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Performance Evaluation of Modulation Techniques in Two-Hop Wireless Link Under Fading Channel

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Abstract:- The radio signals in wireless communication system are ruined by large and small scale fading during transmission. In a two-hop wireless link, the radio signals are affected by multipath fading for which the overall performance of the system degrade. In this thesis performance of different modulation schemas (MPSK, MQAM, DEPSK) are will analyzed under Rayleigh, Nakagami-m and Rician fading environment separately. And their result will be compared to evaluate performance difference between different modulation techniques. At last the result are shown using different graph and also comparison of different modulation techniques are discussed using comparison graph.

Keywords:- *Fading Channel;Probability of Symbol Error; Modulation Performance.*

I. INTRODUCTION

Multipath propagation happens in a wireless channel when electromagnetic wave reflected, refracted or scatteredby surrounding objects. As a result,at receiving end multiple copy of same signal reaches and createsdelay spread. The multipath propagation can be small scale or large scale. In large scale propagation model transmitter and receiver have large distance between them. In small scale propagation the transmitter and receiver have small distance between them such as less than 5 km. This kind of small scale propagation is common in urban or suburban area.In a multipath propagation environment, variation of the amplitude and phase of a composite modulated symbol happens widely and rapidly, which is known as fading. A fading channel has two most important parameters: coherence time and coherence bandwidth [1-2]. Many other parametersplay essential role to change the performance of a wireless link such as:multipath delay spread, symbol period, coherence time/ bandwidth, doppler spread, time variant or invariant property channel gain etc [1-3].

As wireless communication, especially mobile cellular system severely affected by multipath fading, several research party work on this problem and addressed different issue. [3] proposed the performance of 8-PSK and QPSK modulation schemes under Rayleigh and Nakagami-m fading channel. Here performance of two hop link is analyzed taking MRC at the first hop and Alamouti coding at the second hop. [5] proposed a method to evaluate performance of 8-PSK and 16-QAM under Rayleigh and Nakagami-m model. Here firstly the error probability of M-PSK and M-QAM is analyzed and then normalized with moment function to get the output. [4] proposed strategy to evaluate performance according to symbol error rate for two-hop cooperative non-regenerative multi-relay networks. This strategy encapsulates all types of coherent, differentially coherent and non-coherent digital modulation schemes and their performance. In [7] the Q-PSK modulation in observed under mixed Rician and Rayleigh fading channel. In [8], average bit error probability (ABEP) is determined for BPSK, QPSK and M-QAM under Nakagami-m channels. [12] Presents the performance of multi-hop wireless link applicable in ad-hoc network under fading environment. The paper [6], determine the dual-hop relay link performance, when the relay stream only for amplify-and-forward (AF) for coherent and non-coherent binary modulation. Here Nakagami-m fading is considered for both single antenna and selection combining scheme. The paper claimed to derive the generalized expression of BEP of all binary modulation schemes. Based on the concept of [15][14][13], the paper [9] determines how the cooperative diversity performance of wireless link (including direct link between transmitter and receiver, where the signal is also relayed by some some neighboring nodes) under Nakagami-m fading cases. In [16], a strategy is described where M-QAM and multiuser diversity is combined in Nakagami-m fading with delay time τ, a channel estimator at each MS and an error-free feedback path is considered from MS and the BS. In feedback model, according to the feedback SNR the transmitter determines the size of constellation. The previous constellation is combined until getting the feedback SNR, when feedback delay τ is much greater than the symbol period and incurs some additional error. Like [10][11] multiuser diversity is included in the paper. For mixed Rayleigh and Ricean fading channels the outage probability and average bit error probability is evaluated in [15]. [37]–[20] studied how to enhance the overall quality of service by relaying signals for wireless relay networks , manipulated at [15] and [26] whose nodes cooperate with each other . In [41] for distributed space-time coded multiple-input multiple-output (MIMO) systems some of the benefits of cooperation such as wider coverage, transmit power saving and reduced interference are studied. The paper [33] categorize Cooperation schemes as Decode and Forward (DF) (or regenerative systems) and Amplify and Forward (AF) (or non-regenerative systems) based on whether or not signal decoding takes place at the relays. In [46] based on channel statistics the relay gain is chosen a priori, arbitrarily or sometimes semi-blindly.In [31] pdf, mgf, and cdf is derived for CA relaying over non-identical Rayleigh fading links in closed form . for identical

Nakagami-m fading links the results of SNR for CA relaying are extended in [19]. A MIMO system with Rayleigh fading links, a single-antenna relay and no direct S→D paths is analyzed at [41].

In this paper we want to analyze and contribute in area of capacity and error performance of communications over a small-scale multipath fading channel described in[1] and[2], which are Rayleigh fading, Ricean fading and Nakagami-m fading channel for different modulation technique such as M-PSK, M-QAM, Differential psk, pi/4 differential psk, differential Q-PSk,Offset-QPSK etc. and want to find the effective modulation technique for each fading channel. Our approach is inspired by [4] ,[5] and[30]. [4],[6] provides error performance of fading channel under M-PSK and A-QAM modulation.The main objective is to find out a complete and proper performance analysis, for different modulation techniques under dual hope case.

II. SYSTEM MODEL

The system model refers to the processes and steps to implement a system setup using which we can find out the result of the experiment. System model for this paper to perform detail analysis is described below section wise.

A. *Two – Hop Wireless Link*

A two-hop wireless communication link consists of a sender, detector and relay node. Sender sends data to the destination detector or receiver through relay node. Source and destination are not directly linked. The relay forwards the information to the destination detector through amplify-and-forward technique. Although source and relay nodes face statistical quality of service (QoS) constraints, which is considered during transmission, it become limited on the buffer overflow probabilities. With QOS constraints, the maximum arrival rate of two-hop link can be determined by calculating effective capacity of channel links as a function of the QoS parameters, signal-to-noise ratios at the source and relay, and the fading distributions of the links. Here we are using full duplex relay node. The modulation schemes along with fading consequences affects the interactions between the buffer constraints in different nodes.

B. *Calculating symbol error probability P_s*

Ps of MPSK: Now let assume that the transmitter is S, receiver is D and the relay node is R. We will first find out the probability of symbol error, Ps under additive white Gaussian noise (AWGN) channel in a fading environment. We will analysis Ps with two modulation schemas and they are 8-PSK and 16-QAM.

In MPSK modulation, the received signal vector of coherent demodulator on $\varphi_1(t)$ –$\varphi_2(t)$ plane is

$$\mathbf{r} = \begin{bmatrix} r_1 \\ r_2 \end{bmatrix}$$

Where

$$r_1 = \int_0^T \{S_i(t) + n(t)\}\varphi_1(t)dt = \sqrt{E}cos\theta_i + n_1$$

$$r_2 = \int_0^T \{S_i(t) + n(t)\}\varphi_2(t)dt = \sqrt{E}sin\theta_i + n_2$$

The signal $S_i(t)$ is the *i*-th modulated wave in the region $kT \leq t \leq (k+1)T$, E is the energy of transmitted symbol, n_1 and n_2 are the noise of the received signal component.

Now, $r_1 = \rho\cos\hat{\theta}_\iota$and$r_2 = \rho\sin\hat{\theta}_\iota$, as $S_i(t)$ is transmitted the joint PDF of ρ and $\hat{\theta}_\iota$ is [3]:

$$p\{\rho, \hat{\theta}_\iota | S_i(t) \text{ is transmitted}\} = \frac{1}{\pi N_0}\exp\left[-\frac{1}{N_0}\{\rho^2 + \mathrm{E} - 2\rho\sqrt{\mathrm{E}}\cos(\theta_i - \hat{\theta}_\iota)\}\right] \ldots\ldots\ldots (1)$$

Integrating both side of Eq. (1) with respect to ρ and taking$\varphi = \hat{\theta}_\iota - \theta_i \in [-\pi, \pi]$, the PDFof φbecomes,

$$p\{\varphi | S_i(t) \text{ is transmitted}\} = \frac{e^{-\frac{E}{N_0}}}{2\pi}\left[1 + \sqrt{\frac{\pi \mathrm{E}}{N_0}}(\cos\varphi)\mathrm{e}^{-(\mathrm{E}/N_0)\cos^2\varphi}\mathrm{G}(\varphi)\right] \ldots\ldots\ldots (2),$$

where $G(\varphi) = \left\{1 + erf\left(\sqrt{\frac{E}{N_0}}cos\varphi\right)\right\}$

From [3], [12] probability of symbol error can be written as:

$$P_s = 1 - \int_{-\pi/M}^{\pi/M} p\{\varphi | S_i(t) \text{ is transmitted}\}d\varphi$$

$$= \frac{M-1}{M} - 0.5erf\left\{\sqrt{\frac{E}{N_0}}sin\left(\frac{\pi}{M}\right)\right\} - \frac{1}{\sqrt{\pi}}\int_0^{\sqrt{E/N_0}sin\left(\frac{\pi}{M}\right)} e^{-y^2} erf\left(y\cot\frac{\pi}{M}\right)dy;\ M > 4 \ldots\ldots(3)$$

If *E/N0 >> 1*, then Eq. (3) can be simplified to

$$P_s = 2Q\left(\sqrt{\frac{2E}{N_0}}sin\left(\frac{\pi}{M}\right)\right) \ldots\ldots\ldots (4)$$

Ps for MQAM: The above system can be implemented to find out SER of M-QAM schema. A rectangular M-QAM with size *L = M2* can be calculated by considering two M-PAM on in-phase and quadrature components for 16-QAM constellation. The error probability of QAM symbol that can be obtained by the error probability of each branch is:

$$P_s = 1 - \left(1 - \frac{2(\sqrt{M}-1)}{\sqrt{M}} Q\left(\sqrt{\frac{3E}{N_0(M-1)}}\right)\right)^2 \ldots\ldots\ldots(5)$$

The above equation can be simplified and written as:

$$P_s = 4Q\left(\sqrt{\frac{3E}{(M-1)N_0}}\right)\ldots\ldots\ldots(6)$$

We can generalize the above P_s functions using Gaussian Q function [2], $Q(g\sqrt{\gamma})$, where g = constant depending on modulation schema and detection technique and γ = instantaneous SNR per bit, E/N_0.

Also, we know that-
Q(x) =1/2 [1 − erf(x/√2)] ….. (7)
in equation (6) we get-

$$p_s = 4\left[\frac{1}{2}\langle 1 - \mathrm{erf}\left[\sqrt{\sqrt{\frac{3\Upsilon}{M-1}}\Big/\sqrt{2}}\right]\rangle\right]$$

$$so\ , p_s = 4\left[\frac{1}{2}\langle 1 - \mathrm{erf}\left[\sqrt{\frac{3\Upsilon}{2(M-1)}}\right]\rangle\right]\ldots\ldots\ldots(8)$$

Ps for DEMPSK: The differentially encoded information bits of the modulator are used to modulate the carrier. In a DEMPSK signal stream, information is carried by the phase difference Δθi between two consecutive symbols. There are M different values of Δθi and each represents an n-tuple (n = log2M) of information bits.

The derivation of the demodulator is similar to that of binary DPSK. In DEMPSK a message mi of n = log2M bits is represented by the phase difference of two consecutive symbols. Therefore, mi is represented by a symbol with two symbol periods defined as

$$\xi i(t) = \begin{cases} A\cos\,[2\pi fct + \Phi 0], 0 \leq t \leq T \\ A\cos\,[2\pi fct + \Phi 0 + \Delta\theta i], T \leq t \leq 2T \end{cases}$$

The symbol error probability is given by [2]-

$$p_s = \frac{\sin\frac{\pi}{M}}{2\pi}\int_{-\pi/2}^{\pi/2} \frac{\exp\left\{-E/N_0\left[1-\cos\frac{\pi}{M}\cos x\right]\right\}}{1-\cos\frac{\pi}{M}\cos x}\,dx \ldots.(9)$$

For other values of M, it can only be numerically evaluated. Many approximate expressions have been found, a simple one is-

$$P_s \approx 2Q\left(\sqrt{\frac{2E}{N_0}}\sin\frac{\pi}{\sqrt{2}M}\right), \text{(optimum DMPSK)} \ldots..(10)$$

C. Fading Channel

For transmitting signal, we are considering three type of fading channel and they are Rayleigh and Nakagami-m and Rician fading channels.

The cause behind choosing two different fading environments is that we can evaluate the performance for both urban and rural area.

The probability density functions (PDF) of the fading channels are:

$$f_\Gamma(\gamma)|_{Rayleigh} = \frac{1}{\gamma_{avg}} e^{-\gamma/\gamma_{avg}}\ldots\ldots\ldots\ (11)$$

$$f_\Gamma(\gamma)|_{Nakagami-m} = \frac{m^m \gamma^{m-1}}{\gamma_{avg}{}^m \Gamma(m)} e^{-m\gamma/\gamma_{avg}}, \ldots\ldots.\ (12)$$

$$f_\Gamma(\gamma)|_{Nakagami-n}\ (Rician) =$$

$$\frac{(1+n^2)\ \ e^{-n^2}}{\gamma_{avg}} \exp\left(-\frac{(1+n^2)\gamma}{\gamma_{avg}}\right) \times I_0\left(2n\sqrt{\frac{(1+n^2)\gamma}{\gamma_{avg}}}\right)\ \ldots..(13)$$

where m is the Nakagami-m fading parameter which ranges from $^1\!/_2$to $^\infty$.

And n is the Rician fading parameter which ranges from 0 to ∞.

We can write the average probability of error in a fading environment as[11],

$$P_e = \int_0^\infty P_s(\gamma) f_\Gamma(\gamma)\,d\gamma \ldots\ldots\ldots(14)$$

MPSK: for M=8 using equations (3), (11) and (14)
Symbol error probability for Rayleigh channel-

$$P_e = \int_0^\infty \left[\frac{0.875 - 0.5erf\left(0.3827\sqrt{\gamma}\right) - 0.5642I}{\gamma_{av}}\right] e^{-\gamma/\gamma_{av}}\,d\gamma,$$

………… (15)
Where,

$$I = \int_0^{0.5\sqrt{\gamma(2-\sqrt{2})}} e^{-y^2} erf\left\{\frac{y\sqrt{\left(2+\sqrt{2}\right)}}{\sqrt{\left(2-\sqrt{2}\right)}}\right\} dy\,.$$

for M=8 using equations (3), (12) and (14)
symbol error probability for Nalagami-m channel-

$$P_e = \int_0^\infty 4\left[\frac{0.875 - 0.5erf\left(0.3827\sqrt{\gamma}\right) - 0.5642I}{\gamma_{av}}\right]$$

$$\times\left(\frac{\gamma}{\gamma_{av}^2}\right) e^{-2\gamma/\gamma_{av}}\,d\gamma; \quad m = 2.$$

for M=8 using equations (3), (13) and (14)
symbol error probability forNalagami-n (Rician) channel-

$$p_e = \int_0^\infty \frac{(1+n^2)e^{-n^2}\left[0.875 - 0.5\,erf(0.3827\sqrt{\gamma}) - 0.5642I\right]}{\gamma_{avg}}$$

$$e^{\left(\frac{-(1+n^2)\gamma}{\gamma_{avg}}\right)} \times I_0\left(2n\sqrt{\frac{(1+n^2)\gamma}{\gamma_{avg}}}\right) d\gamma \ldots\ldots(17)$$

MQAM: For M=16 using equations (8), (11) and (14)
Symbol error probability for Rayleigh channel-

$$p_e = \int_0^{\infty} \left[\frac{2 \langle 1 - erf \left[\sqrt{\frac{\Upsilon}{10}} \right] \rangle}{\gamma_{avg}} \right] e^{-\gamma/\gamma_{avg}}\, d\gamma \quad \ldots\ldots(19)$$

For M=16 using equations (8), (12) and (14)

Symbol error Probability for Namagami-m channel where m=2

$$p_e = \int_0^{\infty} \left[8 \langle - erf \left[\sqrt{\frac{\Upsilon}{10}} \right] \rangle \right] \frac{\gamma}{\gamma_{avg}^2} e^{-2\gamma/\gamma_{avg}}\, d\gamma \quad \ldots(20)$$

For M=16 using equations (8), (13) and (14)
Symbol error Probability for Namagami-n (Rician) channel

$$p_e = \int_0^{\infty} \left[\frac{\left((1+n^2) e^{-n^2} \right) \langle 2 - 2erf \left[\sqrt{\frac{\Upsilon}{10}} \right] \rangle}{\gamma_{avg}} \right] e^{\left(\frac{-(1+n^2)\gamma}{\gamma_{avg}} \right)}$$

$$\times I_0 \left(2n \sqrt{\frac{(1+n^2)\gamma}{\gamma_{avg}}} \right) d\gamma \quad \ldots\ldots(21)$$

DEMPSK: For M=4 using equations (9), (11) and (14)
Symbol error Probabilityfor Rayleigh channel-

$$\mathrm{p_e} = \int_0^{\infty} \left[\frac{\frac{\sin\frac{\pi}{4}}{2\pi}\ \mathrm{I}}{\gamma_{\mathrm{avg}}} \right] \mathrm{e}^{-\gamma/\gamma_{\mathrm{avg}}}\, \mathrm{d}\gamma \quad \ldots\ldots\ldots\ldots\ldots(22)$$

$$\mathrm{I} = \int_{-\pi/2}^{\pi/2} \frac{exp\left\{ -\gamma \left[1 - \cos\frac{\pi}{4} cosx \right] \right\}}{1 - cos\frac{\pi}{4} cosx}\, dx$$

For M=4,*Symbol error Probability for Namagami-m channel where m=2*

$$p_e = \int_0^{\infty} \left[4 \frac{sin\frac{\pi}{4}}{2\pi}\ I \right] \frac{\gamma}{\gamma_{avg}^2} e^{-2\gamma/\gamma_{avg}}\, d\gamma \quad \ldots\ldots\ldots\ldots(23)$$

$$\mathrm{I} = \int_{-\pi/2}^{\pi/2} \frac{exp\left\{ -\gamma \left[1 - \cos\frac{\pi}{4} cosx \right] \right\}}{1 - cos\frac{\pi}{4} cosx}\, dx$$

using equations (9), (12) and (14)

For M=4 using equations (9), (13) and (14)
Symbol error Probability for Namagami-n (Rician) channel

$$p_e = \int_0^{\infty} \left[\frac{\left((1+n^2) e^{-n^2} \right) \frac{sin\frac{\pi}{4}}{2\pi}\ I}{\gamma_{avg}} \right] e^{\left(\frac{-(1+n^2)\gamma}{\gamma_{avg}} \right)}$$

$$\times I_0 \left(2n \sqrt{\frac{(1+n^2)\gamma}{\gamma_{avg}}} \right) d\gamma \quad \ldots\ldots\ldots\ldots\ldots(24)$$

III. RESULTS AND DISCUSSIONS

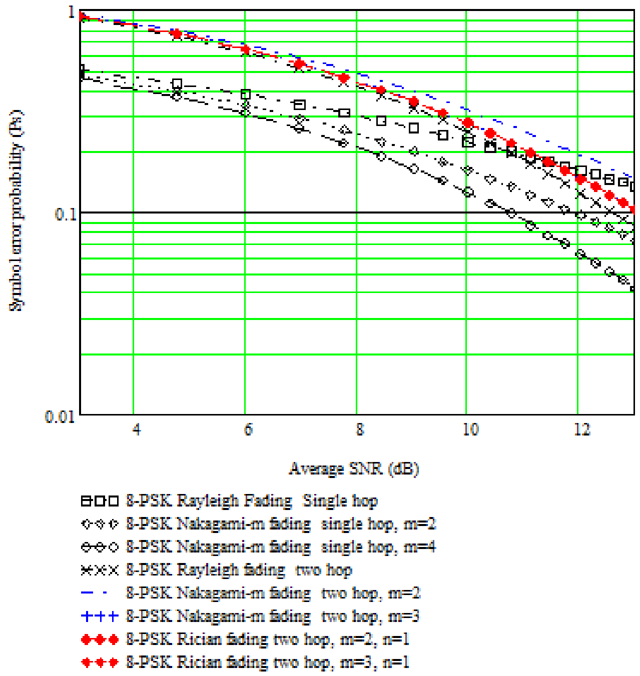

Fig 1:- Comparison of modulation performance of single and dual hop fading channel for 8-PSK scheme.

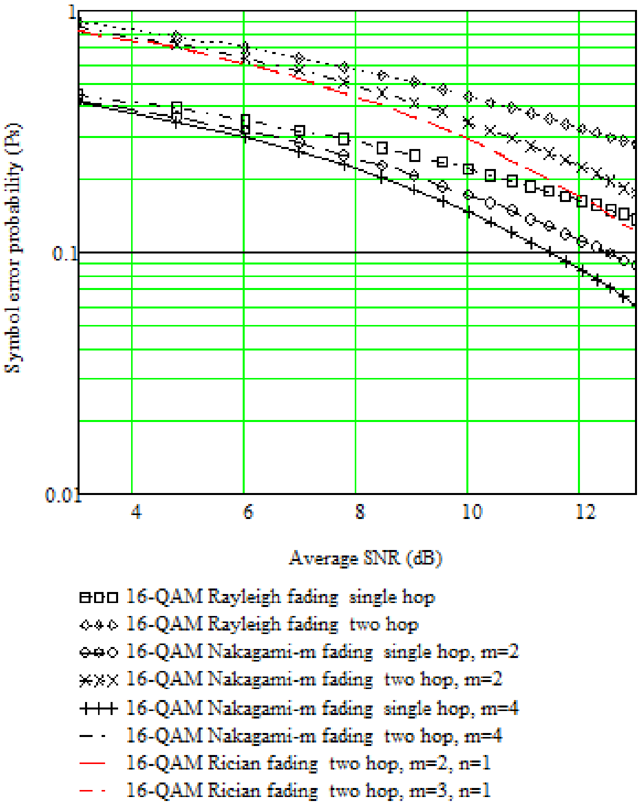

Fig 2:- Comparison of modulation performance of single and dual hop fading channel for 16-QAM scheme.

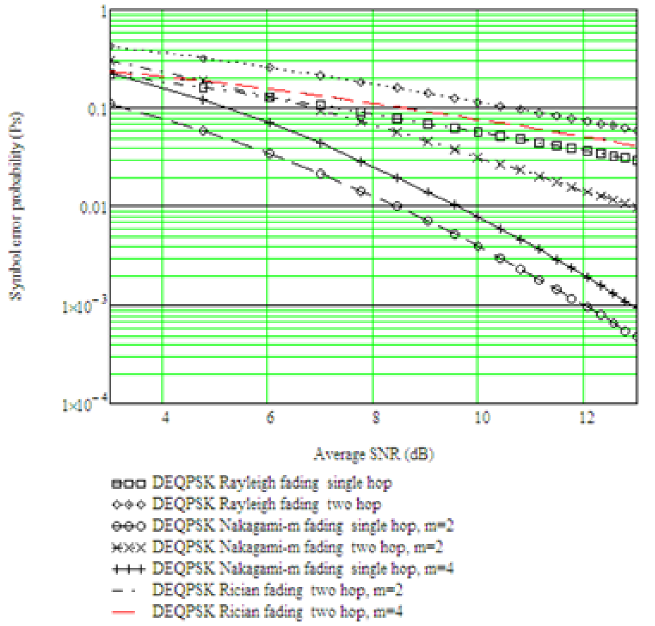

Fig 3:- Comparison of modulation performance of single and dual hop fading channel for DEQPSK scheme.

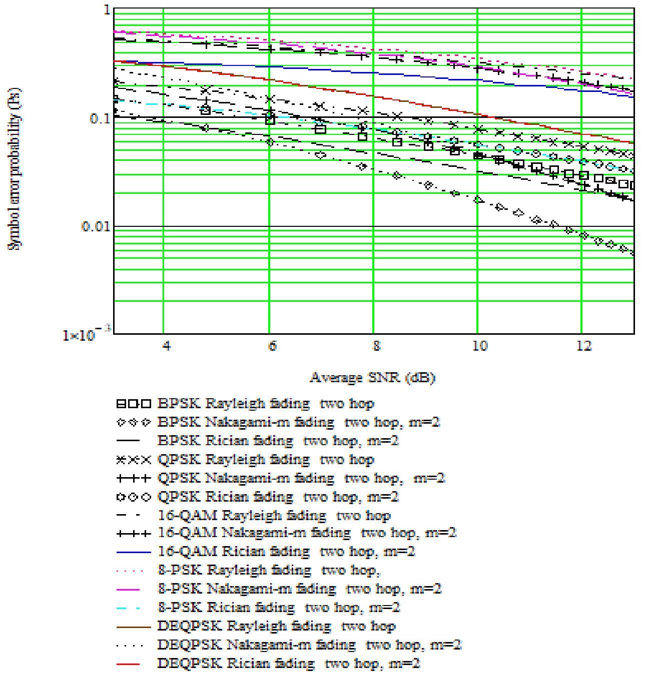

Fig 4:- Comparison of Different modulation scheme on two hop link.

The Figure 1 does illustration for 8PSK cases, how Ps of fading channel varies according to mean SNR (calculated in dB) in single and double hop (Rayleigh, Nakagami-m and Rician) link.Single- link has better performance than duel hop links for all fading cases. Morever when SNR increases the distance between single and double hop curves also increases. The reason of this situation can be illustrated as: Since there is neither forward error correction nor any combining technique considered on the repeater, the second-hop performance rely on the first hop.Nakagami-m(for m= 2) fading channel perform better than Rayliegh fading channel, but has much similar performace with Rician channel. But as m (m=2,3,4) increases Nakagami-m fading channel performance get better illustrated in Figure 1. Figure 2 illustrates similar performane analysis for 16 QAM cases. However, Figure 1 and Figure 2 comparison clarifies that Ps of all 8PSK cases are lower than that of QAM cases and this phenomenon can be understood from single space concept. From figure 3 it is seen that for DEQPSK Nakagami has better performance than Rayleigh and Rician.

Figure 4 shows Ps for modulation schemes BPSK,QPSK,8-PSK,16-QAM and DEQPSK in single and duel hop Rayleigh, Nakagami and Rician fading environment. The performance of the channels are calculated according the signal space of the constellation of the modulation techniques.The comparison shows that, 8PSK Rayleigh (two hop) has the lowest and BPSK Nakagami-m (two hop) has the best performance.

According to the above calculation and comparison , we find the performance of different modulation schemes (8-PSK,16-QAM,DEQPSK) for double hop wireless link under Rayleigh , Nakagami-m and Rician fading channels. As two hop links are highly affected by all type of fading , utilizing some extra procedures would be helpful to gain better performance such as: combining scheme of MISO/SIMO/MIMO, adaptive equalization, incorporation of STBC,etc. Nowdays , although it is quite difficult to do this kind of analysis when multiple antennas exists both at sender and receiver, containing single antenna on repeater, the perrformace gets improved. Here the result section is focused on simulated results. However usually in real environments these results highly regulates with location and time due to smale scale fading. The extension of these research can be done analyzing other modulation techniques like MSK, GMSK, M-PSK, π/4 PSK, OOPSK etc.

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