Performance Comparison of MPAM and MQAM in Nakagami-m and Rician Fading Channel

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ABSTRACT
The analysis of bit error rate (BER) is carried over independent identically distributed (i.i.d) Nakagami-m and Rician fading channel using space time transmit diversity (STTD). Error rates for M-PAM and M-QAM with space time transmit diversity (STTD) is obtained by averaging the conditional BER over the probability density function (pdf) of received signal-to-noise ratio (SNR) per bit for independent identically distributed Nakagami-m fading channel. Error performance plots of MPAM and MQAM modulation techniques has been drawn and compared for different values of Rician parameter K and modulation order M for two transmitting and one receiving antenna.

Keywords
M-ary pulse amplitude modulation (MPAM) , M-ary Quadrature Amplitude modulation (MQAM) , Bit error rate (BER), signal-to noise ratio (SNR), Space time transmit diversity (STTD).

1. INTRODUCTION
As the digital communication industry continues to increase and evolve, the applications of modulation techniques continue to grow as well. We know the digital communication system outperforms the analog in terms of noise performance and flexibility. It is our primary need to achieve the high data rates in limited spectrum bandwidth to improve the performance of signals. The main objective of wireless technology is capable of delivering high data rate signal so that it can transmit high bit rate multimedia content in cellular mobile communication. Due to high data rate requirement there has been renewed interest in M-ary modulation because of their capability of sending multiple bits per transmitted symbols. M-ary modulation schemes are one of the most efficient digital data transmission systems as it achieves better bandwidth efficiency than other modulation techniques and give higher data rate. Multipath fading is one of boundary condition of wireless communication and occurs due to multipath propagation, which can cause fluctuation in received signal's amplitude, phase and angle of arrival [1]. Diversity is the technique which is based on the principle of providing multiple faded replicas of same information bearing signal to the receiver. Transmit diversity has become one of the key contributing technologies in 3G and future mobile wireless communications. The advantage of transmit diversity over classical receiver diversity is that multiple antennas can be employed at the base station (BS) instead of receiver side to reduce the complexity of mobile station (MS). To describe the statistical behavior of multipath fading, there are different models like Rayleigh, Rician and Nakagami-m and many more. Rician distribution is used to model a propagation path that consists of one strong direct Line of Sight (LoS) component and many other weaker non LoS components. Rician fading parameter K is measure of severity of fading; it can be define as ratio of power in LoS component to power in other multipath component. We include Rayleigh fading (when K = 0) and AWGN (when K =∞), as special case of no fading. Probability density function (PDF) of received SNR explicitly includes the received signal statistics of all order, which helps to investigate error rate performance for given modulation schemes over fading channel models with or without diversity [2].

In this paper, performance of different modulation techniques has studied that operates in different fading environment and the results are plotted. These results shows the behavior of modulation techniques for different value of Rician fading parameter K and Modulation order M.

2. SYSTEM PERFORMANCE MEASURE

2.1 Bit Error Rate
In digital transmission, the number of bit errors is the number of received bits of a data stream over a communication channel. Several factors that affect BER include bandwidth, SNR, transmission speed, transmission medium. BER is the number of bits in error divided by the total number of transferred bits during a studied time interval [3]. BER is a unit less performance measure; often expressed as a percentage. The bit error probability (BEP) P_b is the expected value of the BER.

BER = Number of bit in error / Total no of transferred bits (1)

The performance of each modulation is measured by calculating its probability of error. High data rate like 16-QAM can transmit 4 bits per symbol. When a large amount of power is available, it is easy to reduce the bandwidth of modulation schemes; similarly high power is not needed to achieve a low BER. Modulation schemes which are capable of delivering more bits per symbol are more immune to errors caused by the noise and interference in the channel. Moreover, errors can easily be produced as the number of users is increased [4].

2.2 SNR
Signal-to noise ratio (SNR) is a best understood performance measure characteristics of a digital communication system. In general a high SNR is good because it means more signal and

less noise. SNR is used to measure using a logarithmic scale that means the SNR value is a logarithmic of the actual ratio. Generally, high noise means low SNR can lead to high BER. High BER is bad, and usually leads to observable problems with the signal. It is more important to note that probability of error is proportional to E_b/N_o and is a form of signal to noise ratio [5].

3. SYSTEM MODEL

Space time transmit diversity is an open loop technique defined for two transmit antennas, because the type of transmit diversity maximizes diversity gain [6]. Considering a wireless downlink with two transmits and one receive antenna. System model for STTD is shown in Figure 1.

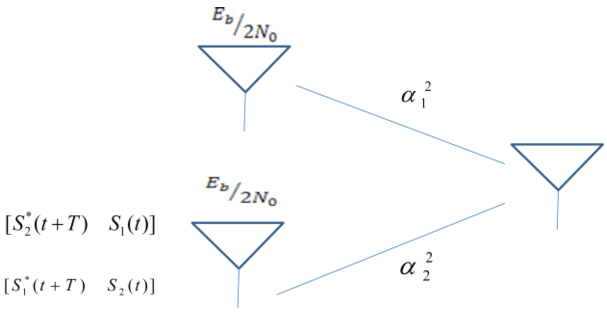

Fig 1: System model for STTD.

Where $E_b/2N_o$ denotes the average transmit SNR per bit in each antenna $S_1(t)$, $S_2(t)$ are the symbols transmitted by both antennas at time (t), $S_1^*(t + T)$ and $-S_2^*(t + T)$ are the symbols transmitted by both antennas at time (t +T), where * represents complex conjugate operation and α_1^2 and α_2^2 are the independent channel gains (square of fading attenuation factor) introduced by fading channel. The pdf of Nakagami distribution $p_\alpha(\alpha)$.

Where $\Omega = E(\alpha^2)$ is average channel gain $m = \frac{\Omega^2}{E[(R^2-\Omega^2)]}$, and

$$m \geq \frac{1}{2},\ E(R^2) = \frac{\Gamma(m+0.5n)}{\Gamma(m)} \left(\frac{m}{\Omega}\right)^{\frac{n}{2}} \tag{2}$$

The pdf of received SNR per bit under Nakagami-m fading channel with STTD is given in [6].

$$p(\gamma_b) = \frac{1}{E_b/N_0} p_\gamma\left(\frac{\gamma_b}{E_b/N_0}\right) = \frac{2\sqrt{\pi}\ m^{2m}\ \gamma_b^{2m-1}}{\Gamma(m)\ \Gamma\left(\frac{1}{2}+m\right)\ \overline{\gamma_b}^{2m}} \exp\left[\frac{-2m\gamma_b}{\overline{\gamma_b}}\right] \tag{3}$$

The BER under fading can be obtained simply by averaging the BER in AWGN channel over the fading signal statistics,

$$P(\gamma) = \int_0^\infty P_{AWGN}(\gamma_b)\ p(\gamma_b)\, d\gamma_b \tag{4}$$

4. M-ARY MODULATION SCHEMES

Different base band data may be sent by varying both the envelope and the phase of RF carrier. As the envelope and phase offer two degrees of freedom and modulation techniques map base band data into four or more possible RF carrier signals. Such modulation techniques are called M-ary modulation schemes. The basic concept behind digital modulation is to identify efficient schemes taking M different symbols in given digital information and transforming them into waveforms that can be successfully transmit the data over the transmission channel. In an M-ary signaling schemes, we may send one of the M possible signals that is $s_1(t)$, $s_2(t)$,………., $s_M(t)$ during each signaling interval of duration T. In many applications, the numbers of possible signals are $M=2^n$, where n is an integer [7]. The symbol duration $T= nT_b$ where T_b is bit duration. The BER for MPAM and MQAM modulation techniques will be discussed and analyzed.

4.1 Error rate for MPAM

Pulse amplitude modulation (PAM) is the transmission of data by varying the amplitudes (voltage or power levels) of the individual pulses in a regularly timed sequence. The number of possible pulse amplitudes can be infinite in the case of analog PAM, but it is usually some power of two so that the resulting output signal can be digital. The signal constellation of MPAM is one dimensional [8].

The probability density function (pdf) of γ of the received SNR per bit for independent identically distributed over Nakagami-m fading channel with space time transmit diversity with two transmit antenna and one receiving antenna is given as [6].

$$p(\gamma_b) = \frac{1}{E_b/N_0} p_\gamma\left(\frac{\gamma_b}{E_b/N_0}\right) = \frac{2\sqrt{\pi}\ m^{2m}\ \gamma_b^{2m-1}}{\Gamma(m)\ .\Gamma\left(\frac{1}{2}+m\right)\ \overline{\gamma_b}^{2m}} \exp\left[\frac{-2m\gamma_b}{\overline{\gamma_b}}\right] \tag{5}$$

The BER under fading can be obtained simply by averaging the BER in AWGN channel over the fading signal statistics that is [9].

$$P(\gamma) = \int_0^\infty P_{AWGN}(\gamma_b)\ p(\gamma_b)\, d\gamma_b \tag{6}$$

The probability of bit error for MPAM is given as

$$P_{AWGN}(\gamma_b) = 0.2 \exp\left[-\frac{3\gamma}{(M^2-1)}\right] \tag{7}$$

After substituting (5) and (7) into (6) we get

$$P(\gamma_b) = 0.4\sqrt{\pi}\left(\frac{m\,(M^2-1)}{2\,m\,(M^2-1)+3\,\overline{\gamma}_b}\right)^{2m} \frac{\Gamma(2m)}{\Gamma(m)\Gamma\left(\frac{1}{2}+m\right)} \tag{8}$$

One to one mapping between the Nakagami-m parameter and Rician K parameter is given as [9]

$$m = \frac{(1+K)^2}{1+2K} \tag{9}$$

Using (9) the probability of bit error for MPAM modulation scheme for independent identically distribution Rician fading channel with space- time transmit diversity (STTD) is given as follows:

$$P(\gamma_b) = 0.4\sqrt{\pi}\left[\frac{\left(\frac{(1+K)^2}{1+2K}\right)(M^2-1)}{2\,\frac{(1+K)^2}{1+2K}(M^2-1)+3\,\overline{\gamma}_b}\right]^{2\,\frac{(1+K)^2}{1+2K}} \frac{\Gamma\left(2\frac{(1+K)^2}{1+2K}\right)}{\Gamma\left(\frac{(1+K)^2}{1+2K}\right)\Gamma\left(\frac{1}{2}+\frac{(1+K)^2}{1+2K}\right)} \tag{10}$$

By substituting K = 0 in above equation, yields the probability of bit error for MPAM modulation scheme over independent identically distribution Rayleigh fading channels with STTD.

$$P(\gamma_b) = 0.8\left[\frac{(M^2-1)}{2(M^2-1)+3\overline{\gamma}_b}\right]^2 \tag{11}$$

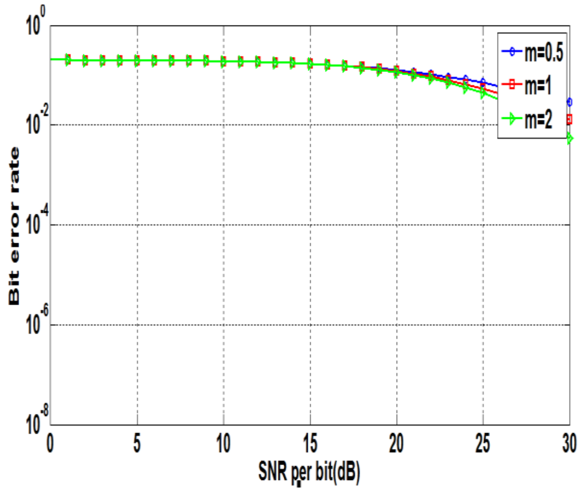

Fig 2: BER of MPAM modulation scheme under Nakagami-m fading channel for M=16.

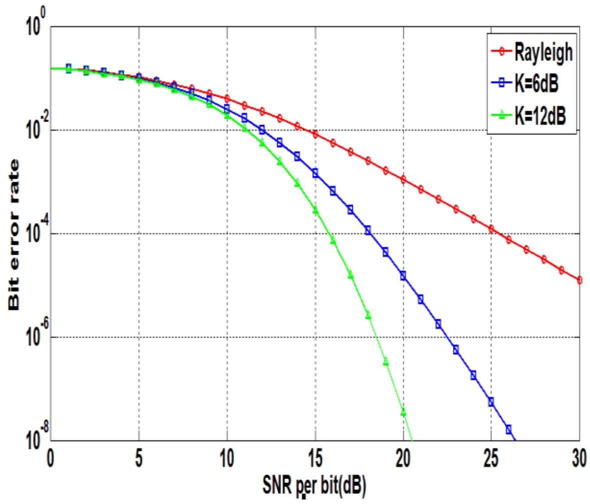

Fig 3: BER of MPAM modulation scheme under Rician fading channel for M=4.

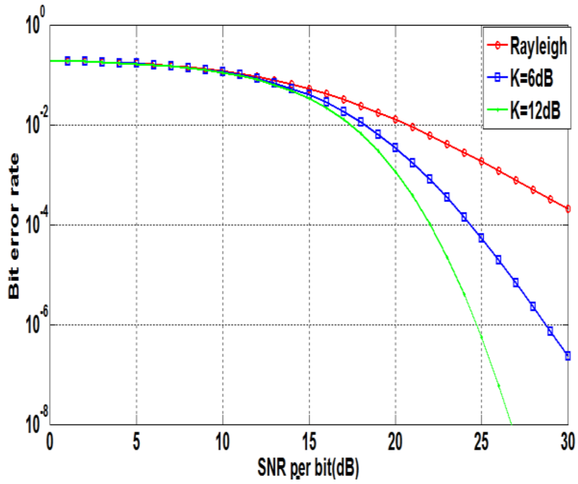

Fig 4: BER of MPAM modulation scheme under Rician fading channel for M=8.

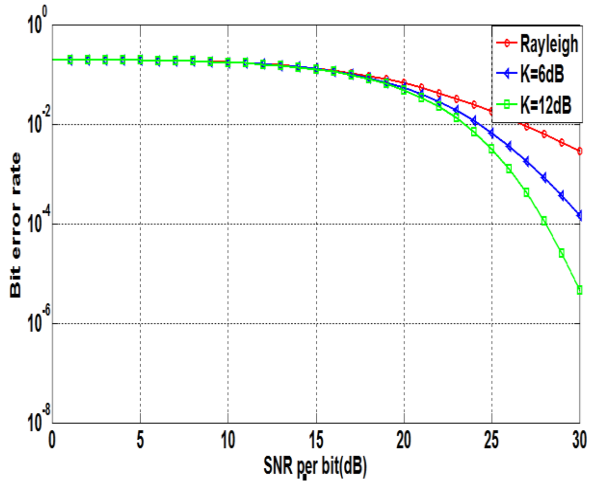

Fig 5: BER of MPAM modulation scheme under Rician fading channel for M=16.

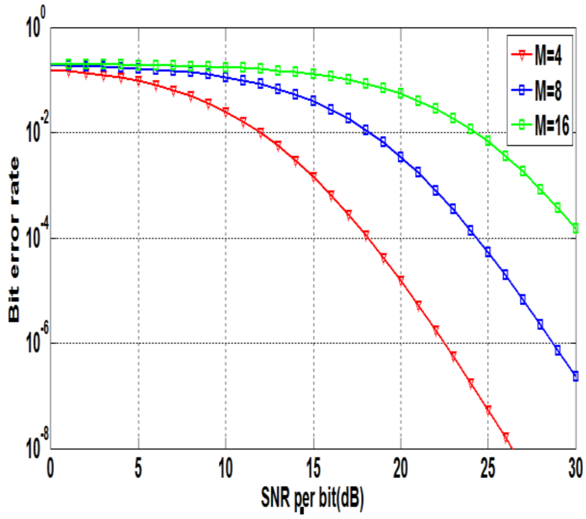

Fig 6: BER of MPAM modulation scheme under Rician fading channel for K=6dB.

Table 1. BER of MPAM for different values of K, M (SNR=20dB)

Different values of K	Bit Error Rate		
	M=4	M=8	M=16
K= 0dB	1.1*10^-3	1.3*10^-4	6.6*10^-2
K= 6dB	1.5*10^-5	3.4*10^-3	5.3*10^-2
K= 12dB	3.5*10^-8	1.1*10^-3	4.8*10^-2

Figure 2, Figure 3, Figure 4, Figure 5 and Figure 6 shows the bit error rate of MPAM over Nakagami-m and Rician fading channel with STTD versus the mean bit SNR. The bit error rate versus the mean values of the bit SNR is shown for various values of the Rician parameter, that is K = 0dB, 6dB, 12dB, for modulation order of M = 4, 8, 16. The Rician distribution follows Rayleigh distribution for K=0. It is clear from the results that for any value of M, as the value of K increases, the BER reduces. As observed from figure 6, for fixed value of K, as the value of M decreases, the BER reduces thereby improving the performance of the system.

4.2 Error rate for MQAM

By allowing the amplitude to vary with phase, a new modulation scheme called Quadrature Amplitude Modulation (QAM) is obtained. It is such a class non constant envelope schemes that can achieve higher bandwidth efficiency than other modulation schemes with the same average signal power. The signal constellation of MQAM is two dimensional [10].

The probability density function (pdf) of γ of the received SNR per bit for independent identically distributed over Nakagami-m fading channel with space time transmit diversity with two transmit antenna and one receiving antenna is given as [6].

$$p(\gamma_b) = \frac{1}{E_b/N_0}\, p_\gamma\left(\frac{\gamma_b}{E_b/N_0}\right) = \frac{2\sqrt{\pi}\; m^{2m}\, \gamma_b^{\,2m-1}}{\Gamma(m)\,\Gamma\left(\frac{1}{2}+m\right)\overline{\gamma_b}^{\,2m}}\; \exp\left[\frac{-2m\gamma_b}{\overline{\gamma_b}}\right] \tag{12}$$

The BER under fading can be obtained simply by averaging the BER in AWGN channel over the fading signal statistics that is [9].

$$P(\gamma) = \int_0^\infty P_{AWGN}(\gamma_b)\; p(\gamma_b)\; d\gamma_b \tag{13}$$

The probability of bit error for M-QAM is given as

$$P_{AWGN}(\gamma_b) = 0.2\,\exp\left[-\frac{1.5\gamma}{(M-1)}\right] \tag{14}$$

$$P(\gamma_b) = 0.4\sqrt{\pi}\left(\frac{m\,(M-1)}{2\,m\,(M-1)+1.5\overline{\gamma}_b}\right)^{2m} \frac{\Gamma(2m)}{\Gamma(m)\Gamma\left(\frac{1}{2}+m\right)} \tag{15}$$

One to one mapping between the Nakagami-m parameter and Rician K parameter is given as [9].

$$m=\frac{(1+K)^2}{1+2K} \tag{16}$$

Using (16) the probability of bit error for M-QAM modulation for independent identically distributed Rician fading channels with space- time transmit diversity (STTD) is given as follows-

$$P(\gamma_b) = 0.4\sqrt{\pi}\left[\frac{\left(\frac{(1+K)^2}{1+2K}\right)(M-1)}{2\,\frac{(1+K)^2}{1+2K}(M-1)+1.5\;\overline{\gamma}_b}\right]^{2} \frac{(1+K)^2}{1+2K}\; \frac{\Gamma\left(2\frac{(1+K)^2}{1+2K}\right)}{\Gamma\left(\frac{(1+K)^2}{1+2K}\right)\Gamma\left(\frac{1}{2}+\frac{(1+K)^2}{1+2K}\right)} \tag{17}$$

By substituting K=0 in above equation, yields the probability of bit error for MQAM over independent identically distribution Rayleigh fading channels with STTD is given as

$$P(\gamma_b) = 0.8\left[\frac{(M-1)}{2(M-1)+1.5\overline{\gamma}_b}\right]^2 \tag{18}$$

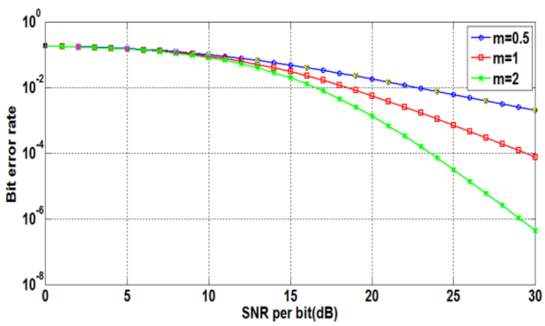

Fig 7: BER of MQAM modulation scheme under Nakagami-m fading channel for M=16.

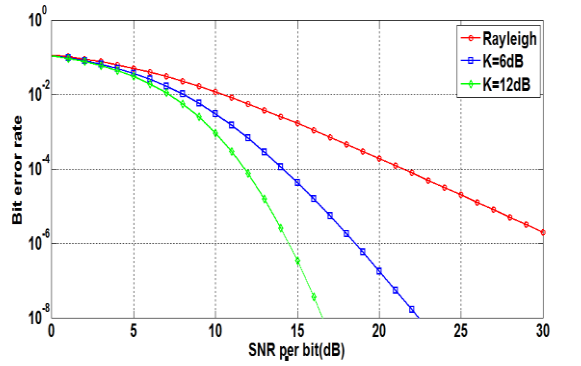

Fig 8: BER of MPAM modulation scheme under Rician fading channel for M=4.

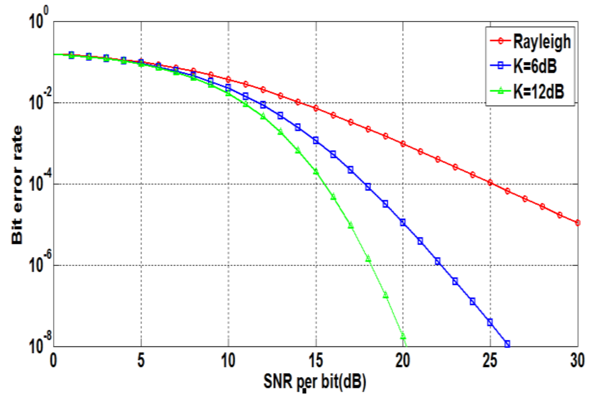

Fig 9: BER of MQAM modulation scheme under Rician fading channel for M=8.

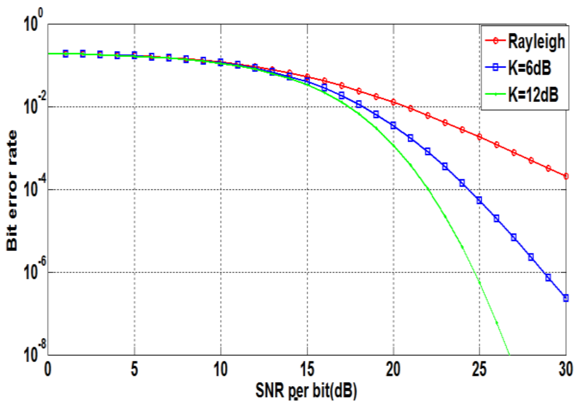

Fig 10: BER of MQAM modulation scheme under Rician fading channel for M=16.

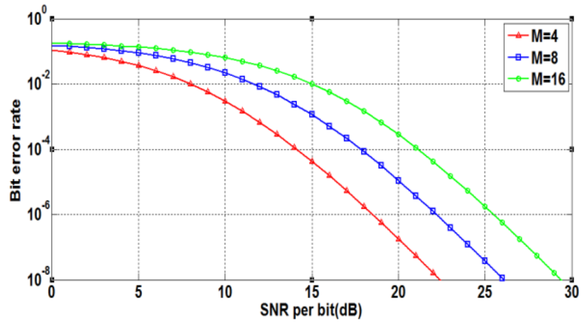

Fig 11: BER of MQAM modulation scheme under Rician fading channel for K=6dB.

Table 2. BER of MQAM for different values of K, M (SNR=20dB)

Different values of K	Bit Error Rate		
	M=4	M=8	M=16
K=0dB	1.9*10^-4	9.5*10^-4	3.7*10^-3
K=6dB	1.8*10^-7	1.1*10^-5	2.8*10^-4
K=12dB	7.5*10^-5	1.7*10^-8	1.5*10^-5

Figures 7, Figure 8, Figure 9, Figure 10 and Figure 11 shows the bit error rate of MQAM over Nakagami-m and Rician fading channel with STTD versus the mean bit SNR. The bit error rate versus the mean values of the bit SNR is shown for various values of the Rician parameter, that is K = 0 dB, 6 dB, 12 dB for the modulation order of M = 4, 8, 16. The Rician distribution follows Rayleigh distribution for K=0. It is clear from the results that for any value of M, as the value of K increases, the BER reduces. As observed that from the figure 11, for fixed value of K, as the value of M decreases, the BER reduces thereby improving the performance of the system.

5. COMPARISON

In Figure 12, Figure 13, performance comparison for MPAM and MQAM is discussed in fading channels with STTD Diversity for different values of Rician parameter K and modulation order M.

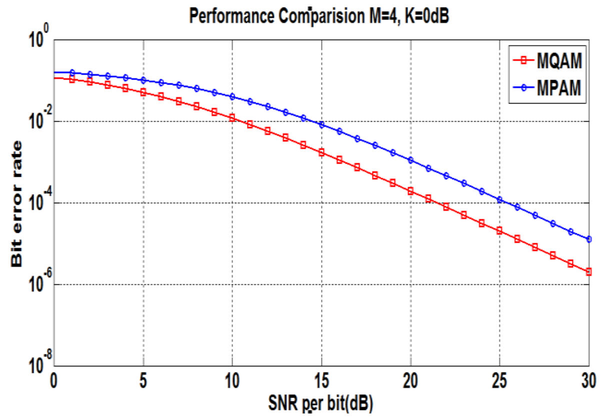

Fig 12: BER of MPAM and MQAM modulation scheme for M=4, K=0dB.

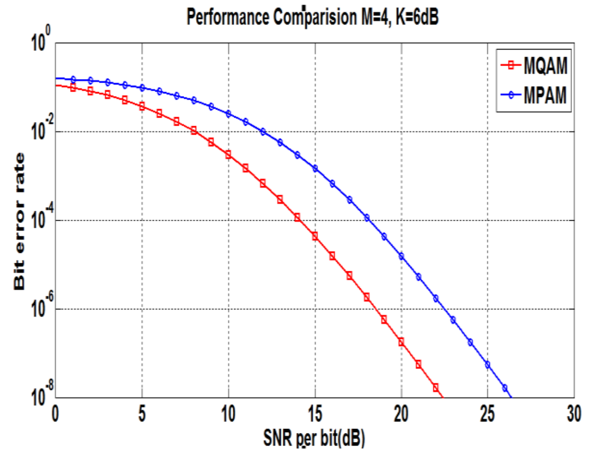

Fig 13: BER of MPAM and MQAM modulation scheme for M=4, K=6dB.

From Figure 12, Figure 13 for M=4 considering 20 dB SNR for M-QAM, at K = 0 dB the BER is approximately 1.9*10^-4, at K = 6 dB the BER is approximately 1.8*10^-7. Again for considering 20 dB SNR for MPAM, at K = 0 dB the BER is approximately 1.1*10^-3, at K = 6 dB the BER is approximately 1.5*10^-5. So for M = 4 and any value of K, MQAM is better than MPAM.

Plots show that Bit error Rate rises with increase in modulation order M by keeping other parameter fixed and BER deceases as value of K increases by keeping other parameter fixed.

6. CONCLUSION

In this paper, error performance of two modulation techniques in Nakagami-m and Rician fading channel are analysed and BER is calculated. Based on numerical calculation the BER of MPAM and MQAM is graphically plotted and compared. From the results, it is observed that the error probability of MPAM, MQAM is decreases within the variation of Rician parameter K. On comparing the results of both modulation techniques at same value of Rician parameter K, MQAM gives better performance. Many of these results can be extended for other cases of diversity reception to combat fading effects.

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