PERFORMANCE OF DUAL-BRANCH EGC RECEIVER OVER GENERALIZED-K FADING CHANNELS

Abstract

The equal gain combining (EGC) receiver performs better as well as the complexity of the EGC receiver is less.In this article, the outage probability and the average bit error rate (ABER) of dual-branch EGC receiver over generalized-K fading channel are presented. The ABER expressions are derived for coherent and non-coherent modulation schemes. The channel between the transmitter and the receiver is assumed to experience generalized-K fading. The probability density function (PDF) of the output SNR for the dual branch EGC receiver is derived based on the generalized-K distribution amplitude PDF. The effect of fading parameters m and k on the performance of the dual-branch EGC receiver has been observed analytically. Computer simulations are performed to assess the accuracy of the proposed mathematical analysis.

Keywords: Generalized-K distribution, Multipath/Shadowing Channels, Equal Gain Combining (EGC), Outage Probability, and Average Bit Error Rate (ABER).

Author

Rajkishur Mudoi
Department of Electronics and Communication Engineering
North-Eastern Hill University
Shillong, India.

I. INTRODUCTION

In wireless communication, a channel may experience fading. Fading occurs due to multiple transmission paths, irregularities of earth surfaces or varying terrains, or human-made disturbances such as buildings or concrete walls etc. As a result, the receiver gets multiple copies of the transmitting signal. Each signal copy will experience differences in attenuation, delay, and phase shift which causes the received signal to fluctuate. To remove this adverse effect, a diversity receiver technique can be used. Among the different diversity combining receivers, the EGC receiver is investigated due to its low complexity and better performance.

The generalized-*K* (K_G) distribution can be utilized to model the fading and shadowing phenomena experience in mobile communication channels [1]. The $K_G$fading is a composite fading that includes Nakagami-*m* and Gamma distribution. The K_G fading model is a generalized model as it can be used to approximate many other fading models, such as *K*fading, Nakagami-*m* and Rayleigh-Lognormal (R-L) [1][2][3]. Furthermore, the primary advantage of using theK_G distribution is that it makes mathematical expressions of performance analysis considerably easier as compared to Lognormal-based models, for instance the Nakagami-*m* or the R-L model. It has been verified that the K_G channel model can simultaneously take into account the propagation path-loss, shadowing, and fast fading. It can usually cover more communications scenarios in real mobile wireless systems than the other composite channel models [4]. In [2], the outage probability and the channel capacity subject to $K_G$fading channel are analyzed and evaluated. The derivation of error performance is reflected in [5] for a system with dual-branch selection diversity and experiencing independent but not necessarily identically distributed generalized-*K* fading. In [6], the performance analysis for the different diversity receivers operating over the composite generalized-*K* fading channel is presented and also the average bit error probability is analyzed for EGC and SC receivers applying the Pad´e approximants method. However, a detailed performance analysis of more general receiver structures such as EGC operating over the K_G channel is not available in the open technical literature. In this article, the outage probability and ABER performance of the Dual-branch EGC receiver over the generalized-*K* fading channel are realized.

In Section II, the system and channel model is described. The PDF of the dual-branch EGC receiver output SNR is also derived in this section. The outage probability and average bit error rate are analyzed in Section III and Section IV, respectively. The numerical results and discussions are provided in Section V. Finally, the conclusions are given in Section VI.

II. SYSTEM AND CHANNEL MODEL DESCRIPTION

We consider a wireless communication system with two receiving antennas at the EGC receiver. The channel between the transmit antenna, and the user is modeled as slow flat fading K_G channel.

EGC is performed with the user of the system to improve the quality of the downlink information. In an EGC receiver, the received signals from all L diversity antennas are cophased and multiplied by a unit weight factor before being added together to form the output signal of the receiver. The complexity of the EGC receiver is less as compared to the MRC receiver. The instantaneous output SNR γ of the EGC receiver is given by [7]

$$\gamma = \frac{E_s}{LN_0}\left(\sum_{i=1}^{L}\alpha_i\right)^2 . \tag{1}$$

Where $E_s = E\left[|s|^2\right]$ with $|.|$ and $E[.]$ denoting absolute value and expectation. s is the transmitted symbol, which can take values from different modulation symbols, for instance M -phase shift keying (MPSK) and M -quadrature amplitude modulation (QAM), N_0 is the single-sided power spectral density of the AWGN. The corresponding average SNR is [2]

$$\bar{\gamma} = \frac{\Omega k E_s}{N_0} . \tag{2}$$

The RV α is the fading envelope, which follows the K_G distribution. The PDF of α is given by [2]

$$f_\alpha(\alpha) = \frac{4m^{(\beta+1)/2}\alpha^\beta}{\Gamma(m)\Gamma(\beta)\Omega^{(\beta+1)/2}} K_x\left[2\left(\frac{m}{\Omega}\right)^{1/2}\alpha\right]; \alpha \geq 0, \tag{3}$$

where, $x = k - m$, $\beta = k + m - 1$, $\Gamma(.)$ is the Gamma function and $K_x(.)$ is the modified Bessel function of order x [8]. Additionally, Ω is the mean power defined as $\frac{E\left[\alpha^2\right]}{k}$. The K_G is a two parameters distribution which are m and k. The PDF expression of the fading envelope can represent the different fading and shadowing models using some specific value combinations for m and k.

With the help of [9], (3) can be simplified as

$$f_\alpha(\alpha) = \frac{2\sqrt{\pi}m^{\frac{2\beta+1}{4}}\alpha^{\beta-\frac{1}{2}}e^{-\left[2\left(\frac{m}{\Omega}\right)^{1/2}\alpha\right]}}{\Gamma(m)\Gamma(\beta)\Omega^{\frac{2\beta+1}{4}}} \sum_{j=0}^{\left|x\right|-\frac{1}{2}} \frac{\left(j+|x|-\frac{1}{2}\right)!}{j!\left(-j+|x|-\frac{1}{2}\right)!}\left(2\left[2\left(\frac{m}{\Omega}\right)^{1/2}\alpha\right]\right)^{-j} . \tag{4}$$

Assuming α_1 and α_2 are the independent envelopes of the signals received at the two diversity branches of the receiver, their joint probability can be deduced from (4) as

$$f_{\alpha_1\alpha_2}(\alpha_1\alpha_2) = \frac{4\pi e^{-\left[2\left(\frac{m}{\Omega}\right)^{1/2}(\alpha_1+\alpha_2)\right]}}{\{\Gamma(m)\}^2\{\Gamma(\beta)\}^2}$$

$$\times\sum_{j_1=0}^{\left|\left|x\right|-\frac{1}{2}\right|}\sum_{j_2=0}^{\left|\left|x\right|-\frac{1}{2}\right|}\frac{m^{\frac{2\beta+1-(j_1+j_2)}{2}}\left(\alpha_1\right)^{\beta-\frac{1}{2}-j_1}\left(\alpha_2\right)^{\beta-\frac{1}{2}-j_2}\left(j_1+\left|x\right|-\frac{1}{2}\right)!\left(j_2+\left|x\right|-\frac{1}{2}\right)!}{4^{j_1+j_2}\Omega^{\frac{2\beta+1-(j_1+j_2)}{2}}j_1!j_2!\left(-j_1+\left|x\right|-\frac{1}{2}\right)!\left(-j_2+\left|x\right|-\frac{1}{2}\right)!}. \qquad (5)$$

Since α_1 and α_2 are two independent envelopes, the convolution of their densitiesis given by [10],

$$f_\alpha\left(\alpha\right)=\int_0^\alpha f_{\alpha_1}\left(\alpha_1\right)f_{\alpha_2}\left(\alpha-\alpha_1\right)d\alpha_1. \qquad (6)$$

Where, $\alpha=\alpha_1+\alpha_2$ .From the formula given in (6) and applying [8, (3.191.1)], the convolution of the joint probability of envelope for dual-branch EGC receiver given in (5) can be written as

$$f_\alpha\left(\alpha\right)=\frac{4\pi e^{-\left[2\left(\frac{m}{\Omega}\right)^{1/2}\alpha\right]}}{\left\{\Gamma\left(m\right)\right\}^2\left\{\Gamma\left(\beta\right)\right\}^2}$$

$$\times\sum_{j_1=0}^{\left|\left|x\right|-\frac{1}{2}\right|}\sum_{j_2=0}^{\left|\left|x\right|-\frac{1}{2}\right|}\frac{m^{\frac{2\beta+1-(j_1+j_2)}{2}}\left(j_1+\left|x\right|-\frac{1}{2}\right)!\left(j_2+\left|x\right|-\frac{1}{2}\right)!}{4^{j_1+j_2}\Omega^{\frac{2\beta+1-(j_1+j_2)}{2}}j_1!j_2!\left(-j_1+\left|x\right|-\frac{1}{2}\right)!\left(-j_2+\left|x\right|-\frac{1}{2}\right)!}$$

$$\times\alpha^{2\beta-j_1-j_2}B\left(\beta+\frac{1}{2}-j_2,\beta+\frac{1}{2}-j_1\right). \qquad (7)$$

Where $B(.,.)$ is the beta function. Performing square transformation of the random variable in (7), it can be shown that,

$$f_{\alpha^2}\left(\alpha\right)=\frac{2\pi e^{-\left[2\left(\frac{m}{\Omega}\right)^{1/2}\sqrt{\alpha}\right]}}{\left\{\Gamma\left(m\right)\right\}^2\left\{\Gamma\left(\beta\right)\right\}^2}$$

$$\times\sum_{j_1=0}^{\left|\left|x\right|-\frac{1}{2}\right|}\sum_{j_2=0}^{\left|\left|x\right|-\frac{1}{2}\right|}\frac{m^{\frac{2\beta+1-(j_1+j_2)}{2}}\left(j_1+\left|x\right|-\frac{1}{2}\right)!\left(j_2+\left|x\right|-\frac{1}{2}\right)!}{4^{j_1+j_2}\Omega^{\frac{2\beta+1-(j_1+j_2)}{2}}j_1!j_2!\left(-j_1+\left|x\right|-\frac{1}{2}\right)!\left(-j_2+\left|x\right|-\frac{1}{2}\right)!}$$

$$\times\alpha^{\frac{2\beta-1-(j_1+j_2)}{2}}B\left(\beta+\frac{1}{2}-j_2,\beta+\frac{1}{2}-j_1\right). \qquad (8)$$

Performing random variable transformation in (8) applying (1) and putting $\frac{E_s}{2N_0}=\frac{\bar{\gamma}_i}{2k\Omega_i}$ from (2), the output SNR of the dual-branch EGC receiver can be derived as

$$f_\gamma(\gamma)=\frac{\pi e^{-\left[\sqrt{\frac{8km\gamma}{\bar{\gamma}_i}}\right]}}{\{\Gamma(m)\}^2\{\Gamma(\beta)\}^2}$$

$$\times\sum_{j_1=0}^{\left||x|-\frac{1}{2}\right|}\sum_{j_2=0}^{\left||x|-\frac{1}{2}\right|}\frac{2^{\frac{2\beta+3-(5j_1+5j_2)}{2}}\left(j_1+|x|-\frac{1}{2}\right)!\left(j_2+|x|-\frac{1}{2}\right)!\gamma^{\frac{2\beta-1-(j_1+j_2)}{2}}}{j_1!j_2!\left(-j_1+|x|-\frac{1}{2}\right)!\left(-j_2+|x|-\frac{1}{2}\right)!}$$

$$\times\left(\frac{mk}{\bar{\gamma}_i}\right)^{\frac{2\beta+1-(j_1+j_2)}{2}}B\left(\beta+\frac{1}{2}-j_2,\beta+\frac{1}{2}-j_1\right). \quad (9)$$

III. OUTAGE PROBABILITY ANALYSIS

The probability that the output SNR falls below a threshold SNR γ_{th} is the outage probability and is given by

$$P_{out}(\gamma_{th})=\frac{\pi}{\{\Gamma(m)\}^2\{\Gamma(\beta)\}^2}$$

$$\times\sum_{j_1=0}^{\left||x|-\frac{1}{2}\right|}\sum_{j_2=0}^{\left||x|-\frac{1}{2}\right|}\frac{2^{\frac{2\beta+3-(5j_1+5j_2)}{2}}\left(j_1+|x|-\frac{1}{2}\right)!\left(j_2+|x|-\frac{1}{2}\right)!}{j_1!j_2!\left(-j_1+|x|-\frac{1}{2}\right)!\left(-j_2+|x|-\frac{1}{2}\right)!}$$

$$\times\left(\frac{mk}{\bar{\gamma}_i}\right)^{\frac{2\beta+1-(j_1+j_2)}{2}}B\left(\beta+\frac{1}{2}-j_2,\beta+\frac{1}{2}-j_1\right)$$

$$\times\int_0^{\gamma_{th}}\gamma^{\frac{2\beta-1-(j_1+j_2)}{2}}e^{-\left[\sqrt{\frac{8km\gamma}{\bar{\gamma}_i}}\right]}d\gamma\,. \quad (10)$$

Applying [8,(3.381.8)], it can be rewritten as

$$P_{out}(\gamma_{th})=\frac{\pi}{\{\Gamma(m)\}^2\{\Gamma(\beta)\}^2}$$

$$\times\sum_{j_1=0}^{\left||x|-\frac{1}{2}\right|}\sum_{j_2=0}^{\left||x|-\frac{1}{2}\right|}\frac{\left(j_1+|x|-\frac{1}{2}\right)!\left(j_2+|x|-\frac{1}{2}\right)!}{2^{2\beta-1+(j_1+j_2)}j_1!j_2!\left(-j_1+|x|-\frac{1}{2}\right)!\left(-j_2+|x|-\frac{1}{2}\right)!}$$

$$\times B\left(\beta+\frac{1}{2}-j_2,\beta+\frac{1}{2}-j_1\right)g\left(2\beta+1-(j_1+j_2),\sqrt{\frac{8km\gamma_{th}}{\bar{\gamma}_i}}\right). \tag{11}$$

Where $g(.,.)$ is the lower incomplete gamma function.

IV. ABER ANALYSIS

The ABER can be defined as [7]

$$p_e\left(\bar{\gamma}\right)=\int_0^\infty p_e\left(\varepsilon|\gamma\right)f_\gamma\left(\gamma\right)d\gamma\,. \tag{12}$$

Where $p_e\left(\varepsilon|\gamma\right)$ is the conditional BER related to the modulation method applied.

1. For Coherent Modulations

The conditional BER is [11], $p_e\left(\varepsilon|\gamma\right)=berfc\sqrt{\frac{\gamma}{c}}$, where $b=0.5$, $c=1$ for Binary Phase Shift Keying (BPSK) modulations and $b=0.5$, $c=2$ for Binary Frequency Shift Keying (BFSK) modulations. By using [12,(8.4.14.2)],

$$p_e\left(\varepsilon|\gamma\right)=b\frac{1}{\sqrt{\pi}}G_{1,2}^{2,0}\left(\frac{\gamma}{c}\middle|\begin{matrix}1\\0,\frac{1}{2}\end{matrix}\right). \tag{13}$$

Where, $G_{q,r}^{u,v}[.]$ is the Meijer's G-function. Putting the values of $p_e\left(\varepsilon|\gamma\right)$ from (13) and $f_\gamma(\gamma)$ from (9) into the expression of (12) and simplifying, the ABER can be given as

$$p_e\left(\bar{\gamma}\right)=\frac{\pi}{\left\{\Gamma(m)\right\}^2\left\{\Gamma(\beta)\right\}^2}$$

$$\times\sum_{j_1=0}^{\left||x|-\frac{1}{2}\right|}\sum_{j_2=0}^{\left||x|-\frac{1}{2}\right|}\frac{2^{\frac{2\beta+3-(5j_1+5j_2)}{2}}\left(j_1+|x|-\frac{1}{2}\right)!\left(j_2+|x|-\frac{1}{2}\right)!}{j_1!j_2!\left(-j_1+|x|-\frac{1}{2}\right)!\left(-j_2+|x|-\frac{1}{2}\right)!}$$

$$\times\left(\frac{mk}{\overline{\gamma}_i}\right)^{\frac{2\beta+1-(j_1+j_2)}{2}} B\left(\beta+\frac{1}{2}-j_2,\beta+\frac{1}{2}-j_1\right)$$

$$\int_0^{\infty}\frac{b}{\sqrt{\pi}}G_{1,2}^{2,0}\left(\frac{\gamma}{c}\middle|\begin{matrix}1\\0,\frac{1}{2}\end{matrix}\right)\times\gamma^{\frac{2\beta-1-(j_1+j_2)}{2}}e^{-\left[\sqrt{\frac{8km\gamma}{\overline{\gamma}_i}}\right]}d\gamma\,. \tag{14}$$

Similarly, (14) can be rewritten using [12, (8.4.3.1)] as,

$$p_e\left(\overline{\gamma}\right)=\frac{\pi}{\left\{\Gamma(m)\right\}^2\left\{\Gamma(\beta)\right\}^2}$$

$$\times\sum_{j_1=0}^{\left|\left|x\right|-\frac{1}{2}\right|}\sum_{j_2=0}^{\left|\left|x\right|-\frac{1}{2}\right|}\frac{2^{\frac{2\beta+3-(5j_1+5j_2)}{2}}\left(j_1+\left|x\right|-\frac{1}{2}\right)!\left(j_2+\left|x\right|-\frac{1}{2}\right)!}{j_1!j_2!\left(-j_1+\left|x\right|-\frac{1}{2}\right)!\left(-j_2+\left|x\right|-\frac{1}{2}\right)!}$$

$$\times\left(\frac{mk}{\overline{\gamma}_i}\right)^{\frac{2\beta+1-(j_1+j_2)}{2}} B\left(\beta+\frac{1}{2}-j_2,\beta+\frac{1}{2}-j_1\right)$$

$$\times\frac{b}{\sqrt{\pi}}\int_0^{\infty}\gamma^{\frac{2\beta-1-(j_1+j_2)}{2}}G_{1,2}^{2,0}\left(\frac{\gamma}{c}\middle|\begin{matrix}1\\0,\frac{1}{2}\end{matrix}\right)G_{0,1}^{1,0}\left[\sqrt{\frac{8km}{\overline{\gamma}_i}}\gamma^{\frac{1}{2}}\middle|\begin{matrix}-\\0\end{matrix}\right]d\gamma\,. \tag{15}$$

The integration in (15) is simplified with the help of [13] as

$$p_{e,coh}\left(\overline{\gamma}\right)=\frac{b}{\left\{\Gamma(m)\right\}^2\left\{\Gamma(\beta)\right\}^2}$$

$$\times\sum_{j_1=0}^{\left|\left|x\right|-\frac{1}{2}\right|}\sum_{j_2=0}^{\left|\left|x\right|-\frac{1}{2}\right|}\frac{2^{\frac{2\beta+3-(5j_1+5j_2)}{2}}\left(j_1+\left|x\right|-\frac{1}{2}\right)!\left(j_2+\left|x\right|-\frac{1}{2}\right)!}{j_1!j_2!\left(-j_1+\left|x\right|-\frac{1}{2}\right)!\left(-j_2+\left|x\right|-\frac{1}{2}\right)!}$$

$$\times\left(\frac{ckm}{\overline{\gamma}_i}\right)^{\frac{2\beta+1-(j_1+j_2)}{2}} B\left(\beta+\frac{1}{2}-j_2,\beta+\frac{1}{2}-j_1\right)$$

$$\times G_{2,3}^{2,2}\left[\frac{2ckm}{\overline{\gamma}_i}\left|\begin{matrix}\Delta\left(1,-\frac{2\beta-1-(j_1+j_2)}{2}\right),\Delta\left(1,\frac{-2\beta+(j_1+j_2)}{2}\right)\\ \Delta(2,0),\Delta\left(1,-\frac{2\beta+1-(j_1+j_2)}{2}\right)\end{matrix}\right.\right], \qquad (16)$$

where, $\Delta(\Phi,\Upsilon)=\frac{\Upsilon}{\Phi},\frac{\Upsilon+1}{\Phi},...,\frac{\Upsilon+\Phi-1}{\Phi}$.

2. **For Non-coherent Modulations :** The conditional BER for non-coherent modulations is given by $p_e(\varepsilon|\gamma)=\frac{1}{2}\exp(-a\gamma)$. Where, $a=0.5$ for Non-coherent Frequency Shift Keying (NCFSK) and $a=1$ for DPSK modulations.

Putting the values of $p_e(\varepsilon|\gamma)$ and $f_\gamma(\gamma)$ from (9) into the expression of (12) and simplifying, the ABER can be given as

$$p_e(\overline{\gamma})=\frac{\pi}{\{\Gamma(m)\}^2\{\Gamma(\beta)\}^2}$$

$$\times\sum_{j_1=0}^{\left||x|-\frac{1}{2}\right|}\sum_{j_2=0}^{\left||x|-\frac{1}{2}\right|}\frac{2^{\frac{2\beta+3-(5j_1+5j_2)}{2}}\left(j_1+|x|-\frac{1}{2}\right)!\left(j_2+|x|-\frac{1}{2}\right)!}{j_1!j_2!\left(-j_1+|x|-\frac{1}{2}\right)!\left(-j_2+|x|-\frac{1}{2}\right)!}$$

$$\times\left(\frac{mk}{\overline{\gamma}_i}\right)^{\frac{2\beta+1-(j_1+j_2)}{2}}B\left(\beta+\frac{1}{2}-j_2,\beta+\frac{1}{2}-j_1\right)$$

$$\times\int_0^\infty\frac{1}{2}\exp(-a\gamma)\gamma^{\frac{2\beta-1-(j_1+j_2)}{2}}e^{-\left[\sqrt{\frac{8km\gamma}{\overline{\gamma}_i}}\right]}d\gamma\,. \qquad (17)$$

Solving (17) with the help of [8, (3.462.1)]

$$p_{e,ncoh}(\overline{\gamma})=\frac{\pi e^{\frac{mk}{a\overline{\gamma}}}}{\{\Gamma(m)\}^2\{\Gamma(\beta)\}^2}$$

$$\times\sum_{j_1=0}^{\left||x|-\frac{1}{2}\right|}\sum_{j_2=0}^{\left||x|-\frac{1}{2}\right|}\frac{2^{1-2(j_1+j_2)}\left(j_1+|x|-\frac{1}{2}\right)!\left(j_2+|x|-\frac{1}{2}\right)!}{j_1!j_2!\left(-j_1+|x|-\frac{1}{2}\right)!\left(-j_2+|x|-\frac{1}{2}\right)!}$$

$$\times\left(\frac{mk}{a\bar{\gamma}_i}\right)^{\frac{2\beta+1-(j_1+j_2)}{2}}B\left(\beta+\frac{1}{2}-j_2,\beta+\frac{1}{2}-j_1\right)$$

$$\times\Gamma\left(2\beta+1-(j_1+j_2)\right)D_{-(2\beta+1-(j_1+j_2))}\left(\sqrt{\frac{4mk}{a\bar{\gamma}_i}}\right). \qquad (18)$$

In (18), $D_v(z)$ is the parabolic cylindrical function defined in[8, (9.240)]. Where

$\nu=-\left(2\beta+1-(j_1+j_2)\right)$ and $z=\sqrt{\frac{4mk}{a\bar{\gamma}_i}}$.

V. NUMERICAL RESULTS WITH DISCUSSIONS

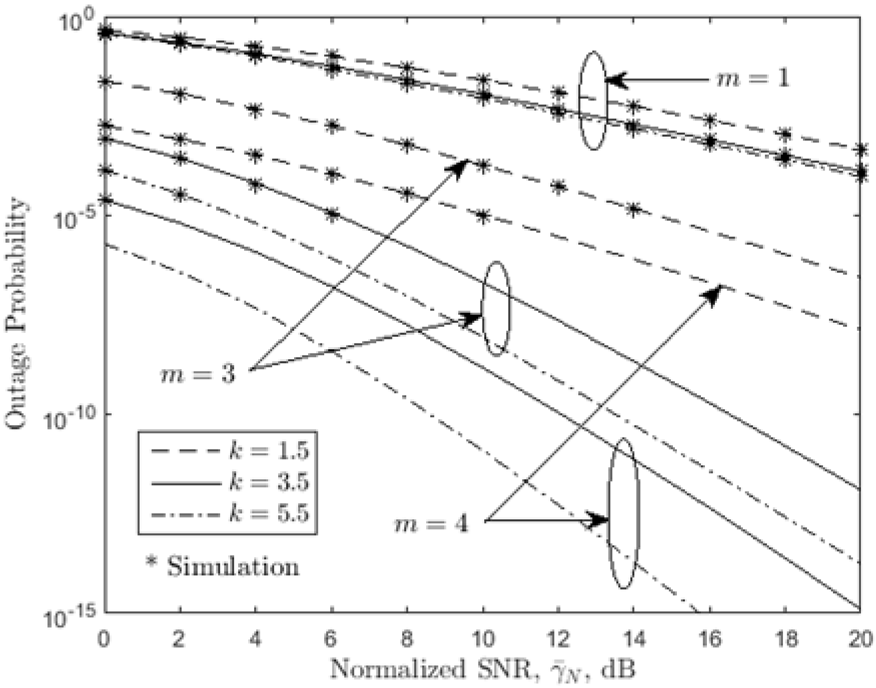

Figure 1: Outage Probability (P_{out}) vs. Normalized SNR ($\bar{\gamma}_N$) for different values of fading parameters.

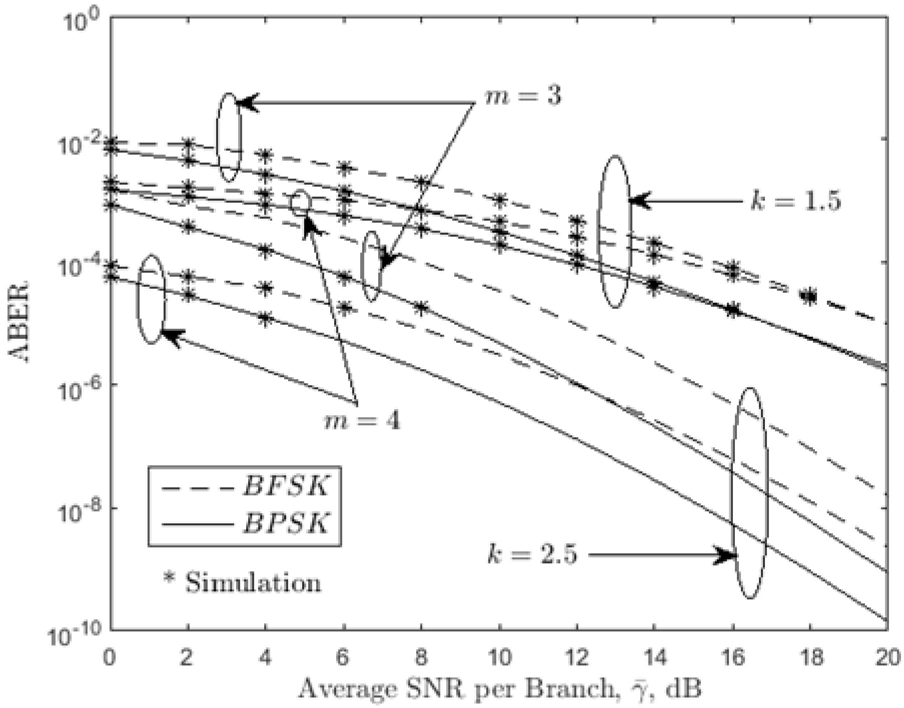

Figure 2: ABER vs. Average SNR ($\bar{\gamma}$) for BFSK and BPSK systems with different values of fading parameters.

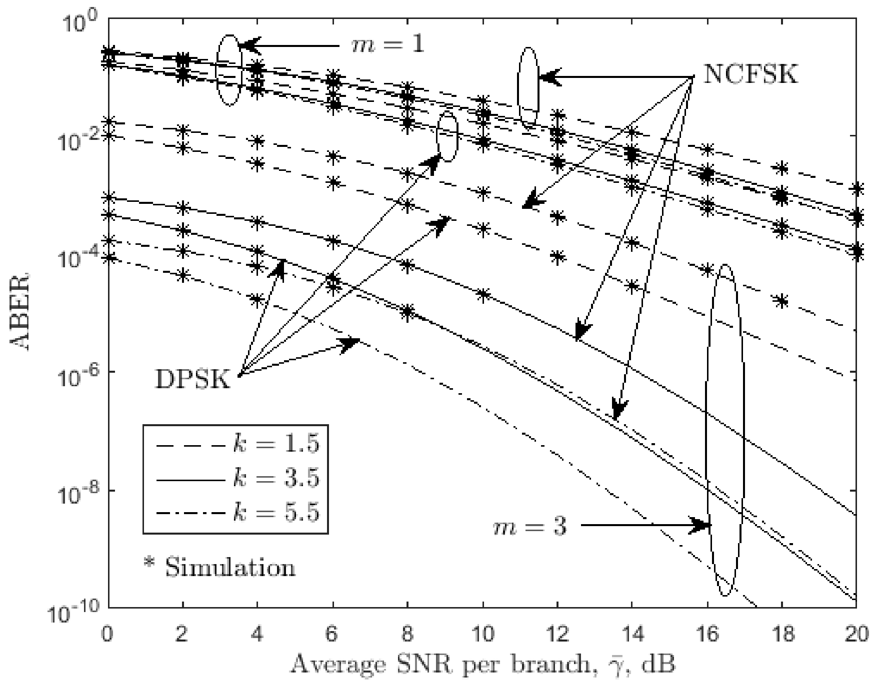

Figure 3: ABER vs. Average SNR ($\bar{\gamma}$) for NCFSK and DPSK systems with different values of fading parameters.

Numerically evaluated results for outage probability and ABER of coherent and non-coherent modulation schemes have been presented in this section. The results are plotted considering different levels of fading parameters m and k.

Outage Probability (P_{out}) vs. Normalized SNR ($\bar{\gamma}_N$) has been plotted in Figure 1, for different values of fading parameters. From Figure 1, it is noticed that the outage performance improves as the value of m increases, corresponding to that the fast fading becomes less severe. Similarly, it has been observed that for a fixed value of m, the outage performance improves as the value of k increases, implying that the channel becomes less shadowing. The performance of the system gets better with the rise of the fading parameters. This is because the smaller is the fading parameter, the severe is the channel fading, and the worse is the system performance. Moreover, the outage Probability (P_{out}) improves with the increase in normalized SNR ($\bar{\gamma}_N$).

In Figure 2, ABER vs. Average SNR per branch ($\bar{\gamma}$)for BFSK and BPSK modulation schemes have been illustrated with different values of fading parameters. The ABER performance improves with an increase in fading parameter m for a constant value of fading parameter k. Similarly, one can observe that with an increase in fading parameter k for a constant value of m, the ABER performance improves. The ABER performance improves with BPSK modulation as compared to BFSK modulation. It is seen that the ABER performance using BPSK modulation is better for $m = 3$, $k = 1.5$ than using BFSK modulation with $m = 4$, $k = 1.5$ after 8dB input average SNR per branch.

In Figure 3, the ABER vs. Average SNR per branch ($\bar{\gamma}$), has been plotted for NCFSK and DPSK modulation schemes with different values of fading parameters. From Figure 3, one can observe that the ABER performance improves with increase in fading parameter k with the fixed value of m. Similar observations can be made by increasing the parameter m for a fixed value of k. It is observed that ABER performance for DPSK modulation system improves with $k = 3.5$, after 8dB average input SNR per branch, compared to NCFSK modulation system with $k = 5.5$ and keeping a fixed value of $m = 3$. The ABER performance degrades with NCFSK modulation as compared to DPSK modulation system. The results obtained numerically through the derived expressions have been validated by Monte Carlo simulations. The simulated points are in close agreement with the analytical results.

VI. CONCLUSIONS

The outage probability and ABER, operating over the generalized-k fading channels are investigated. In this work, dual input diversity branches EGC receiver scenario is considered. The expressions of outage probability and the ABER have also been derived in terms of beta function, incomplete gamma function, Meijer's G-function, and parabolic cylindrical function. These functions are evaluated by MATHEMATICA software. The ABER expressions are derived for coherent and non-coherent modulation schemes. Arbitrary values of fading parameters are considered for the analysis. Finally, computer simulations have been provided to assess the accuracy of the proposed analytical framework.

REFERENCES

[1] P. M. Shankar, "Error rates in generalized shadowed fading channels", Wireless Personal Communications, Vol. 28, No. 4, February 2004, pp. 233–238.
[2] Petros S. Bithas, Nikos C. Sagias, P. TakisMathiopoulos, George K. Karagiannidisand Athanasios A. Rontogiannis, "On the performance analysis of digital communication over Generalized-*K* fading channel," IEEE Communication Letters, Vol. 10, No. 5, May 2006, pp. 353-355.
[3] A. Abdi and M. *K*aveh, "*K*distribution: An appropriate substitute for Rayleigh-lognormal distribution in fading-shadowing wireless channels," Electronics Letters, Vol. 34, No. 9, April 1998, pp. 851–852.
[4] Jianfei Cao, Lie-Liang Yang and ZhangduiZhong, "Performance of multihop wirelesslinks over generalized-*K*fading channel", IEEE 72ndVehicular Technology Conference-Fall, September 2010.
[5] Imran Shafique Ansari, Saad Al-Ahmadi, Ferkan Yilmaz, Mohamed-Slim Alouini and HalimYanikomeroglu, "A new formula for the BER of binary modulations with dual-branch selection over Generalized-*K* composite fading channels," IEEE Transactions on Communications, Vol. 59, No. 10, October 2011, pp. 2654 – 2658
[6] Petros S. Bithas, P. TakisMathiopoulos, and Stavros A. Kotsopoulos, "Diversity reception over Generalized-*K* (K_G) fading channels," IEEE Transactions on Wireless Communications, Vol. 6, No. 12, December 2007, pp. 4238-4243
[7] M.K. Simon and M. S. Alouni, Digital Communication over Fading Channels, 2nd Edition, Wiley-Interscience, John Wiley and Sons, Inc. January 2005.
[8] I.S. Gradshteyn and I.M. Ryzhik, Table of Integrals, Series and Products, 6th Edition, San Diego, CA:Academic. 2000.
[9] http://functions.wolfram.com/03.04.03.0004.01
[10] Athanasios Papoulis and S. Unnikrishna Pillai, Probability, Random Variables and Stochastic Processes, TATA McGraw- Hill Edition, 4thEdition, 2002.
[11] A. Annamalai, C. Tellambura, and Vijay K. Bhargava, "Equal-Gain diversity receiver performance in wireless channels," IEEE Transactions on Communications, Vol. 48, No. 10, October 2000, pp. 1732-1745.
[12] A. P.Prudnikov, Y. A.Brychkov, & O. I. Marichev, Integrals and Series, Vol. 3: More Special Functions. Oxford University Press US. (1986).
[13] V. S.Adamchik, & O. I.Marichev,The Algorithm for Calculating Integrals of Hypergeometric Type Functions and Its Realization in Reduce System, Byelorussian University, Minsk, USSR, July1990, pp. 212-224.