Design and BER Performance Analysis of MIMO and Massive MIMO Networks under Perfect and Imperfect CSI

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Abstract— **With upcoming 5G networks, higher data rate and higher capacity are required for a commercial wireless communication system. This has attracted huge interest and formed a substantial research challenge in the context of the emerging WLANs and many multimedia networks. After sternly affecting bit error rate of communication system, multipath fading in wireless communication system also gives weak signal strength. Multi input- multi output (MIMO) and Massive MIMO system is used to overcome this drawback. Multiple antennas are used to gives a higher data rate, higher transmit and receive diversity through spatial multiplexing in a wireless communication system. On the other hand, massive MIMO technology allows expo-sure to numerous users in the same time-frequency block with the help of the base station having a large number of antennas. This research paper presents the salient features of MIMO and massive MIMO networks and investigates its BER performance under AWGN (white Gaussian noise) and Rayleigh fading communication channel under the effects of perfect and imperfect channel state information (CSI) modes, along with the consideration of trials and prospects.**

Keywords— 5G networks, MIMO, massive MIMO, BER, AWGN, CSI, Imperfect CSI

I. INTRODUCTION

In radio, a bulk of radio connection is done for the achievement of multipath propagation the method of multiplication of transmissions and receiving antennas. Different types of Wi-Fi networks, 3G, 4G and extensive time process are the main focus for the development of wireless communication standards included. For the past few year developments of MIMO has played a vital role. In addition, new technologies are needed to be upgraded to empower MIMO to be fully implemented along with the basic concepts which are required to be conveyed. Spatial multiplexing along with the spatial diversity gain [2] are allowed to present the new levels of dispensation and structures. To get the high-grade signal combination of signal and switching between the antenna was done till the late 90s which was limited by spatial diversity. But the system was limited due to the grade of processing and different forms of the beam were executed. The possibility of using spatial diversity and full spatial multiplexing by accumulating the process. It is the overview technique of transmission and receiving of the data signal at the same time as of radio channel by misusing multipath propagation.

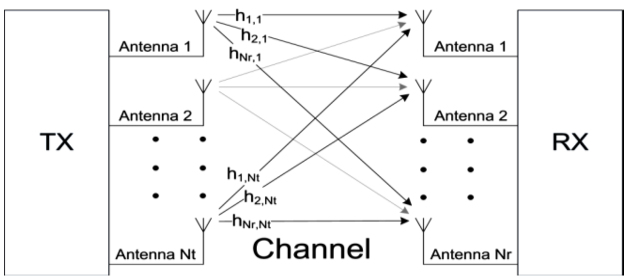

Fig. 1. MIMO system block diagram.

It shows the communication of same information signals at the same time through multiple antennas using one radio channel. Signal quality is improved by multiple antennas and RF channels in the usage of antenna diversity. Signal to noise ratio is affected by signal fading in communication. To reduce the error rate and improve its function diversity comes in play. For improving SNR, spatial multiplexing and spatial diversity are the two way used and they are categorized into various forms of fading for reliability.

II. MASSIVE MIMO

It is an evolving technology that balances the MIMO by the information in comparison with magnitude to the existing condition. Frequency-division depleting (FDD) and time-division duplexing (TDD) systems can be implementing the massive MIMO. However, the massive MIMO system is larger in comparison to that of TDD system which shows CSI gaining in FDD, the number of BS antennas are proportional to the feedback channel and an improper number of pilots [8].

III. BIT ERROR RATE

It usually shows the errors per bit in a simulation of a given number of bit transmission. Basically, it is shown in a ratio format. The transmission, receiver, the path it takes and the environment takes the category of the factors such as noise, attenuation, fading, and error detection and correction systems used in the interface standard.

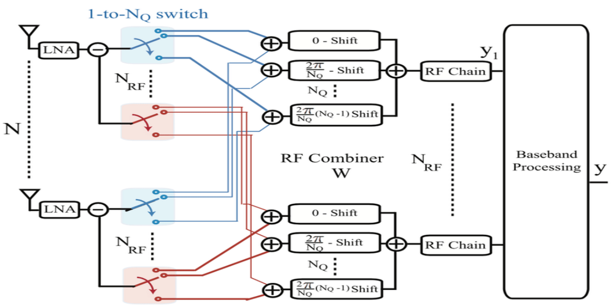

Fig. 2. Massive MIMO diagram

TABLE I. THEORETICAL COMPARISON OF MIMO AND MASSIVE MIMO [3,4].

Comparison between	MIMO	Massive MIMO
Number of Antennas and users	Both are equal	Number of antennas exceeds far more than the number of users.
Duplex mode operation	Supports both time division and frequency division.	Mainly designed for time division duplex operations to enhance channel reciprocity.
Channel acquisitions	Follows standard rule books and have a set value of angular beams	Completely depending on number of uplinks and utilizing channel reciprocity.
Post precoding link quality	Both frequency and time variant due to smaller frequency range and fading scale.	Almost independent on time and frequency variations.
Allocating resources	Any change applied is rapidly reflected for variations in channel quality.	Allocation takes place in a predefined way owing to less channel quality variation.
Edge performing capability	Needs complete cooperation of base station to perform well.	Performance is dependent on the number of antennas and does not cause any interferences between the cells.

A. *Importance Of Bit Error Rate* :-

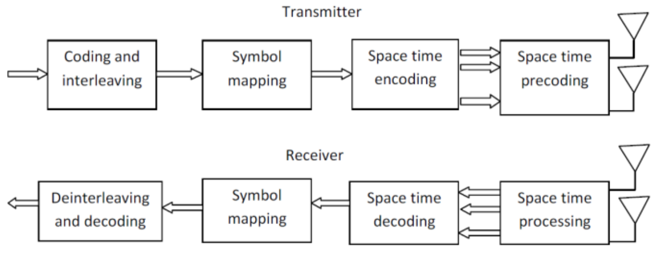

Fig. 3. MIMO system

The figure shows that a conventional encoder is used to encode the information bits which are to be transmitted. The encrypted words are plotted to data symbols by symbol mapper. These symbols are input to a space-time encoder which gives an output of data streams. The space-time pre-coding shows the spatial data stream of the transmit antenna. A signal is transmitted through a channel to the receiver antenna array, which is collected at each output receiver antenna and reverse the operation transmitter to decode the receive space-time processing, space-time decoding, de-interleaving and decoding.

BER is a metric which can be implied to characterize the performance of the communication system. The bit error rate is the average rate of bit error for communication

$$BER = \frac{number\ of\ bit\ errors}{total\ number\ of\ bits\ transmitted} \ldots(1)$$

The bit error rate is frequently expressed as of probability this is denoted by Pe (probability of bit error rate) the value of Pe lies between 0 to 0.5.
This paper study the performance of bit error rate of massive MIMO system under AWGN and Rayleigh fading channel.

B. AWGN

As the signal pass through white Gaussian noise is added in AWGN. Noise adds in AWGN depends only what is the input signal is applied where the input is complex Gaussian noise and output is also complex in nature. When the inputs signal is used real output is also real and add real Gaussian noise. The distribution in the normal time domain with an average time is known as Gaussian. Specifically used for weakening the transfer in continuous accumulation of white band or unchanged spectral density with noise and amplitude distribution is Gaussian. Modulation signals pass through AWGN channel amplitude and phase distortion, not loss only change in phase. This does not tell for declining, frequency selectivity, interference and nonlinearity. The only distortion is introduced in (2) the received signal y (t) which is simplified to equation (2)

$$Y(t) = X(t) + n(t) \text{ ....(2)}$$

Where n (t) denotes AWGN Gaussian noise and the density function probability can be expressed as equation below

$$P(n) = \frac{1}{2}\sqrt{2\pi\sigma^2}\; e^{\frac{-(n-\mu)^2}{2\sigma^2}} \text{ ....(3)}$$

Where n= grey level, μ= mean grey value and σ = standard deviation

C. RAYLEIGH

Three main mechanisms of electromagnetic wave propagation are a mirror image, diffraction and spreading. The Rayleigh fading model combination of scattering and reflected signal. It is used for modulation the signal of troposphere and ionosphere. A case approximation of attenuation due to multipath fading wireless channel can be done by Rayleigh fading channel. Its distribution can also be used by taking two identically distributed zero-mean Gaussian random variables as the real and imaginary part of a complex number and then taking its magnitudes this is given in equation given below:

$$h_{ij} = \frac{1}{\sqrt{2}}\Big(normal(0,1) + \sqrt{-1}normal(,1)\Big) \text{ ....(4)}$$

Received signal of receiver side can also be written as an equation

$$R(n) = \sum(h,\tau) * \delta(n-m) + w(n) \text{ ......(5)}$$

D. BIT ERROR RATE OF AWGN SIGNAL

Probability of BER in AWGN channel for BPSK modulation can be written as an equation

$$P_B = Q\left(\sqrt{\frac{E_b}{N_O}}\right) = Q\big(\sqrt{SNR}\big) \text{ .... (6)}$$

Where Q denotes tail distribution function of the standard normal distribution
Eb denotes Bit Energy, N0 stands for Noise Ratio. The flowchart of BER calculation is depicted below:

E. CHANNEL STATE INFORMATION

It signified as network assets of a communication link. Channel estimation defines how a signal circulates from the transmission end to the receiver end and characterize the joint result. As an example, it shows the spreading, declining, and power deterioration with distance. By fixing the transmission of the channel complaint which makes it a reliable communication the large data rate can be got in CSI multi-antenna system.

It is basically of two types of CSI, which are as follows:

Instantaneous CSI (Perfect): Impulse response of a digital filter can be observed by means of the acknowledged current channel conditions. For enhancing the receiving signal for spatial multiplexing or to reach short error of bit rate the transmitting signal is needed to be modified to the impulse response and getting the values.

Statistical CSI (Imperfect): The statistical characterization of a channel can be known by the distribution in fading, channel average gain, a component of a line of sight, and the correlation in spatial. Transmission optimization can be done by this information with perfect CSI. The fast change in channel conditions is determined by the in effect with the CSI acquirement. The transmission of a single information symbol occurs due to the fast-fading systems, but numerically CSI is practical.

MRC:- In maximum-ratio combining is a combining diversity of signals from every channel which are added together, ratio-squared combining and pre-detection combining is defined as the rms signal of every channel gain is made proportional and the mean square noise is made an inversely proportional level in that channel different proportionality constants are used in every channel. It is the optimal combiner for autonomous AWGN channels. MRC can reestablish a signal to its real shape.

ZF: - This stands out for a form of a linear equation that constitutes an algorithm which is used in communication channels. This algorithm is mainly governed by the inverse of the frequency response of the channel. This is used for the retrieval of the original signal by the application of the zero forcing equalizer which computes the mathematical inverse on the received signal. The main aim of Zero forcing is to generate a noise-free signal by bringing the inter-symbol interference to zero. This is of major significance on the event of comparison of the ISI with noise.

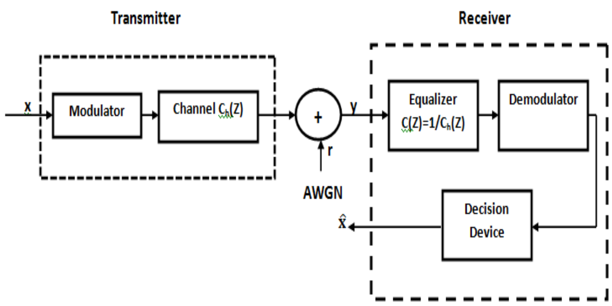

Fig. 4. Zero forcing

IV. SIMULATION RESULTS

In this section, the computer simulation results and discussion is presented. The simulation tool taken is Matlab R2018a software. The important parameters used for simulation are depicted in Table II below.

TABLE II. IMPORTANT SIMULATION PARAMETERS [16-17]

Parameters	Value
Channel	AWGN, Rayleigh fading channel
Max. No. of BS antennas	0-500
No. of Users	30
No. of Iterations	200
Block Length	100
No. of Blocks	10000
SNR(dB)	0-15

Analysis of MIMO and massive MIMO is done with BER performance evaluation.

Massive MIMO simulations:

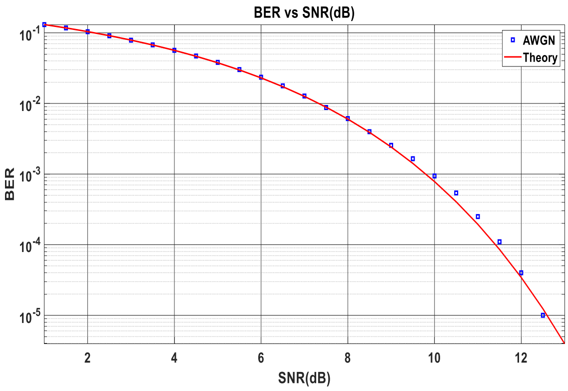

Fig. 5. MIMO analysis with AWGN and plot between BER vs SNR.

The above figure depicts the behavior of MIMO in the presence of AWGN and is compared to calculated values with respect to BER vs. SNR.

TABLE III. COMPARISON OF SNR VS BER IN CASE OF AWGN

	SNR(dB)	BER
THEORY	1.0000	0.1309
	9.5000	0.0014
	13.0000	0.0000
AWGN(PRACTICAL)	1.0000	0.1324
	9.5000	0.0016
	13.0000	0

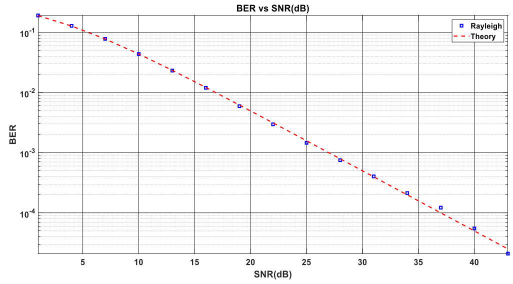

Fig. 6. MIMO analysis with Rayleigh and plots between SNR and BER.

TABLE IV. COMPARISON OF SNR VS BER IN CASE OF RAYLEIGH CHANNELS

	SNR(dB)	BER
THEORY	1	0.2113
	22	0.0213
	43	0.0112
RAYLEIGH	1	0.1881
	22	0.0029
	43	0

The above figure analyses the behavior of MIMO systems in the presence of Rayleigh fading channel. The BER and SNR are compared between the theoretical values and the actual values with the Rayleigh channel.

The below plot demonstrates the sum rate of Massive MIMO under perfect CSI.

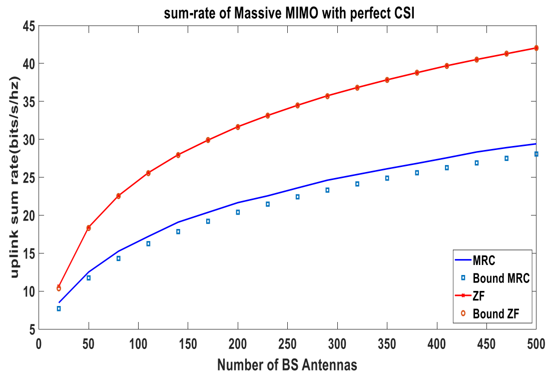

Fig. 7. Sum rate of Massive MIMO under perfect CSI.

Figure 7 depicts the performance of the MIMO channel in two cases namely MRC and ZF. It is seen that the system performance is much better in the case of ZFs both in bounded and unbounded condition as compared to MRCs and bounded MRCs.

TABLE V. PERFORMANCE COMPARISON IN CASE OF PERFECT CSI

	Number of BS antenna	Uplink(bits/sec/Hz)
MRC	20	8.4100
	230	22.4259
	500	29.2891
BOUND MRC	20	7.7012
	230	21.4335
	500	27.9964
ZF	20	10.8324
	230	33.3958
	500	42.2451
BOUND ZF	20	10.4849
	230	33.3472
	500	42.2561

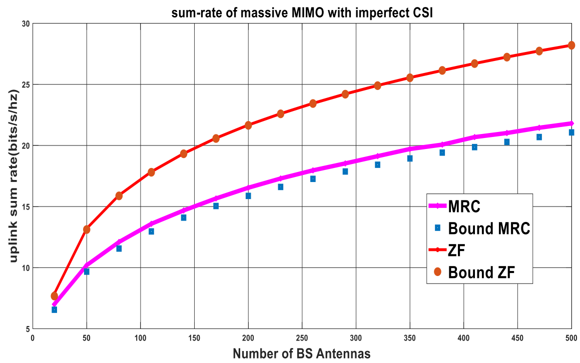

Figure 8: sum rate of massive mimo under imperfect CSI

The above figure analyses the performance of the MIMO system in the case of Imperfect Channel state information (CSI) when the number of users is taken to be 10. The system is simulated under 1000 iterations and the performance is noted. It is seen that the system in case of imperfect CSI performs a lot better under ZF than MRC in both bounded and unbounded condition.

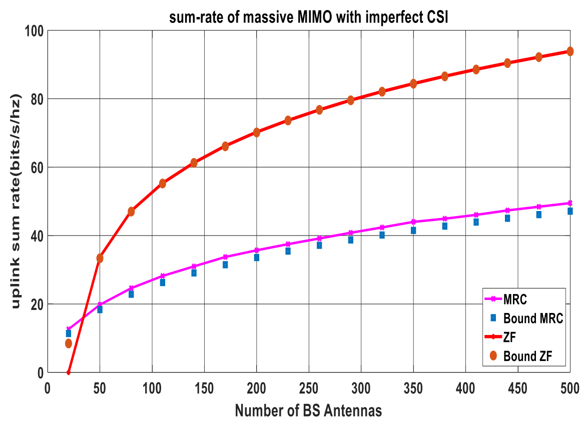

Figure 9: sum rate of massive mimo under imperfect CSI

The above simulation has been done under a user limit of 30 and iteration number 200. It depicts the superior performance of the system under ZFs as compared to MRCs in case of imperfect CSI when the system is operating in both bounded and unbounded mode.

TABLE VI. PERFORMANCE COMPARISON IN CASE OF IMPERFECT CSI

	Number of BS antenna	Uplink(bits/sec/Hz)
MRC	20	12.5047
	230	37.2733
	500	49.1874
BOUND MRC	20	11.2880
	230	35.2936
	500	46.9960
ZF	20	0.0000
	230	72.0248
	500	91.9825
BOUND ZF	20	32.1398
	230	71.9411
	500	91.9671

IV. LIMITATION

The limitations of MIMO are:

Single antenna-based system requires high resource and hardware complexity. RF units need a separate antenna. For mathematical signal processing, a DSP chip is required. It reduces the battery lifetime as hardware need high power to process complex signal algorithm at high speed. It cost is high. Massive MIMO limitations: Propagation Models- As the number of antenna increases, the user channels are spatially are not linked and their channel automatically becomes sets orthogonally in propagation conditions.TDD and FDD Modes: It is only based on channel estimation and feedback. But many ways are there for FDD mode to be operated in massive MIMO.

Modulation: A low-cost power-efficient RF amplifiers are needed for construction of BS with a large number of an antenna.

Pilot Contamination: A non-orthogonal pilot may be used because it has a smaller number of users and results in pilot contamination.

V. CONCLUSION

The proposed paper discusses the performance of the MIMO and massive MIMO system under channel state information modes. The MIMO system is tested for its performance in the presence of Additive White Gaussian Noise and Rayleigh fading channel. The analysis of the system is further done in Zero forcing mode and maximum ratio combination. It is seen that on simulating the system under various iterations and user combinations, MIMO system performance has increased under ZF mode when seen both under perfect and imperfect CSI.

VI. FUTURE SCOPE

In the adoption of 5G for massive MIMO, the limited spectrum bottleneck in a wireless network in the large scale active antenna array on 4G will be eliminated and the internet value will be strengthened. Increase in bandwidth evolution is not the only value many application like IoT application, high-quality content and many more will come. The spatial multiplexing binds a high-speed single-user experience in the high-capacity system. Massive MIMO offers equivalent bandwidth to fixed networks. It will provide better broadband for a home with a fiber-grade private line. It will help in industry line for a specific frequency band to carry services. The spatial multiplexing can reuse the high spectrumand boost uplink for commercial to develop an enterprise application. Massive MIMO is ready to set an example in future of the 5G era and benefit both the home and enterprise.

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