Performance Evaluation and Simulation of Binary Signalling with EGC in Generalized Flat-Fading Channels

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Abstract

In this paper, a performance investigation of Equal Gain Combining (EGC) multichannel receiver over Generalized Flat-fading channels is presented. The Generic-Gamma fading model has been used here which is versatile enough to represent most of the short term fading conditions as well as long term Shadowing. The Average Bit Error Rate (ABER) has been evaluated for Coherent and Differentially-Coherent binary modulation formats. With the aid of Moment based approach, computationally efficient rational expressions have been derived. Using these novel expressions, the performance of multichannel wireless receiver with EGC and without diversity combining has been evaluated in variety of generalized flat-fading conditions. The results have been validated through simulations which shows perfect match.

Keywords: Diversity Combining, Binary Differential Phase Shift Keying, Coherent Phase Shift Keying, Moment Generating Function, Equal Gain Combining

1. Introduction

Due to ever-increasing demand and ubiquitous access of personal communication services, wireless systems are required to operate in increasingly hostile environments. Wireless systems designers have augmented interest in accurate and flexible models for characterizing the performance of wireless communication systems over fading channels in order to adequately predict the performance. Fading has long been modeled using Rayleigh and Rician models, but they lack flexibility to fit in these new increasingly diverse fading scenarios. Nakagami-m and Weibull distributions based on single fading parameter are widely accepted because they provide better fit with experimental results. These models cover a range of fading scenarios which includes the Rayleigh distributions as special cases and can closely approximate the Rician and Hoyt distributions. More importantly, situations are encountered for which none of these distributions seem to adequately fit experimental data, though one or another may yield a moderate fitting [1]. This may be attributed to the fact that fading distributions are derived assuming homogeneous diffuse scattering field, resulting from randomly distributed point scatterers [2]. The assumption of homogeneous diffuse scattering field is definitely an approximation because the surfaces are spatially correlated characterizing a heterogeneous environment [3]. More recently, a versatile wireless channel model based on two-parameter Generalized-Gamma distribution has gained rekindled interest that can generalize almost all commonly used models for multipath fading [4]. It includes short term fading models such as Rayleigh, Nakagami-m, & Weibull as special cases and long term shadowing model as the limiting case. Therefore, Rayleigh, Rician and one sided Gaussian are also special cases indirectly. Given this, the performance analysis of wireless systems using this flexible small scale fading models is valuable because the literature on performance analysis is relatively sparse in this case. ABER closed form expressions for binary phase shift keying and binary frequency shift keying modulations in terms of MeijerG and Fox's-H special functions were presented in [5]. The Generic-Gamma model has also been used recently in [6] for single channel receivers analysis and generalized switched diversity combining system in [7]. Moreover, the detailed and unified performance analysis for the SNR statistics of EGC diversity receivers operating over Generic-Gamma fading is not available in the open literature and thus is the topic of our contribution. In this paper, Padé method has been used to obtain computationally efficient rational expressions for the moment generating function (MGF). Using these novel expressions, the ABER of important binary digital modulation schemes for wireless receivers employing EGC diversity combining have been evaluated. Computer simulations are also generated for the result verifications. Earlier, the Padé method was used for performance analysis of diversity systems in Nakagami-m fading [8] and in Weibull fading [9].

The rest of the paper is organized as follows. In the next section, Multichannel Fading model has been presented. Section 3 details the performance analysis of the system in terms of Statistical moments of output SNR, EGC diversity, and error rate. Moments based rational expressions have also been presented in this section. The numerical and simulation results have been presented in Section 4, before the paper is finally concluded in Section 5.

2. Multi-Channel Fading Model

The magnitude of the complex fading envelope through channel can be modeled as wide sense stationary random process $x(t) = |h(t)|$ and all frequency components of the received signal will be subjected to same channel gain. The transmitted signal can be assumed to be received through spatial diversity as multiple copies through diverse multilink L independent fading channels. Because of the flat-fading and stationary environment assumption, each channel amplitude and phase at any given time or space are represented as random variables x_l and ϕ_l, respectively. It is also assumed that the channel amplitude, phase and delay associated with each channel are constant over the signaling interval. Thus, the received signal at the l^{th} branch can be written as

$$y_l = x_l e^{-j\phi_l} \left(s - t\tau\right) + n \in \{1 \quad ,\}. \qquad \text{............(1)}$$

where, $s(t-\tau_l)$ is the delayed transmitted signal with energy E_s, and τ_l is the channel delay and n_l is AWGN with power spectral density $N_l/2$ per dimension. It is assumed that the phase shift introduced by the channel is perfectly tracked at the receiver. Moreover, analyses of systems employing coherent modulations assume that the phase effects due to fading are perfectly corrected at the receiver. While, for non-coherent modulations, phase information is not needed and therefore the phase variation due to fading does not affect the performance in this case. Hence, performance analyses over fading channels require the knowledge of only the fading envelope amplitude statistics. The fading envelope amplitudes $\{x_l\}_{l=1}^{L}$ are assumed to be statistically independent Random Variables (RV) whose mean square values $\left\{\overline{x_l^2}\right\}_{l=1}^{L}$ are denoted by $\{\bar{\Omega}_l\}_{l=1}^{L}$ and whose PDFs are dependent on the variety of wireless channel scenarios. These Generalized fading channels have been modeled here by Generic-Gamma distribution, which can generalize almost all commonly used models for multipath fading [4]. It includes flat-fading models such as Rayleigh, Nakagami-m, & Weibull as special cases. This versatile model has demonstrated a superior fit to the measured data over a wide range of physical channel conditions in [10]. The PDF of the Generic-Gamma RV is given by

$$p_{x_l}(x_l) = \frac{2\nu_l x_l^{(2\nu_l m_l - 1)}}{\Gamma(m_l)\left(\bar{\Omega}_l / m_l\right)^{m_l}} exp\left(-\frac{m_l x_l^{2\nu_l}}{\bar{\Omega}_l}\right) \qquad x_l \geq 0 \qquad \text{.................(2)}$$

where ν_l is the shape parameter, m_l is the fading parameter , $\bar{\Omega}_l$ is the average SNR scaling parameter and $\Gamma(.)$ is the Gamma function. The fact that this distribution has one more parameter than the well-known distributions renders it more flexible to better adjust with measurement data. Moreover, this model is based on more realistic heterogeneous scattering environment. For wireless systems, generalized gamma model provides a simple way to model all forms of channel fading conditions including shadowing. By varying the two parameters v and m, different fading and shadowing conditions can be described. For instance, $v = 1$, (2) represent Nakagami-m fading; $m = 1$, (2) represent Weibull fading; $m = v = 1$, (2) represent Rayleigh fading. The lognormal distribution used to model shadowing can also be well approximated for limiting case for $m \to \infty$ and $v \to 0$.

3. Performance Analysis

It is well known that the performance of wireless communication system, in terms of ABER will depend on the statistics of the SNR. The received instantaneous signal power in the l^{th} channel is affected by two random processes AWGN and fading power x_l^2. The AWGN is assumed to be statistically independent from the channel fading or complex fading envelope, i.e., $E\left[n_j h_l^*\right] = 0$ for any j *and* $l \in \{1,....,L\}$ where z^* and $E[z]$ denote the complex conjugate and the average of z. AWGN with identical double-sided power spectral densities is added to each diversity branch signal $(N_l = N_0)$ for any $l \in \{1,....,L\}$. Moreover, the AWGN is assumed to be uncorrelated between different branches, i.e., $E\left[n_j n_l^*\right] = N_0 \delta_{jl}$, where δ_{jl} is the Kronecker delta function defined as $\delta_{jj} = 1$, and $\delta_{jl} = 0$ for $j \neq l$. Thus, with all aforesaid considerations the instantaneous SNR per bit can be expressed as $\gamma_l = x_l^2 E_s / N_0$. Further, all channel gains are assumed to have same average power, i.e., $E\left[\left|h_j\right|^2\right] = E\left[\left|h_l\right|^2\right] = \bar{\Omega}_0$ for any $j, l \in \{1,....,L\}$ and the average SNR per bit will be written as $E[\gamma] = \bar{\gamma} = \bar{\Omega}_0 E_s / N_0$.

3.1 Moment Statistics of output SNR

The computation of statistical moments of output SNR is required in this moment based analysis. Using (2), the PDF of Generic Gamma fading amplitude and the RV transformation $p_{\gamma_l}(\gamma_l) = p_{x_l}\left(\sqrt{\bar{\Omega}_l \gamma_l / \bar{\gamma}_l}\right) \Big/ 2\sqrt{\gamma_l \bar{\gamma}_l / \bar{\Omega}_l}$, the PDF of instantaneous output SNR through l^{th} branch with single channel reception can be obtained as

$$p_{\gamma_l}(\gamma_l) = \left(\frac{\Gamma\left(m_l + \frac{1}{v_l}\right)}{\Gamma(m_l)\bar{\gamma}_l}\right) \frac{v_l \gamma_l^{v_l m_l - 1}}{\Gamma(m_l)} exp\left\{-\left(\frac{\Gamma\left(m_l + \frac{1}{v_l}\right)\gamma}{\Gamma(m_l)\bar{\gamma}_l}\right)^{v_l}\right\} \quad \gamma_l \geq 0 \quad \text{.........(3)}$$

To find n^{th} order moment using (3), an integral of the form I, given below

$$I = \int_0^{\infty} \gamma_l^{n + v_l m_l - 1} \exp\left\{-\left(\Gamma\left(m_l + 1/v_l\right)\gamma_l / \Gamma(m_l)\bar{\gamma}_l\right)^{v_l}\right\} d\gamma_l \quad \text{............(4)}$$

need to be solved. By applying transformation $\gamma_l^{v_l} = t$ and using [11, Eq. 3.381.4], in I the closed form expression of n^{th} moment of output SNR through the l^{th} channel can be obtained as

$$E\left[\gamma_l^n\right] = \bar{\gamma}_l^n \frac{\Gamma\left(m_l + \frac{n}{v_l}\right)\Gamma^{n-1}(m_l)}{\Gamma^n\left(m_l + \frac{1}{v_l}\right)} \quad \text{................(5)}$$

3.2 EGC Diversity Receiver Analysis

Among the different diversity combining techniques EGC provides intermediate solution in terms of performance and the implementation complexity. In EGC receivers, each signal branch is multiplied by a complex weight and then added up as outlined in the Figure 1. Each complex weight can be considered as consisting of a phase correction that causes the signal amplitudes to add up coherently, while noise is added incoherently. Further, each branch is real amplitude weighted with same factor, irrespective of the signal amplitude. Thus the decision statistics at the combiner output for equally likely transmitted symbols over generalized gamma faded channels can be given in terms of output SNR as

$$\gamma_{egc} = \frac{E_s}{LN_0}\left(x_1 + x_2 + \cdots + x_L\right)^2 \qquad \text{…………(6)}$$

Using the instantaneous SNR in each of the L branches can be rewritten as

$$\gamma_{egc} = \frac{1}{L}\left(\sum_{l=1}^{L}\sqrt{\gamma_l}\right)^2 \qquad \text{…………(7)}$$

Using the n^{th} order moment of the EGC output SNR is given as

$$E\left[\gamma_{egc}^n\right] = \frac{1}{L^n}E\left[\left(\sum_{l=1}^{L}\sqrt{\gamma_l}\right)^{2n}\right] \qquad \text{…………..(8)}$$

Expanding the term $\left(\sqrt{\gamma_1} + \cdots + \sqrt{\gamma_L}\right)^{2n}$ and using multinomial theorem [12, eq. 24.1.2], results in

$$E\left[\gamma_{egc}^n\right] = \frac{(2n)!}{L^n}\sum_{\substack{h_1, h_2, \ldots h_L = 0 \\ h_1 + h_2 + \ldots + h_L = 2n}}^{2n} E\left[\prod_{l=1}^{L}\frac{\gamma_l^{h_l/2}}{h_l!}\right] \qquad \text{…………(9)}$$

For statistically independent branches the term $E\left[\prod_{l=1}^{L}\gamma_l^{h_l/2}/h_l!\right]$ can be written as

$$E\left[\prod_{l=1}^{L}\frac{\gamma_l^{h_l/2}}{h_l!}\right] = \prod_{l=1}^{L}\frac{E\left[\gamma_l^{h_l/2}\right]}{h_l!} \qquad \text{……………(10)}$$

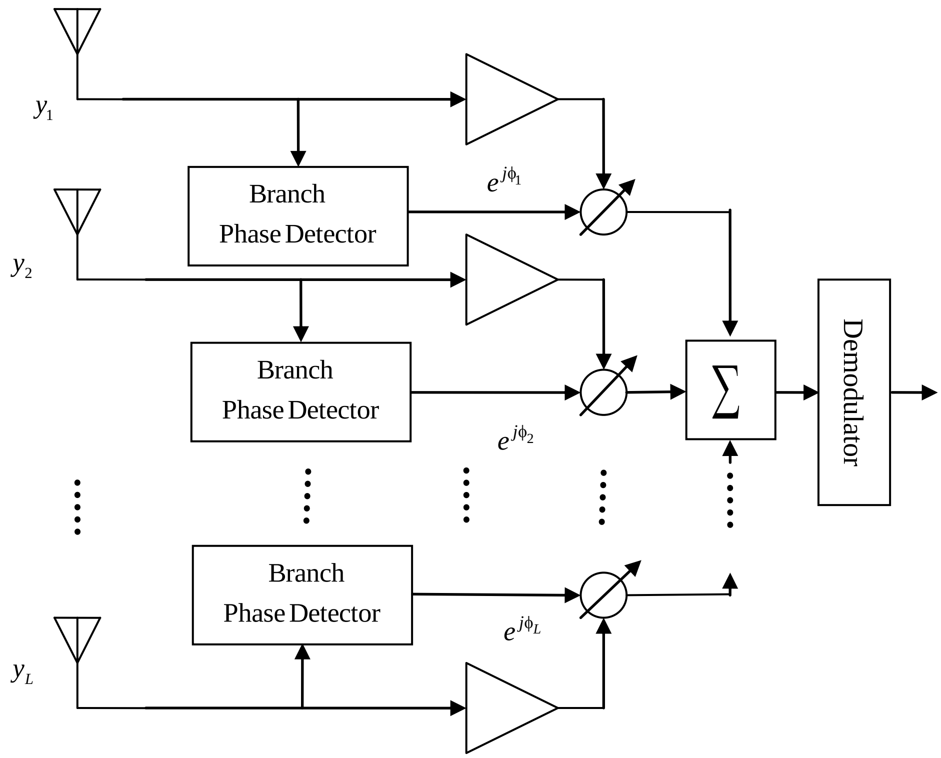

Fig. 1 : EGC Diversity Receiver Model

Using (10), (9) reduced to simple expression for the n^{th} order moment of the EGC output SNR as

$$E\left[\gamma_{egc}^{n}\right]=\frac{(2n)!}{L^{n}}\sum_{\substack{h_1,h_2,\ldots h_L=0\\ h_1+h_2+\ldots+h_L=2n}}^{2n}\prod_{l=1}^{L}\frac{E\left[\gamma_l^{h_l/2}\right]}{h_l!} \qquad \ldots\ldots\ldots\ldots(11)$$

Thus, the statistical moment of EGC receiver as derived in (11) is dependent only on the statistical moments of the output SNR $E\left[\gamma_l^{n}\right]$ per branch through the generalized gamma faded paths.

3.3 Error Rate Analysis

The moments based error rate analysis using Padé method carried out here for generalized fading channels has been given in [6]. Using Padé method, tractable rational functions (RAF) are derived for different channel scenarios represented by generic-gamma fading model that represent variety of channel fading conditions such as Rayleigh, Weibull, Nakagami-m and shadowing (in limiting sense) for particular values of parameters *m* and *v*. Interestingly, in special case of $m = v = 1$, the RAF found to be in simple closed form given by

$$R^{GG}_{\langle A-1/A\rangle} = \frac{1}{1+s\bar{\gamma}_l} \quad \ldots\ldots\ldots\ldots (12)$$

The above closed form expression is exactly the same expression as that of MGF of output SNR given in [13] for Rayleigh faded envelope. Further, in the case of (m = 5, v = 1) Hankel matrix is rank deficient except for D = 5 and the RAF found in this case is given by

$$R^{GG}_{\langle A-1/A\rangle} = \frac{1}{1+s\bar{\gamma}+(2/5)s^2\bar{\gamma}^2+(2/25)s^3\bar{\gamma}^3+(1/125)s^4\bar{\gamma}^4+(1/3125)s^5\bar{\gamma}^5} = \frac{1}{(1+0.2s\bar{\gamma})^5} \quad \ldots\ldots(13)$$

The simple closed form expression (13) matches exactly with the MGF of output SNR given in [13] for Nakagami-m faded envelope with m = 5. Hence, moment based method leads to exact expressions for the special cases. Moreover, computationally simple rational expression for different fading scenarios can also be derived as given next. Using parameter values $m = 1$ *and* $v = 1.5$ representative Weibull fading condition results and the corresponding expression is given by

$$R^{GG}_{\langle A-1/A\rangle} = \frac{1+.04t-.03t^2-0.1t^3-.09t^4-.05t^5-.01t^6-.001t^7-0.5e^{-4}t^8-1.2e^{-7}t^9}{1+t+.3t^2-.14t^3-.22t^4-.17t^5-.08t^6-.02t^7-.4e^{-2}t^8-.3e^{-3}t^9-.4e^{-5}t^{10}} \quad \ldots\ldots (14)$$

$$where\ t = (\bar{\gamma}s),\ e^{(.)} = 10^{(.)}$$

Using $m = 1$ *and* $v = 0.75$, worst than Rayleigh fading condition can be represented with generic gamma model and the expression for such severe fading is computed as

$$R^{GG}_{\langle A-1/A\rangle} = \frac{1+13.7t+88.6t^2+402.6t^3+1382.9t^4+3201.1t^5+4391.6t^6+3163.5t^7+987.6t^8+83.1t^9}{1+14.7t+101.8t^2+486t^3+1755.1t^4+4453.7t^5+7174.4t^6+6714.8t^7+3258.7t^8+658.4t^9+29.9t^{10}}$$

$$where\ t = (\bar{\gamma}s)$$

$$\ldots\ldots(15)$$

In the limiting sense lognormal shadowing has been represented for high value of $m = 10$ and small value of $v = 0.5$, and corresponding expression is given by

$$R^{GG}_{\langle A-1/A\rangle} = \frac{1+3.8t+3.4t^2-3.8t^3-8.8t^4-5.6t^5-1.2t^6-0.01t^7+0.64e^{-3}t^8-0.15e^{-4}t^9}{1+4.8t+7.5t^2+0.75t^3-11.5t^4-15.4t^5-9.5t^6-3.1t^7-0.5t^8-0.05t^9-0.13e^{-2}\ t^{10}} \quad \ldots\ldots(16)$$

$$where\ t = (\bar{\gamma}s),\ e^{(.)} = 10^{(.)}$$

Performance analysis of multichannel diversity receiver, over different fading scenarios using generic-gamma model, employing EGC has also been carried out. The expressions for EGC receiver output SNR, $R^{GG_e}_{\langle A-1/A\rangle}$ can be obtained in tractable form using (11) and Padé method described in [6] as

$$R^{GG_e}_{\langle A-1/A\rangle} = \sum_{n=0}^{2A-1} \frac{(-1)^n}{n!} E\left[\gamma^n_{egc}\right] s^n + O\left(s^{2A}\right) \quad \ldots\ldots\ldots\ldots\ldots(17)$$

where , $E\left[\gamma_{egc}^{n}\right]$ can be easily evaluated in terms of moments of output SNR for single channel $E\left[\gamma_{l}^{n}\right]$, that is available as (5) in simple closed function form.

The average BER expressions are given below in terms of RAF for the single channel receiver. For single channel binary phase shift keying (CBPSK) receiver with coherent detection the conditional BER is given in [13] as $P_e\left(E/\gamma_l\right)=\frac{1}{\pi}\int_0^{\pi/2} exp\left(-\gamma_l/sin^2\left(\varphi\right)\right)d\varphi$ and with Binary Differentially Phase Shift Keying (BDPSK) the conditional BER is $P_e\left(E/\gamma_l\right)=0.5exp\left(\gamma_l\right)$. Using the moment based method the ABER of CBPSK and BDPSK can be given by (18) and (19), respectively.

$$P_e\left(E\right)=\frac{1}{\pi}\int_0^{\pi/2} R_{\langle A-1/A\rangle}^{GG_e} d\varphi \qquad \text{...............(18)}$$

$$where\ s=1/sin^2\left(\varphi\right)$$

$$P_e\left(E\right)=.5R_{\langle A-1/A\rangle}^{GG_e} \qquad \text{.............(19)}$$

$$where\ s=1$$

4. Numerical and Simulation Results

Numerical evaluation of analytical work done to this point is required to estimate or quantify the performance characteristics of the wireless receivers with and without diversity over the generalized flat-fading channels.

4.1 Spectral Efficiency Slope

This parameter can be used to study the spectral efficiency of flat-fading channels in the high noise or power limited regions [14]. In a general class of average power limited fading channels, the minimum bit energy per AWGN noise level required for reliable communication is $\left(E_b/N_0\right)_{\min}=\log_e 2=-1.59\,\text{dB}$ that can be achieved only in asymptotic regime of infinite bandwidth. Spectral Efficiency slope can be computed from first and second order moment statistics already derived in the previous section. Considering minimum bit energy as not a sufficient criterion a formula for wideband slope [15] defined as the Slope of spectral efficiency curve η_s in bits/s/Hz/3dB at zero spectral efficiency can be given by

$$\eta_s=\frac{2\bar{\gamma}_l^2}{E\left[\gamma_l^2\right]} \qquad \text{...........(20)}$$

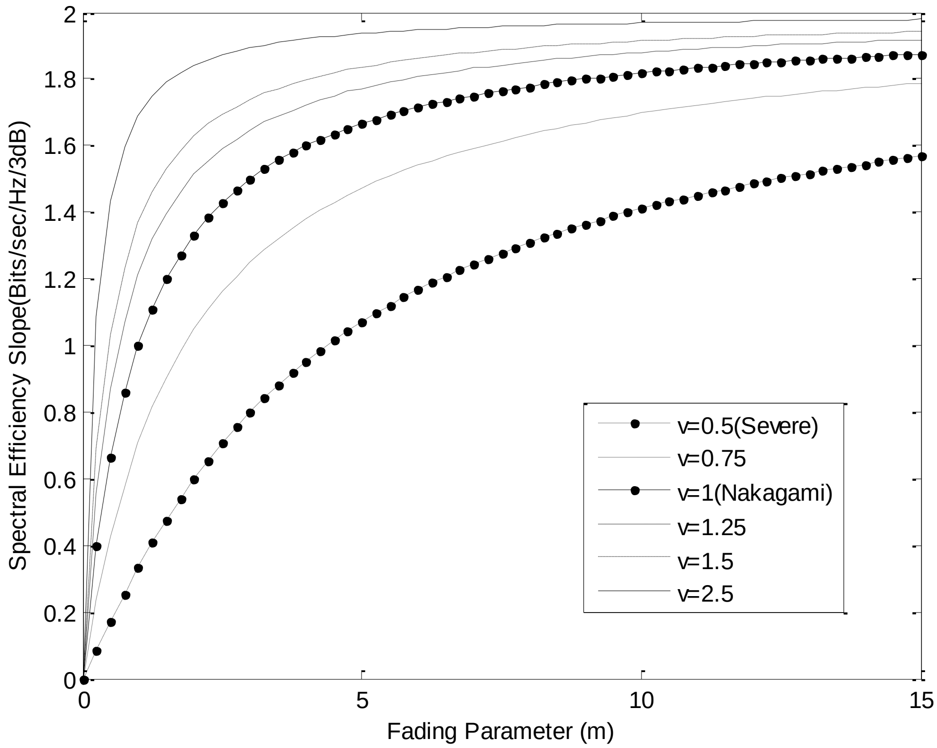

Fig. 2: Spectral Efficiency Curve Slope in Different Generalized Fading Conditions

This wideband slope closely approximates the growth of the spectral efficiency curve in the power limited region and hence is a new tool providing insightful results with finite resource bandwidth.

Using (5), (20) can be written in terms of fading parameters as

$$\eta_s = \frac{2\Gamma^2\left(m+1/\nu\right)}{\Gamma\left(m+2/\nu\right)\Gamma\left(m\right)} \qquad \ldots\ldots\ldots\ldots..(21)$$

Figure 2 plots the slope of the spectral efficiency curve in the high noise region for the receiver operating in compound fading environment, for several values of m and ν. The higher slope value indicates better spectral efficiency.

4.2 ABER

ABER of binary digital modulations through Generalized fading channel have been numerically evaluated using simple rational functions derived in previous section and compared for accuracy with simulation results. The brief mathematical description of the simulation model used to generate different channel conditions using generic gamma model has been described here. This model considers a received signal composed of clusters of multipath components propagating in a non-homogeneous environment. In each cluster of multipath components, the phases of the scattered waves are random and have similar delay times (frequency flat-fading). However, the delay time spreads of different clusters being relatively large. The clusters are assumed to have the scattered multipath components with identical envelope powers and the resulting envelope amplitude is obtained as a non-linear function of the modulus of the sum of the multipath components. The number of multipath components can be given at a point by parameter m and non-linearity (representative of non-homogeneous scatter field) by the parameter v of the generalized gamma model. Thus, the received envelope at any point is assumed to consist of m number of multipath components and the non-linearity of this heterogeneous environment represented in the form of an exponent $(1/v)$ so that the resultant generic gamma distributed envelope of any diversity branch can be generated using

$$x_l = \left(\sqrt{\sum_{i=1}^{m} p_i^2 + \sum_{i=1}^{m} q_i^2} \right)^{1/v} \qquad \text{..............(22)}$$

where p_i and q_i are independently distributed Gaussian variables with zero mean and unit variance. The expressions for ABER of BDPSK and CBPSK given in previous section are computed numerically for different channel fading conditions. These numerical results along with simulation results without diversity combining are shown graphically in Figure 3 for different values of fading parameters, i.e. m=1, v=0.75 (severe fading); m = 1, v = 1 (Rayleigh fading); m = 1, v = 1.5 (Weibull fading); m = 1, v = 2 (Weibull fading); m = 2, v = 1 (Nakagami-m fading); m = 5, v = 1(Nakagami-m fading); m = 10, v = 0.5 (lognormal shadowing). It can be seen from nearly linear average BER curves contrary to that of exponential decay found in non-fading channels, severe penalty in terms SNR has to be paid due to small scale fading. A simple increase in transmitted signal power to combat this loss may not be practically feasible in many cases due to power constraints. Thus, EGC as alternative power efficient diversity technique has been tried here to assess the performance gain.

The generic forms of ABER expressions for EGC are evaluated numerically to compute the diversity gain over the no diversity system. Computer simulations of ABER with dual EGC for the six representative channel fading conditions (m = 1, v = 0.75; m = 1, v = 1; m = 1, v = 1.5; m = 1, v = 2; m = 5, v = 1; m = 10, v = 1) have been obtained from a sample set of 10,000 values for each SNR and compared with numerically evaluated results for similar channel conditions. The comparison of these performance results with that of no diversity system has also been made, which indicate significant performance improvement in terms of diversity gain.

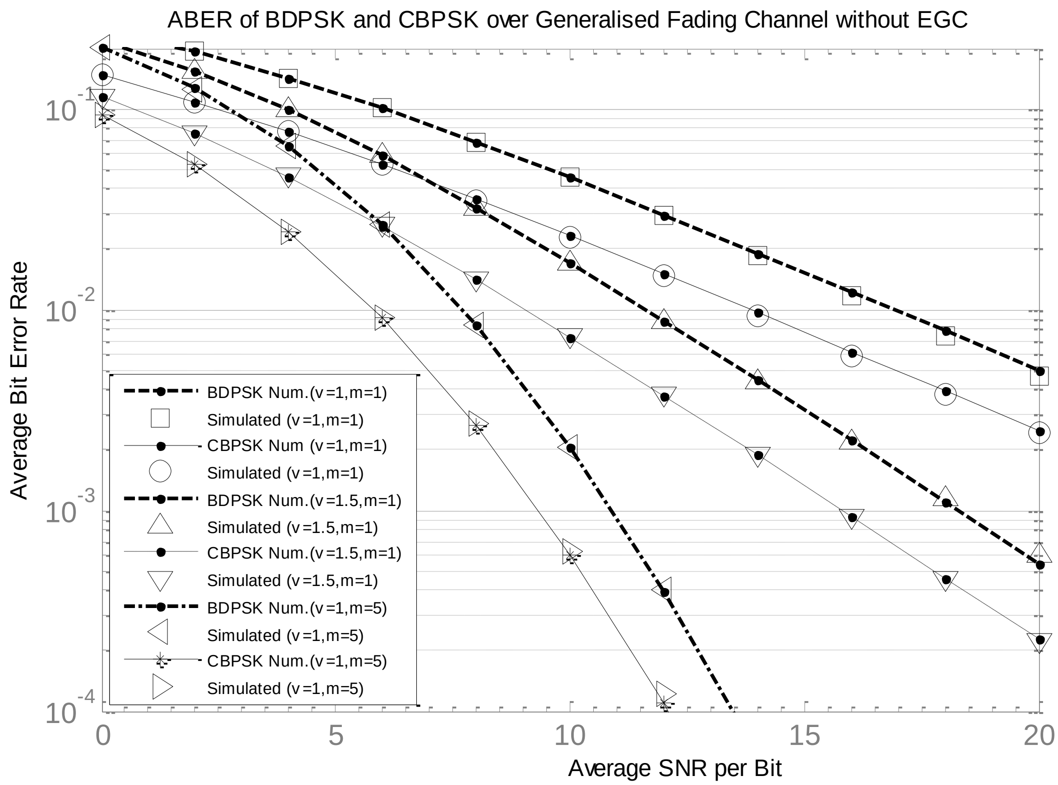

Fig. 3: ABER vs Average SNR of BDPSK and CBPSK Without Diversity Combining

The diversity gain results for CBPSK and BDPSK over Rayleigh, Weibull and Nakagami-m fading conditions using Generic gamma fading model has been tabulated in Table 3.1. The average BER results of CBPSK and BDPSK with dual EGC used in this diversity gain comparison are depicted in Figure 3 and 4, respectively. The comparison of no diversity systems and dual EGC system average BER curves shows that the diversity gain is more in case of severe fading ($m = v = 1$) as compared to the case of less severe fading ($m = 5$, $v = 1$). This verifies that by using EGC diversity combining the degradation in performance due to severe fading can be compensated more effectively.

Type of Fading	*CBPSK*		*BDPSK*	
	10^{-2}	*10^{-3}*	*10^{-2}*	*10^{-3}*
Rayleigh (m = 1,v = 1)	8.1	10.8	9.0	13.8
Weibull (m = 1, v = 1.5)	5.3	8.8	6.6	9.0
Nakagami-m (m = 5,v = 1)	4.0	4.5	3.2	4.6

Table 1 : Diversity gains (in dB) of modulation techniques with Dual EGC for different ABER values

It can also be observed that the diversity gain increases with the increase in average SNR. Table 1 shows that for a given fading condition and modulation technique, diversity gain increases with the decrease in the target BER value.

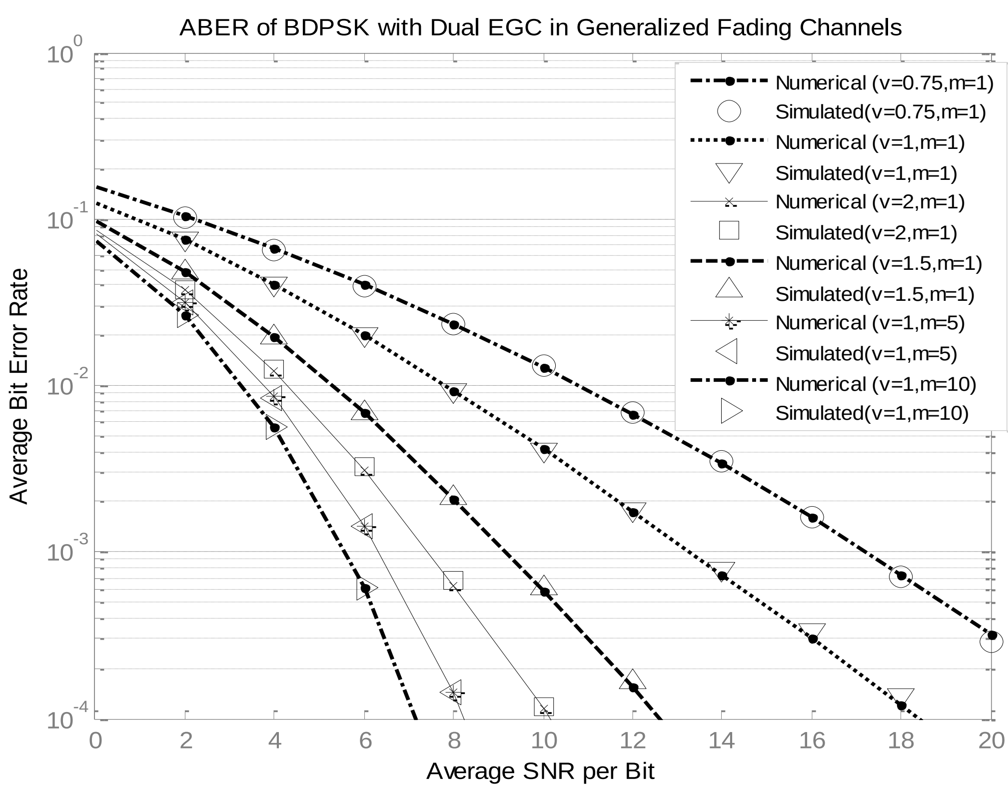

Fig. 4 : ABER vs Average SNR of BDPSK with EGC

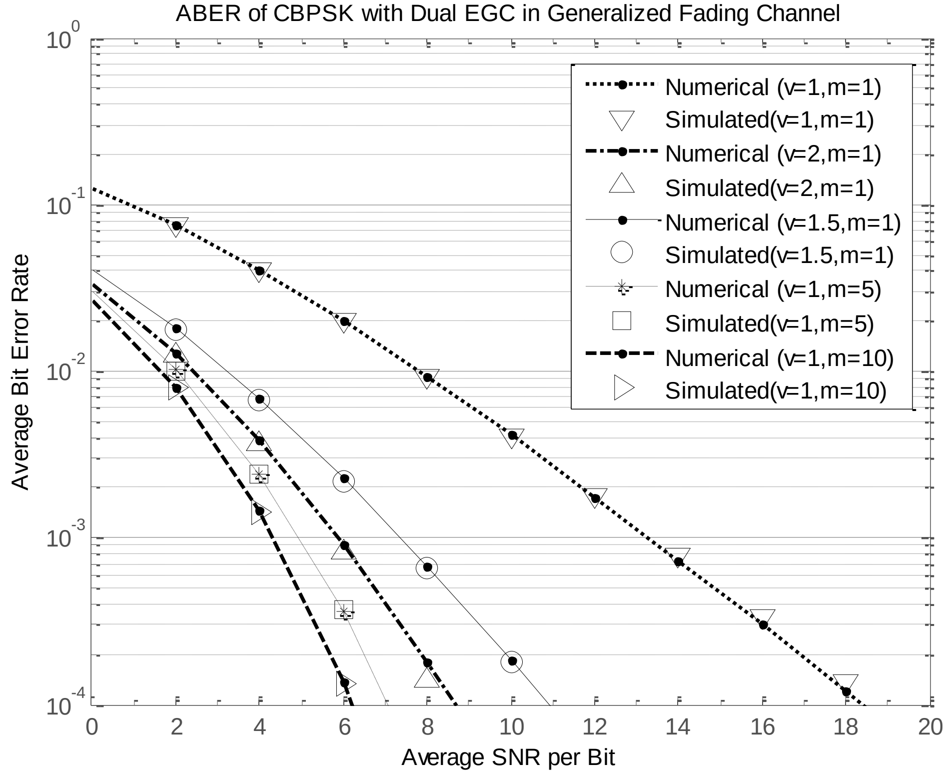

Fig. 5 ABER vs Average SNR of CBPSK with EGC

It is also apparent from the figures that in general the ABER improves as average SNR per bit ($\bar{\gamma}$) increases and for a fixed value of $\bar{\gamma}$ also, ABER improves with an increase of *v* and/or *m*. As evident from depicted results that the numerical results obtained for variety of channel fading conditions obtained using moment based approach used here and computer simulation results show perfect agreement. On the other side, the performance results obtained in [5] for binary modulations were based on complicated expressions involving Meijer'sG and Fox'sH special functions. Numerical evaluation of these special functions even with the modern mathematical packages such as Mathematica & Maple is tricky, because they fail to handle the integrals involving such special functions [13, sec. 2.2.1.5], especially the higher values of fading parameter *m* and *v* leads to numerical instabilities and erroneous results. Moreover, the Fox's H special function can't be evaluated using these software packages. Thus, the analytical approach presented here has provided alternative simple to evaluate rational expressions that resulted in unified performance analysis of wireless systems over generalized flat-fading conditions. From the depicted results, it is also evident that this unified approach has provided very accurate and stable performance results for arbitrary values of fading parameters *v* and *m*.

5. Conclusions

The performance evaluation of generalized fading channels using Generic-Gamma model has been done. This model embodies almost all forms of multipath fading and shadowing conditions, which has been exemplified throughout this work. The performance of multichannel wireless receiver in variety of fading channel conditions with EGC diversity combining has been investigated. Using moment based Padé method; simple to evaluate rational expressions for the MGF of the receiver's output SNR have been derived. Performance measures related to wireless system design such as Spectral efficiency slope and ABER have been evaluated. Numerical and simulation results are presented to complement the theoretical content of the paper. The results obtained from numerical evaluation of rational expressions and computer simulation shows perfect match. The existence of two fading parameters m and v make it possible to describe different levels of fading individually or collectively. Thus, the Generic-Gamma model and unified analyses presented here provide a significant enhancement in the ability to evaluate the multi-channel wireless system performance over all existing models, including the Rayleigh, Nakagami-m, Weibull and lognormal.

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