PERFORMANCE ANALYSIS OF BFSK MULTI-HOP COMMUNICATION SYSTEMS OVER K-μ FADING CHANNEL USING GENERALIZED GAUSSIAN-FINITE-MIXTURE TECHNIQUE

Murad A.AAlmekhlafi[1], Shafea M. Al-yousofi[1] , Mohammed M. Alkhawlani[2]

[1]Department of Electrical Engineering – Division Electronic Communications.
Sana'a University- Faculty of Engineering, Sana'a, Yemen
[2]Department of Electronics Engineering, University of Science and Technology, Sana'a, Yemen

ABSTRACT

Multi-hop communication systems gained popularity in wireless communications; they can be used to extend the coverage of the network and reduce the transmitted power. The transmission of data from the source node to the destination node in multi-hop communications undergoes through intermediate relay nodes. In this paper, we study the performance of multi-hop communication systems, in terms of average bit error rate (BER) with Binary frequency shift keying assuming the κ-μ fading channel model. Due to the difficulty in finding the probability density function (PDF) of the end-to-end signal to noise ratio (SNR) and hence for the performance metrics, we use Gaussian Mixture (GM) approximation technique to approximate the PDF of the end to end SNR assuming the κ-μ fading models as weighted sums of Gaussian distributions. Numerical results are provided for the BER of binary frequency shift keying (BFSK) of amplify and forward (AF) multi-hop communication systems assuming different values for the fading parameters (κ,η) and for different number of hops. Numerical results are validated by comparing them with simulation results.

KEYWORDS

Multi-hop;κ-μ ; gaussian mixture ;BER ; BFSK

1. INTRODUCTION

In wireless communication networks, there is a high degradation in the signal quality because of severe attenuation due to fading. Therefore, several techniques have been used in the literature such as the well-known space diversity technique, maximum ratio combining (MRC), equal gain combining (EGC), selection combining (SC) and switching combining (SWC). Cooperative diversity is also considered as another type of space diversity since it provide relay nodes as a virtual antennas to assist the transmission between the source node and the destination node. Moreover, using cooperative communication with diversity is the good solution to combat the effects of fading and enhance the communication system performance in terms of outage probability, capacity and bit error rate. Cooperative communications, is a promising technique in utilization use of the spectrum.This technique has an important advantage, expanding the coverage of the network without the need for additional power at the source furthermore,

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expanding battery life of the communication devices.The ideas comes from the broadcast nature of the wireless channel to make nodes help each other [1]. In addition, cooperative systems are classified into two types, the non-regenerative and regenerative. The goal behind this technique iswillingness to share power between all nodes, and thus, savings of overall network resources [2]. The performance of communication system and transmission capacity are improved by the relaysystem as it allows nodes to send information through relay [3]. As commonly known, wireless communications face a fading problem, in which the signals decay as they travel for long distances and different paths until they arrive to the receiver [4]. The cooperative communications of dual hop presented in [5]. The source node sends information, the destination node receives the information and the relay node receives the information from source node and retransmits information to the destination node, while promoting and developing the communication between the source and the destination [6,7].

2. Gaussian Mixtue Technique

GM is a technique used to estimate the PDF of random variables from their statistical samples. In GM Estimation, we assumed that the PDF $f\tilde{x}\ (x)$ can be estimated by a weighted sum of G-PDFs $(x;\ \theta i)$. The parameters of each PDF will be estimated using N samples taken from the distribution, where (G << N). Mathematically, the PDF of a random variable $\tilde{x}$ be estimated or represented by $f\tilde{x}\ (x)$ [8,9,10].

$$f_{\tilde{x}}(x) \simeq \sum_{i=1}^{G} w_i\, \Phi_i(x;\theta_i) \tag{1}$$

Where wi is the weight coefficient of the ith term and the mean and variance parameters representedby vectorθi. The term G represents the number of PDFs which must be determined in advanced.

Fig.1 shows the algorithm that we use in our work.

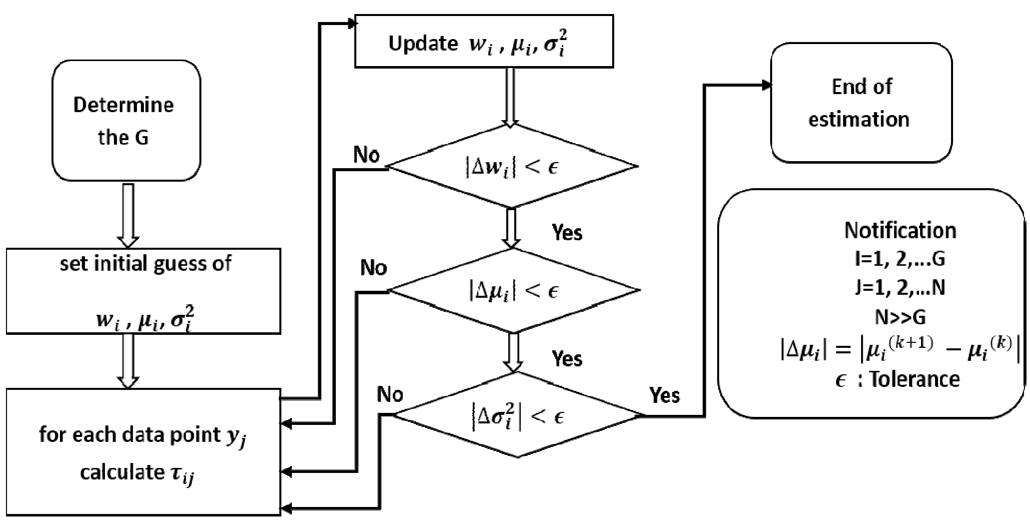

Fig. 1: GM procedural algorithm.

In this technique, we have several steps:

We guess the initial parameters and weighting coefficients. Once the initial parameters and weighting coefficients are estimated, they can be updated by GM update equations, which is derived from the following equation [10].

$$\sum_{j=1}^{N} \tau_{ij}^{(k)} \frac{\partial}{\partial \xi_i} log \left[\sum_{i=1}^{G} w_i \, \Phi_i(y_j;\theta_i) \right] = 0 \tag{2}$$

whereξ_i can be weighting coefficient w_i or, which represent the mean and variance parameters, $\tau_{ij}^{(k)}$ is the kth estimated posteriori probability that the sample point y_j belongs to the ith weighted PDF, which determined by the following equation:

$$\tau_{ij}^{(k)} = \frac{w_i{}^{(k)} \Phi_i\left(y_j;\theta_i{}^{(k)}\right)}{f_Y\left(y_j\right)} \quad , \qquad i = 1,2,\dots\dots\dots, G \,, \qquad j = 1,2,\dots, N \tag{3}$$

The updated equations which are used to estimatew_i ,μ_i and $\sigma_i{}^2$ respectively [10]:

$$\begin{aligned} w_i{}^{(k+1)} &= \frac{\sum_{j=1}^{N} \tau_{ij}^{(k)}}{N} \\ \mu_i{}^{(k+1)} &= \frac{\sum_{j=1}^{N} \tau_{ij}^{(k+1)} y_j}{\sum_{j=1}^{N} \tau_{ij}^{(k)}} \\ \sigma_i{}^{2(k+1)} &= \frac{\sum_{j=1}^{N} \tau_{ij}^{(k)} \left(y_j - \mu_i{}^{(k)}\right)^2}{\sum_{j=1}^{N} \tau_{ij}^{(k)}} \end{aligned} \tag{4}$$

we can expressed these PDFs mathematically as the sum of the weighted Gaussian PDFs using GM with EM technique as follows [10].

$$f_{\tilde{n}^2}(n^2) \simeq \sum_{i=1}^{N_n} \frac{w_{n,i}}{\sqrt{2\pi}\sigma_{n,i}} \exp\left(- \frac{\left(n^2 - \mu_{n,i}\right)^2}{2\sigma_{n,i}{}^2} \right) \tag{5}$$

We summaries the GM algorithm in this work as follows:

1. We use the weighting coefficients, mean and variance values to find the sum of the weighted Gaussian PDFs of κ-μ fading models. In addition, we compare the exact analytical PDF with GM PDF of κ-μ.
2. Study the BER performance metric of multi-hop κ-μ fading models hence, we compare the simulation BER with GM BER of κ-

3. SYSTEM MODEL

Multi-hop wireless communication is a very promising technique used to reduce the power of the transmitter and to increase the coverage by dividing the link between the source node (S) and the destination node (D) into several hops hence, extending the battery life. In multi-hop technique, the transmission of data from source to the destination undergoes through intermediate relay nodes (R_i). Each link between successive nodes undergoes a certain fading model (a_i) that might be same for all nodes [11]. In this study, it's important to obtain some performance measures for the multi-hop system, such as the bit error rate. In order to do this, it's important to PDF of the overall SNR at the link between ($S \rightarrow D$). However, it is not easy to find the PDF unless we use certain technique to approximate this PDF, such as the Gaussian Mixture technique.

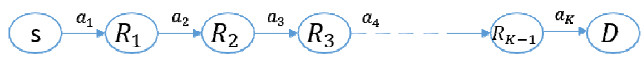

Fig.2: wireless communication system with K-hop

We obtain some performance measures for the multi-hop system, such as the bit error rate and outage probability. First, we considered the κ-μ fading model at the link $(S \rightarrow R)$ and at the link $(R \rightarrow D)$with instantaneous SNR γ_1 and γ_2 respectively in the dual hop. In addition, we generalize this procedure in multi-hop with many relays.

The PDF of κ-μ distribution is given by [12]:

$$f_\gamma(\gamma) = \frac{\mu(1+\kappa)^{0.5(\mu+1)}\gamma^{0.5(\mu-1)}}{\kappa^{0.5(\mu-1)}\, exp(\mu\kappa)\bar{\gamma}^{0.5(\mu+1)}} exp\left(-\frac{\mu(1+\kappa)\gamma}{\bar{\gamma}}\right) \mathrm{I}_{\mu-1}\left(2\mu\sqrt{\frac{\kappa(1+\kappa)\gamma}{\bar{\gamma}}}\right) \quad (6)$$

Where κ represents the ratio between the total power of the dominant components and the total power of the scattered waves, μ is related to the Multipath clustering, the average signal to noise ratio is $\bar{\gamma}$ and exp $(.)$is the exponential function.

We compared the exact PDF of κ-μ fading model and GM PDF for these fading models using ten weighted Gaussian PDFs *(with tolerance* $\varepsilon = 10^{-3}$ *and accuracy* $(|error| < 1\%)$)at different values of κ and μ, The weighted coefficients for estimated (GM) PDF of κ-μ fading model is summarized in the tables below:

These following figures are a part of our work which illustrate the agreement between the analytical PDF and GM PDF at different values for κ and μ. From the figures bellow, we see that when the value of κ or μ is increased with fixed another parameter, the degree of agreement between the analytical PDF and GM PDF will increase.

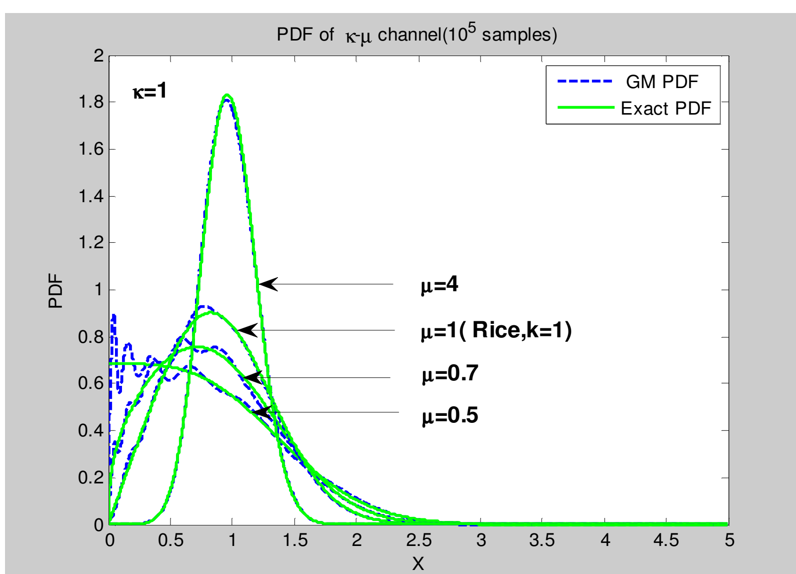

Fig. 3: Comparison between exact and GM PDF of the κ-μ at κ=1 and various values of μ

Fig.3. illustrates a comparison between exact analytical PDF and estimated PDF using GM technique of the κ-μ at κ=1 and various values of μ , it can be seen that the two PDFs matched with each other at different values of μ, we are using 10^5sample.For this figure, special cases of the κ-μ are taken,the weighting coefficients, means and variances of the ten components of GM techniquefor κ=1, μ=1, are given in Table 1.

Table 1: GM parameters and weighting coefficients using for estimation κ-μ PDF for κ=1, μ=1.

i	weight	Mean	Variance
1	0.0960	1.3193	0.0834
2	0.1049	1.0191	0.0654
3	0.0998	1.2452	0.0929
4	0.0634	1.5531	0.1411
5	0.1325	0.3860	0.0153
6	0.1213	0.6404	0.0211
7	0.0333	0.1681	0.0049
8	0.1252	0.7426	0.0353
9	0.1062	1.0046	0.0616
10	0.1172	0.9340	0.0503

4. AVERAGE BIT ERROR RATE (BER)

BER in wireless communication systems, is considered to be one of the main metrics to evaluate the performance of several systems. In this paper, we study the BER performance of multi-hop communication systems overκ-μfading model. Hence, other fading models such as Nakagami-m, Rice, Rayleigh and one-sided Gaussian can be considered as special cases for the κ-μ fading model. BER importance comes from its use to describe the functionality of a digital communication system and modulation types. TheBER given by:

$$BER = \int_0^\infty p_e(\gamma) p_\gamma(\gamma)\,.\,d\gamma \tag{7}$$

In BFSK case,

$$p_e(\gamma) = Q(\sqrt{\gamma})$$

So the equation of BER became

$$BER = \int_0^\infty Q(\sqrt{\gamma}) p_\gamma(\gamma)\,.\,d\gamma \tag{8}$$

In the dual-hop communication systems, the equivalent SNR γ_{eq} is given by:

$$\gamma_{eq} = \frac{1}{2}\mu_H \tag{9}$$

Where μ_H is the harmonic mean that is defined by [13]

$$\mu_H(X_1\,, X_2) = \frac{2}{\frac{1}{X_1} + \frac{1}{X_2}} = \frac{2X_1X_2}{X_1 + X_2} \tag{9}$$

Therefore, the equivalent end-to-end SNRγ_{eq} for dual-hop is given by

$$\gamma_{eq} = \frac{\gamma_1\gamma_2}{\gamma_1 + \gamma_2} \tag{10}$$

In addition, the equivalent end-to-end SNRγ_{eq} for multi-hop is given by [14,15]

$$\gamma_{eq} = \left[\prod_{n=1}^{N}\left(1 + \frac{1}{\gamma_n}\right) - 1\right]^{-1} \tag{11}$$

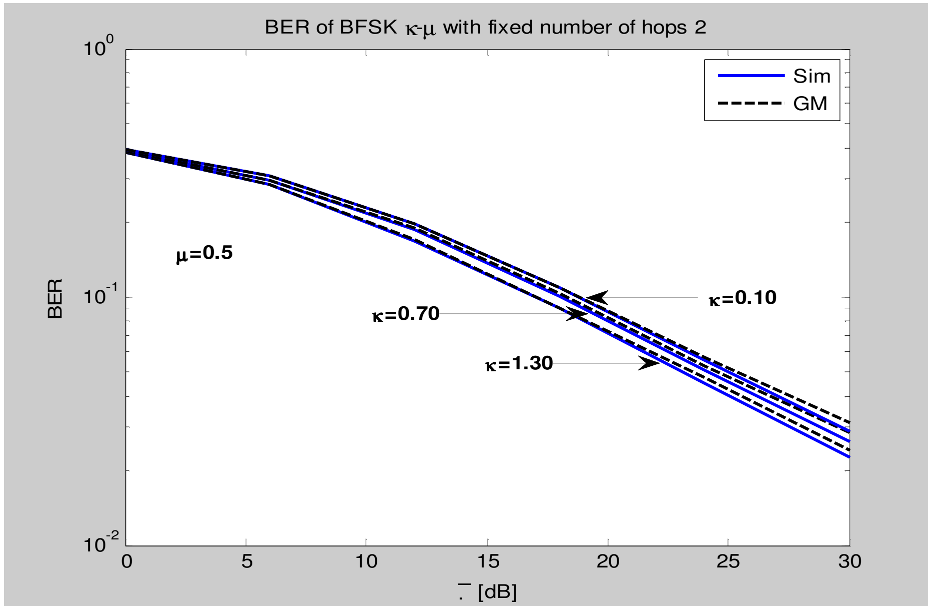

Fig 4 : average bit error rate of the dual hop for fixed μ=0.5 and change κ using GM Technique compared with simulation results

Fig.4 shows a comparison between the simulation results of the average bit error rate performance employing BFSK modulation scheme and the approximated average bit error rate using GM technique for dual-hop communication systems over κ-μ fading model with fixed μ=0.5 and change κ=0.10,0.70, and 1.30. It is clear that the GM matched with simulation results of average bit error rate. For this figure, the BER decrease by increase the value of κ.

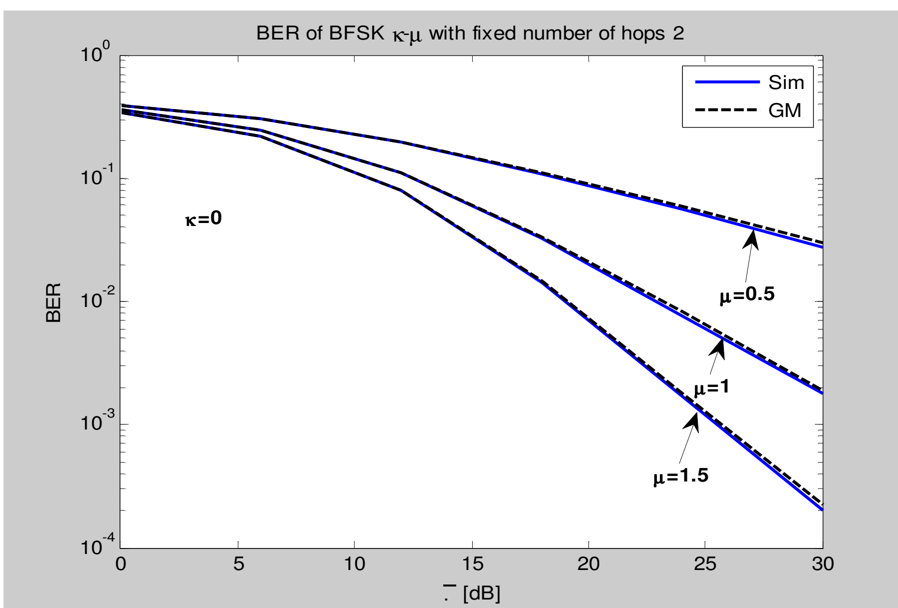

Fig 5 : average bit error rate of the dual hop for fixedκ =0 and changeμ=0.5, 1, and 1.5 Using GM Technique compared with simulation results

Fig. 5 shows a comparison between the simulation results of the average bit error rate performance employing BFSK modulation scheme and the approximated average bit error rate using GM technique for dual-hop communication systems over κ-μ fading model with fixed κ=0 and change μ=0.5,1,1.5. It is clear that the GM matched with simulation results of average bit error rate. For this figure, the BER decrease by increase the value of μ.

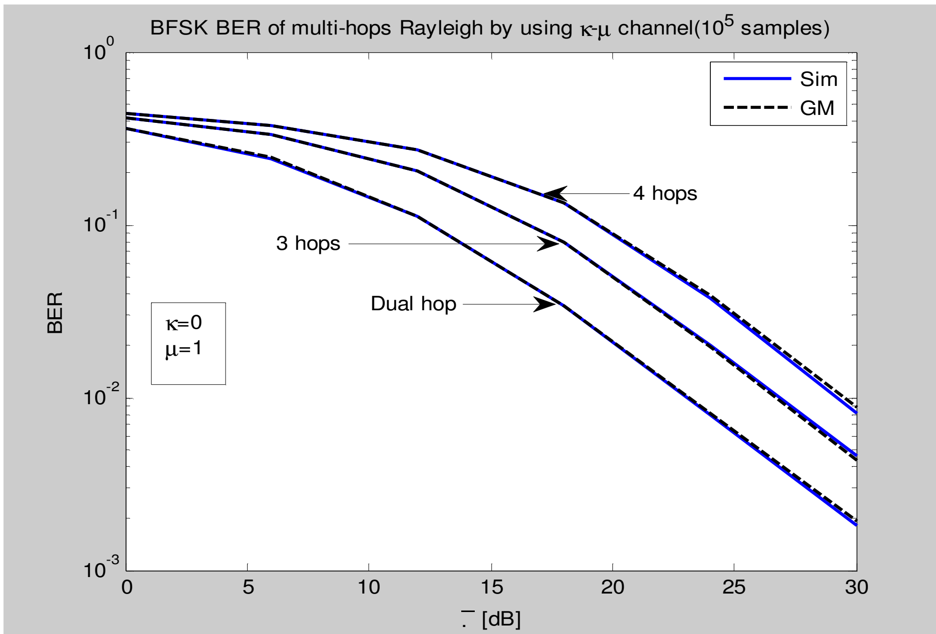

Fig 6 : Bit error rate of the multi-hop for κ=0 and μ =1 (Rayleigh) over κ-μ fading channel Using GM technique compared with simulation results

Fig.6 shows a comparison between the simulation results of the average bit error rate performance employing BFSK modulation scheme and the approximated average bit error rate using GM technique for multi-hop communication systems over κ-μ fading model with κ=0 and μ=1 (Rayleigh). It is clear that the GM matched with simulation results of average bit error rate. For this figure, the BER increase by increase the number of hops.

5.CONCLUSION

In this paper, we studied the Performance Analysis of BFSK multi-hop communications systems overthe κ-μfading model. In order to do this, we opted for the Gaussian Mixture technique, a technique used to estimate the PDF of random variables from their statistical samples. In addition, it provides us with a tool to study the performance metric, such as BER. In the BER case, we use the BFSK modulation scheme and we observe improvement in BER by increasing parameters κ and μ. On the other hand increase the number of hops can be the reason for the decline in performance.This is because we use the non-regenerative (amplify-and-forward) relay type, which is amplifies both signal and noise received from the first hop. The accumulated noises over increasing number of hops lead to substantial performance loss.Increase in BER by increasing number of hops is not a big problem we can solve it by using different diversity or coding techniques. Moreover, it has been shown that the simulation results were identical to the GM technique results at all special cases of κ-μ fading model. We found the simulation results almost identical with GM technique result at all special cases of κ-μ fading model. Furthermore,these results did not exist or have not been mentioned in literature earlier.

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