

Multipath Rayleigh Fading analysis and Remedial Measures Technique Based on Healthcare Wireless Ad Hoc and Sensor Networks applied to disaster rescue

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Abstract—Recently, there has been increased interest in the district of ad-hoc networks, that can operate without infrastructure and capable of handle node mobility as well as dynamic network topologies. Due to these possessions, ad-hoc networks have been used in a lot of critical applications, such as military, law enforcement, and disaster-relief operations. Managing of resources in a disaster is not easy, while a rescue staff spread across broad swaths of the disaster district, situational responsiveness is preserved by hand-written tables and charts, and updates arrive in the form of oral messages using radio or messenger. Hence in this location wireless ad hoc and sensor networks (WASNs) can greatly improve situational awareness by enhancing an automating to update, checking and reacting to status modifies, and increasing data communications across the whole disaster. Thus, statistical model which is the best way for estimating signal and channel behavior in multi-paths fading is done for WASNs system with various probabilities. Moreover, this paper investigates remedial measures against Rayleigh fading by BER performance simulation for Quadrature amplitude modulation QAM, Phase Shift Keying PSK and Differential DPSK with cooperative MIMO. The performance analysis with different modulation modes (M) and diversity order (L) with Matlab simulation shows that bit error rate gain performance is much better when increasing L than when increasing M.

Index Terms— Wireless Ad-hoc and sensor network (WASNs), Rayleigh fading, remedial measures, BER

1 INTRODUCTION

There is increased interest in the research area of district of ad-hoc networks, that can operate without infrastructure and capable to handle node mobility as well as dynamic network topologies. Due to these possessions, ad-hoc networks have been used in a lot of critical applications, for example military, law enforcement, and disaster-relief operations [1]. Managing of resources in a disaster is not easy. Rescue staff spread across broad swaths of the disaster district. Situational responsiveness is preserved by means of hand-written tables and charts. Updates arrive in the form of oral messages using radio or messenger. In this location, wireless ad hoc and sensor networks (WASNs) can greatly improve situational awareness by enhancing and automating to update, checking and reacting to status modifies, and increasing data communications across the whole disaster [2]. Wireless ad-hoc networks accomplish larger geographic coverage and improved energy and spectral efficiency during multi-hop relaying, through which each packet is delivered to its destination. Although the received signal envelope is Rayleigh faded beneath non-line-of-sight, narrowband frequency flat-fading propagation conditions, but the mobility of both the sender and the receiver results in diverse statistical characteristics of mobile-to-mobile wireless channels [3] & [4]. Designing of efficient wireless communication schemes requires good understanding of the radio propagation channel. The radio channel characteristics will vary very much with operating frequency and propagation environment, such as, line-of-sight

(LOS) broadcast and non-line-of sight (OLOS), fixed versus mobile transmitters and receivers [5]. In multipath channel situations, the distribution of large numbers of wireless impairments such as reflecting, refracting, diffracting, and scattering substances becomes random. Thus, several multiple paths can be created and will be very difficult to effort to model the channel deterministically. In this case, statistical model becomes the best way for estimating signal and channel behavior.

2 SYSTEM MODEL

Fading is a word used to explain the fluctuations in a received signal according to multipath components. It can be classified into fast and slow fading, also can be classified into flat and frequency selective fading. Fast fading is a transmission which is characterized by fast fluctuations over very short distances, as a result to scattering from close objects, and hence is named small-scale fading. Normally fast fading can be viewed up to half-wavelength distances. Therefore, when there is no direct path then a Rayleigh distribution is the best fit for this type of fading, otherwise a Rician distribution can be used to model fast fading [6]. By referring to Fig.1, of ad-hoc and sensor network, applied to the disaster rescue, the composite received signal between the rescue team and survivor, consist of a large number of sinusoidal components, thus the complex envelope $g(t) = g_1(t) + jg_2(t)$ can be treated as a complex Gaussian ran-

dom process. If $g_1(t)$ and $g_2(t)$ are assume that at any time t_1 are independent identically Gaussian random variable with zero mean and variance $b_0 = E[g_1^2(t_1)] = E[g_2^2(t_1)]$. Here the magnitude of a received complex envelope

$$\alpha \square |g(t_1)| = \sqrt{g_1^2(t_1) + g_2^2(t_1)} \quad (1)$$

has a Rayleigh distribution at any time as in [5], that is

$$p_a(x) = \frac{x}{b_0} \exp\left\{-\frac{x^2}{2b_0}\right\}, \quad x \geq 0 \quad (2)$$

the average envelope power is $\Omega_p = E[\alpha^2] = 2b_0$ so that

$$p_a(x) = \frac{2x}{\Omega_p} \exp\left\{-\frac{x^2}{\Omega_p}\right\}, \quad x \geq 0 \quad (3)$$

this kind of fading is called Rayleigh fading. The corresponding spread envelope $\alpha^2 = |g(t)|^2$ is exponentially distributed at any time t_1 with density

$$p_a(x) = \frac{1}{\Omega_p} \exp\left\{-\frac{x}{\Omega_p}\right\}, \quad x \geq 0 \quad (4)$$

According to disaster nature we assume no direct path between the survivor and rescue team or between two rescue teams.

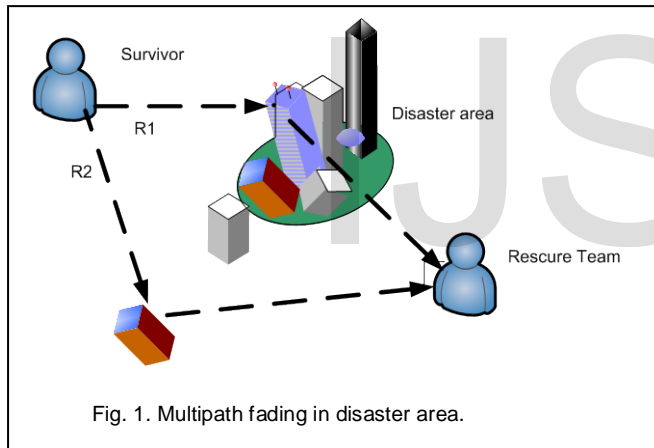


Fig. 1. Multipath fading in disaster area.

3 SYSTEM ANALYSIS

3.1 Fast fading without direct path

If we assume no direct path between the sender and receiver, as in fig. 1. The received voltage phasor can be expressed as the sum of all the probable multipath component voltages surrounded by the receiver. In this scenario, the channel is modeled as the sum of all the possible

$$v_{rs} = \sum_{n=1}^N a_n e^{-j(kr_n - \alpha_n)} = \sum_{n=1}^N a_n e^{j\phi_n} \quad (5)$$

where, a_n and α_n are the random amplitude and random phase associated with the n^{th} path respectively, r_n length of n^{th} path, and $\phi_n = -kr_n + \alpha_n$.

If a randomly distributed of scattering is assumed large, then the phases ϕ_n can be assumed uniformly distributed. Thus, the time domain of received voltage can be expressed as

$$v_r = \sum_{n=1}^N a_n \cos(\omega_0 t + \phi_n) = \sum_{n=1}^N a_n \cos(\phi_n) \cos(\omega_0 t) - \sum_{n=1}^N a_n \sin(\phi_n) \sin(\omega_0 t) \quad (6)$$

If we further simplify the Eq. (6) by using trigometric identity, then we get

$$v_r = X \cos(\omega_0 t) - Y \sin(\omega_0 t) = r \cos(\omega_0 t + \phi) \quad (7)$$

where, $X = \sum_{n=1}^N a_n \cos(\phi_n)$, $Y = \sum_{n=1}^N a_n \sin(\phi_n)$, $r = \sqrt{X^2 + Y^2} = \text{envelope}$, and $\phi = \tan^{-1}\left(\frac{Y}{X}\right)$. With referring to Central Limit Theorem, the random variables X and Y will follow a Gaussian distribution with zero mean and standard deviation σ , and that in the limit as $N \rightarrow \infty$. As well, the phase ϕ can be modeled as a uniform distribution $p(\phi) = \frac{1}{2\pi}$ for $0 \leq \phi \leq 2\pi$. The envelope r is indicated the result of a 2π transformation of the random variables X and Y and proven to be followed a Rayleigh distribution. The density function of the Rayleigh probability can be described as

$$p(r) = \frac{r}{\sigma^2} e^{-\frac{r^2}{2\sigma^2}} \quad r \geq 0 \quad (8)$$

Fig. 2. shows a simulation of a Rayleigh distribution for three different standard deviations. Clear when the variance increases, the height of the Rayleigh probability density function decreases.

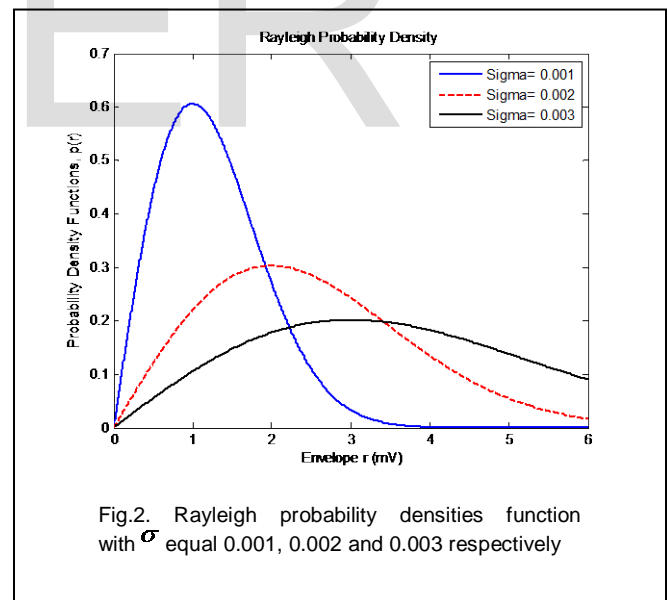


Fig.2. Rayleigh probability densities function with σ equal 0.001, 0.002 and 0.003 respectively

3.2 Fast fading with direct path

Considering a probability of direct path, with the direct path amplitude A (volts)

$$v_r = A \cos(\omega_0 t) + \sum_{n=1}^N a_n \cos(\omega_0 t + \phi_n) = \left[A + \sum_{n=1}^N a_n \cos(\phi_n) \right] \cos(\omega_0 t) - \sum_{n=1}^N a_n \sin(\phi_n) \sin(\omega_0 t) \quad (9)$$

Again, the envelope $r = \sqrt{X^2 + Y^2}$. The random variables X and Y will be

$$\begin{aligned} X &= A + \sum_{n=1}^N a_n \cos(\phi_n) \\ Y &= \sum_{n=1}^N a_n \sin(\phi_n) \end{aligned} \quad (10)$$

Here the random variable X indicates Gaussian with mean of A and standard deviation of σ . Random variable Y indicates Gaussian with zero mean and standard deviation of σ . The probability density function for the envelope at the moment is a Rician distribution and is given by

$$p(r) = \frac{r}{\sigma^2} e^{-\frac{(r^2 + A^2)}{2\sigma^2}} I_0\left(\frac{rA}{\sigma^2}\right) \quad r \geq 0 \quad A \geq 0 \quad (11)$$

Where $I_0(\cdot)$ = Modified Bessel function of the first kind of a zero-order.

The Rician distribution can be characterized by a parameter $k = A^2 / (2\sigma^2)$, where, K is the direct signal power to the multipath variance ratio and is called Rician factor, it can be expressed in dB as

$$k(dB) = 10 \log_{10} \left(\frac{A^2}{2\sigma^2} \right) \quad (12)$$

If $A = 0$, then the Rician distribution reverts to a Rayleigh distribution

3.3 Motion and multipath fading

Since motion means changing the position of the transmitter or receiver, it changes the channel behavior. Furthermore, motion introduces a lot of discrete Doppler shifts in a received signal. As ad-hoc node moves at a constant velocity, then many factors change with time. The angles θ_n of each multipath signal will be time dependent. Every multipath experiences a different Doppler shift for the reason of scattering with respect to the moving ad-hoc node is different for every scattering object. Moreover, the overall phase shift α_n will be changed with time as the propagation delays are changing. So the maximum possible Doppler shift can be given by:

$$f_d = f_0 \frac{v}{c} \quad (13)$$

Where f_d is doppler frequency, v is node velocity, and c is the speed of light. Since the direction of ad-hoc node travel is at an angle θ_n with the n^{th} multipath, and then the Doppler shift is modified accordingly. The Doppler shift for a known path is given by

$$f_n = f_d \cos \theta_n = f_n \frac{v}{c} \cos \theta_n \quad (14)$$

By rewriting Eq. (6) accounting for the Doppler frequency shifts f_n then

$$\begin{aligned} v_r &= \sum_{n=1}^N a_n \cos(2\pi f_n t + \phi_n) \cos(\omega_0 t) \\ &- \sum_{n=1}^N a_n \sin(2\pi f_n t + \phi_n) \sin(\omega_0 t) \\ &= \sum_{n=1}^N a_n \cos(2\pi f_d \cos(\theta_n) t + \phi_n) \cos(\omega_0 t) \end{aligned}$$

$$- \sum_{n=1}^N a_n \sin(2\pi f_d \cos(\theta_n) t + \phi_n) \sin(\omega_0 t) \quad (15)$$

Now we have three random variables; those are a_n , ϕ_n and θ_n . The amplitude coefficients are Gaussian distributed while the phase coefficients are supposed to have a uniform distribution such that $0 \leq \phi_n$ and $\phi_n \leq 2\pi$. For the second time, the envelope of v_r has a Rayleigh distribution. The envelope r is given by

$$r = \sqrt{X^2 + Y^2} \quad (16)$$

where $X = \sum_{n=1}^N a_n \cos(2\pi f_d \cos(\theta_n) t + \phi_n)$, and

$$Y = \sum_{n=1}^N a_n \sin(2\pi f_d \cos(\theta_n) t + \phi_n) \quad \text{and is called Clarke flat.}$$

3.4 Modeling the discrete multipath channel

If the radio channel is assumed to be modeled as a linear filter, then the features of the channel can be modeled by obtaining the impulse response of the channel. In case the multipath channel is composed of a group of discrete resolvable components that produced as reflections or scattering from small constructions like houses and small hills it is named a discrete multipath channel. The model here in general has variable tap gains, variable delays beside the number of taps, and is applicable, mostly to fast changing environments [6] & [7]. The discrete multi-path channels can be modeled by

$$y(t) = \sum_n a_n(t) s(t - \tau_n(t)) \quad (17)$$

Where $s(t)$ is the bandpass input signal, $|a_n(t)|$ is the attenuation factor for a signal received on a given path, and $\tau_n(t)$ is the equivalent propagation delay. If we explain $s(t)$ as

$$s(t) = \text{Re}\{s^{\sim}(t) e^{j2\pi f_c t}\}$$

next channel output can be expressed as

$$y(t) = \text{Re}\left\{ \left[\sum_n a_n(t) e^{-j2\pi f_c \tau_n(t)} s^{\sim}(t - \tau_n(t)) \right] e^{j2\pi f_c t} \right\} \quad (18)$$

The complex envelope of the output is given by

$$\begin{aligned} y^{\sim}(t) &= \sum_n a_n(t) e^{-j2\pi f_c \tau_n(t)} s^{\sim}(t - \tau_n(t)) \\ &= \sum_n a_n^{\sim}(\tau_n, t) s^{\sim}(t - \tau_n(t)) \end{aligned} \quad (19)$$

Eq. 19 explains that the fading channel can be expressed with a time-varying, complex, and low pass corresponding to the impulse response $c^{\sim}(\tau_n(t), t)$,

$$c^{\sim}(\tau_n(t), t) = \sum_n a_n^{\sim}(\tau_n(t), t) \delta(t - \tau_n(t)) \quad (20)$$

The discrete multipath channel of Eq. 20 is given by

$$c^{\sim}(\tau, t) = \sum_{n=1}^{N(t)} a_n^{\sim}(\tau_n(t), t) \delta(t - \tau_n(t))$$

With the equivalent lowpass-equivalent output

$$y^{\sim}(t) = \sum_{n=1}^{N(t)} a^{\sim}_n(\tau_n, t) s^{\sim}(t - \tau_n(t)) \quad (21)$$

Not only, the number of discrete components is assumed to be constant for many channels, but also the delay values is assumed to be differ very slowly. Then the model then simplifies to

$$c^{\sim}(\tau, t) = \sum_{n=1}^N a^{\sim}_n(t) \delta(\tau - \tau_n) \quad (22)$$

With the lowpass-equivalent output

$$y^{\sim}(t) = \sum_{n=1}^N a^{\sim}_n(t) s^{\sim}(t - \tau_n) \quad (23)$$

and is as well represented as a tapped delay line.

4 PERFORMANCE OF MODULATION UNDER FADING

4.1 BER analysis

The received signal power on the fading channel is vary locally around an average. The average bit error probability over a multipath fading distribution is the suitable performance measure with such channels [8]. So, by assuming the bit error probability in additive white Gaussian noise (AWGN) is known, then the conditional bit error probability on the fading channel will be represented by $p_b(\text{error} | \gamma_b)$ where γ_b is the instant received E_b/N_0 . Given that γ_b is just a scaled version of the received power, it is simple to find the pdf of γ_b , since the pdf of the received power is known. The expected value of the signal to noise ratio (SNR) over the fading distribution $\mathcal{E}\{\gamma_b\}$ will be indicated by Γ_b and will be referred to as the average E_b/N_0 . Then the average bit error probability will be

$$p_b = \mathcal{E}\{p_b(\text{error} | \gamma_b)\} = \int_0^{\infty} p(\gamma_b) p_b(\text{error} | \gamma_b) d\gamma_b \quad (24)$$

Where p_b is implicitly a function of Γ_b .

The conditional bit error probability for both BPSK and QPSK with coherent detection will be $p_b(\text{error} | \gamma_b) = Q(\sqrt{2\gamma_b})$, while on a Rayleigh fading channel the probability of average bit error becomes

$$p_b = \frac{1}{2} \left(1 - \sqrt{\frac{\Gamma_b}{1 + \Gamma_b}} \right) \quad (25)$$

With the limiting value

$$p_b \rightarrow \frac{1}{4\Gamma_b} \text{ as } \Gamma_b \rightarrow \infty \quad (26)$$

The formula in Eq. (26) can be used to get an expression for the average bit error probability for each modulation/detection system and any fading distribution, since the probability in AWGN and the pdf of the received power are known. Figure 4, indicates that the simulation results are close to the theoretical predictions computed by bit error rate fading, but we all still searching for better results.

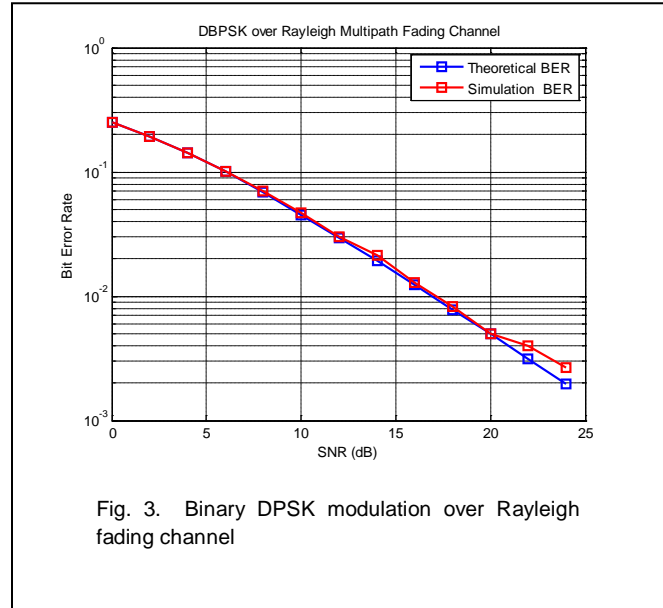


Fig. 3. Binary DPSK modulation over Rayleigh fading channel

Quadrature amplitude modulation (QAM) is an appropriate technique to transmit data in modern digital communications. It has been extensively used due to its high-bandwidth efficiency. If the number of bits per symbol is even, the transmission can be simply implemented by using square QAM [9] & [10]. For obtaining high bit rate transmissions in wireless communication networks, a restriction of the limitation on spectrum resources is important. The utilize of M-ary QAM is considered the good technique to overcome this restriction because of its high spectral efficiency, beside it has been considered and proposed for wireless systems by a number of authors [11]. Base on this, a theoretical BER simulation of a Rayleigh fading for three modulations techniques, mainly Quadrature amplitude modulation QAM, Phase Shift Keying PSK and Differential DPSK are obtained in Fig. 4. The analysis of simulation shows that at $m = 8$ and for the same BER, the curve of the QAM is identical to that of PSK, while DPSK needs more than 2 dB energy to noise power spectral density. Furthermore at $m=16$ and BER equal 10^{-2} , QAM modulation needs more than 2 dB less than PSK and more than 4 energy to noise power spectral density than DPSK. Moreover, for $m=32$ QAM achieves best energy to noise power spectral density than the other type of modulations.

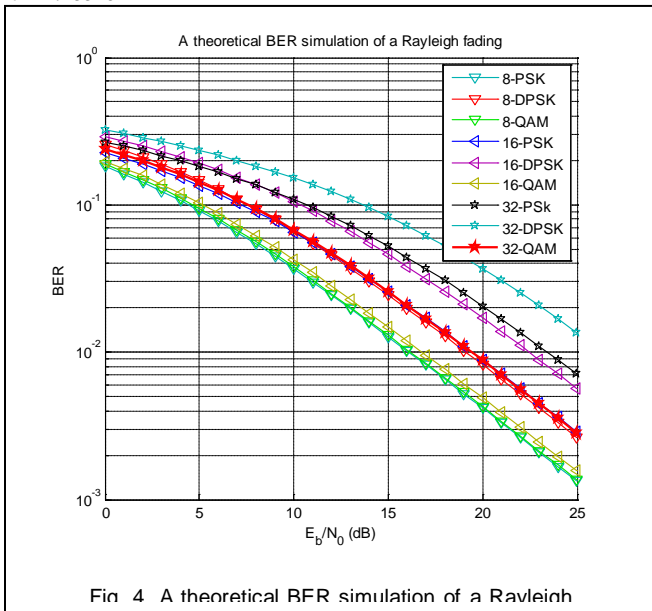


Fig 4 A theoretical BFR simulation of a Ravleigh

4.2 Modulation and Diversity Techniques

Fading in Rayleigh can decrease the BER performance of modulation techniques significantly. Remedial measures against this type of fading must be adopted to conserve or at least partially conserve the BER performance. One of the measures against fading is to utilize a differential modulation scheme in which carrier phase synchronization is not required, and the other one is the diversity technique [12 - 14].

An ad hoc wireless network is a group of wireless movable nodes that self-configure to form a network with no infrastructure. In addition of using Multiple-input multiple-output (MIMO) techniques in ad-hoc networks when a node in the network has multiple antennas, the clusters of nodes that are situated close together can swap information to make a virtual antenna array, guiding to a distributed MIMO system. This means the nodes that are close together on the transmit side can swap information to shape a multiple-antenna transmitter, also nodes close to each other on the receiver side can swap information to shape a multiple-antenna receiver [15].

4.3 Simulation Result

Fig. 5, 6, and seven show the simulations' results of different modulation techniques with virtual diversity. By comparing the computer simulation results of bit error rate of PSK, DPSK, and QAM modulations with diversity, we find that at 10^{-4} , QAM requires 4dB less than PSK and DPSK respectively, which is enhanced the power used. Therefore, we can conclude that the QAM is achieved better performance than other techniques. Furthermore, we compare the same diversity order with different mode for the 16-QAM, and we find that there is a considerable gain in performance achieved by increasing diversity order. The gain in performance achieved with an increase in m is somewhat small. Conversely, when the diversity order increases the gain obtained with enlarge m as well increases. Accordingly, as shown in Fig. 8, 9, and 10,

that an increase in diversity order more efficient than the increase in modulation mode, and this why we propose 16-QAM as best modulation in order to preserve the BER performance.

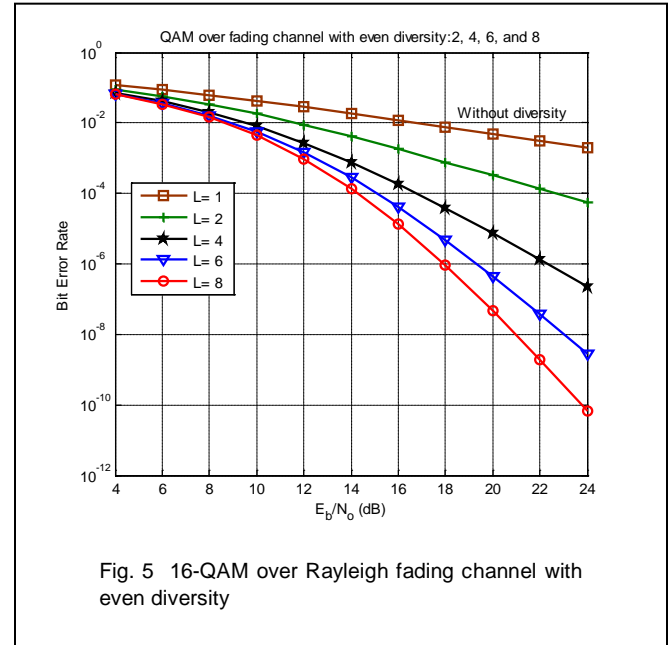


Fig. 5 16-QAM over Rayleigh fading channel with even diversity

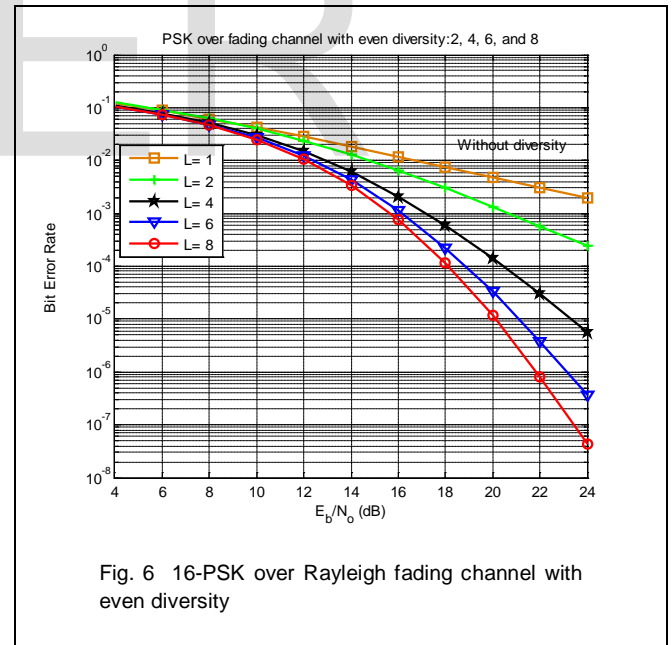


Fig. 6 16-PSK over Rayleigh fading channel with even diversity

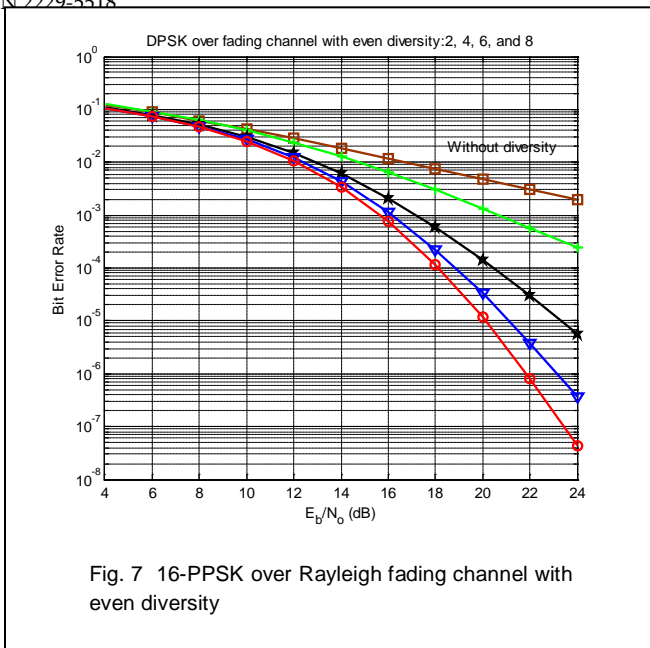


Fig. 7 16-PPSK over Rayleigh fading channel with even diversity

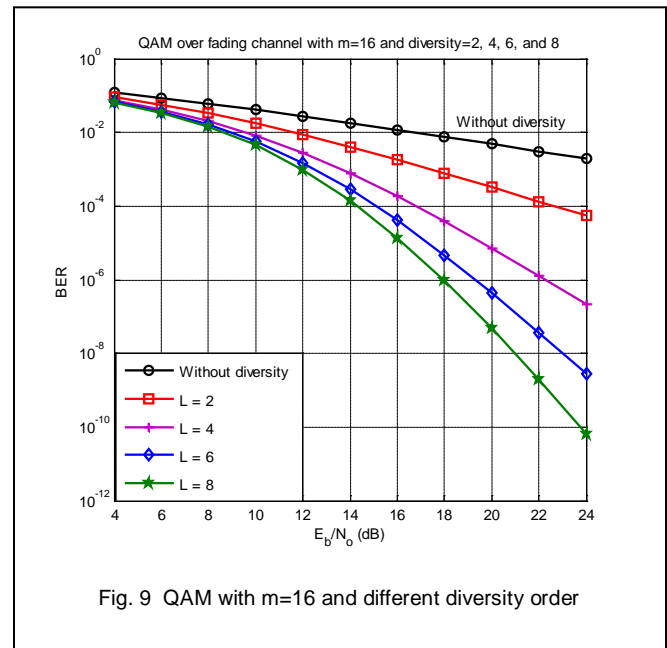


Fig. 9 QAM with m=16 and different diversity order

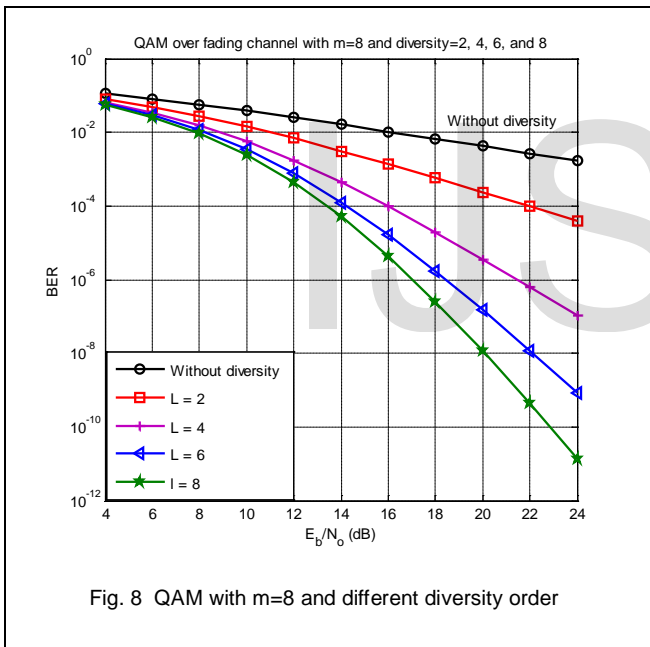


Fig. 8 QAM with m=8 and different diversity order

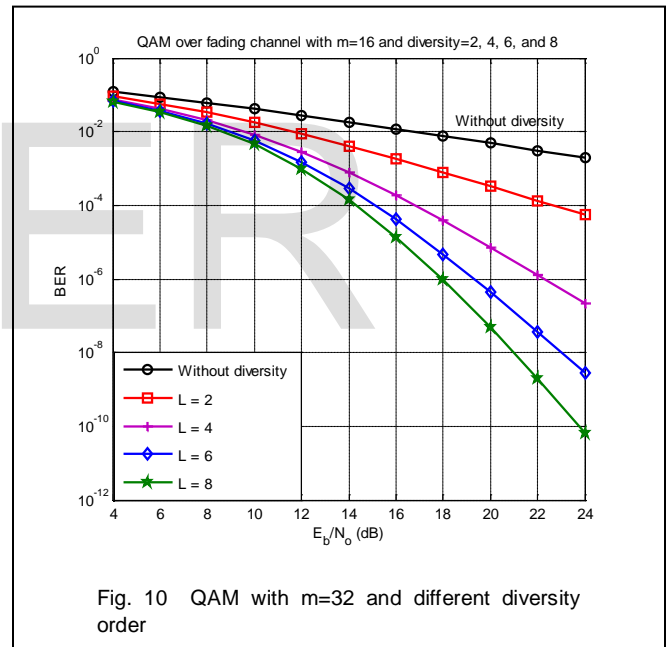


Fig. 10 QAM with m=32 and different diversity order

5 CONCLUSION

This paper presents statistical model for WASNs which is consider the best way for estimating signal and channel behavior in multi-paths fading. Moreover, remedial measures against Rayleigh fading are performed by obtaining simulation results of BER performance for QAM, PSK and Differential DPSK with cooperative MIMO. From the previous diagrams it is clearly shown that the best choice will be when increasing diversity order than when increasing modulation modes.

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