### C. NAKAGAMI-M DISTRIBUTION:

The capacity of MIMO system in terms of bits/sec/Hz is determined under Nakagami-M distribution for eight transmitter and receiver antennas over the range of -10dB to 40dB SNR. The results in the Figure.4 shows the deviation of capacity with number of antennas used.
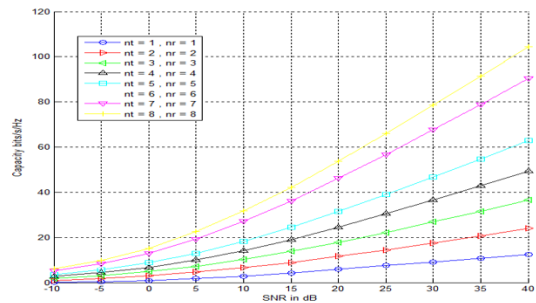


Fig.3: Channel capacity of MIMO system over Nakagami-M distribution

Fig.5 shows that the capacity is increasing function to the number of antennas in both transmitter and receiver sides.

### D. WEIBULL DISTRIBUTION:

The capacity of MIMO system in terms of bits/sec/Hz is calculated under Weibull distribution for eight transmitter and receiver antennas over the range of -10dB to 40dB SNR. The results in the Figure.5 shows the deviation of capacity with number of antennas used.
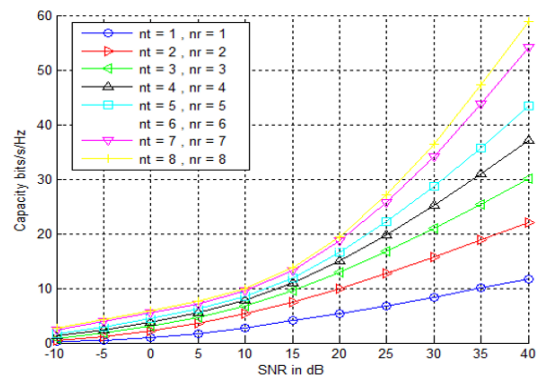


Fig.5: Channel capacity of MIMO system over Weibull distribution

## IV. CONCLUSION

The obtained results give an inspection to influence of the distribution selection over the capacity of MIMO system estimation and led the better understanding of each distribution and how it can be used in different environments. In this paper waterfilling model is used to analyze the performance of 8x8 MIMO system. We studied 8x8 MIMO system over Rayleigh, Rician, Weibull and Nakagami-M fading channel which give us enhanced capacity. The capacity can also be more enhanced by increasing number of antennas

at transmitter and receiver side of MIMO system. The MIMO system has greater capacity over Rician fading channel and lesser over Weibull fading channel within same SNR. At low SNR capacity enhances linearly but with high signal-tonoise-ratio(SNR) it enhances logarithmically. It is also shown that if number of antennas will increased at transmitter and receiver side, intersymbol interference will increase.

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