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Dual-hop Transmissions with Fixed Gain Relays over Composite Fading Channels using Mixture Gamma Distribution

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Abstract

The end-to-end performance of dual-hop wireless communication system with fixed gain relays is investigated over independent non-identical composite Nakagami-lognormal fading channels using mixture gamma distribution. Novel closed-form expressions for the outage probability, the average symbol error rate and the nth moments of end-to-end signal to noise ratio (SNR) for the considered system are derived, respectively. Numerical and simulation results are shown and discussed to verify the accuracy of the analytical results under different scenarios, such as varying average SNR, fading parameters per hop, and the location of relaying nodes.

Keywords: *Dual-hop relaying; fixed gain relays; Nakagami-lognormal fading channels; Mixture Gamma distribution; Performance analysis*

1. Introduction

Multihop relaying transmission has emerged as a promising technique for extending coverage, enhancing connectivity, and saving transmitter power in wireless communications networks, such as bent pipe satellites and microwave links, as well as modern ad-hoc, cellular, WLAN, and hybrid wireless networks. In such networks, one source communicates with one destination via one or several intermediate terminals called relays. Generally, there are two main categories of multi-hop wireless systems: decode-and-forward (DF) and amplify-and-forward (AF) systems [1]. In the former, the relays re-encode and retransmit the signals towards the destination after demodulating and decoding the received signals from the source. The latter uses less complex relays to amplify and re-transmit the signals without any sort of decoding. Moreover, the latter can be further classified into two subcategories, namely, channel state information (CSI)-assisted relays and blind relays. AF systems with CSI-assisted relays use instantaneous CSI of the first hop to control the gain introduced by the relays. In contrast, AF systems with blind relays employ at the relaying nodes amplifiers with fixed gains. Although such systems are not expected to perform as well as systems with CSI-assisted relays, their low complexity and ease of deployment make them attractive from a practical standpoint.

In the past few years, AF systems with fixed gain relays have been widely studied over different system and fading channel models in [2][11], and the references therein. In [2], the end-to-end performance of a dual-hop system with AF fixed gain relays over flat Rayleigh fading channels is firstly evaluated. After that, a lot of papers investigated the performance of various relaying system models with fixed gain relays based on the end-to-end signal to noise ratio (SNR) over Nakagami-m fading channels, such as multihop system models in [3], dual-hop system models in [4] and cooperative system model in [5], and so on. In [6]-

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[7], the performance of dual hop systems with fixed-gain relays is studied over generalized gamma and generalized $\eta-\mu$ fading channels, respectively. The authors in [8] investigated the end-to-end performance of a dual-hop system with a fixed-gain relay over generalized-K (KG) fading channels. The authors in [9] and [10] evaluated the performance of the dual-hop fixed gain relaying system over Nakagami/KG fading channels. The authors in [11] investigated the ergodic capacity of AF dual-hop relaying systems with both fixed and variable gain relaying in $\mathcal{G}$ fading channels.

Unfortunately, since the PDFs of their average SNR include modified Bessel functions in the KG and $\mathcal{G}$ fading channels, mathematical complications arise in the evaluation of system performance over composite multipath/shadowing fading environments. Their cumulative distribution function (CDF), moment generation function (MGF) and average bit/symbol error rate (ABER/ASER) usually include some more complicated special functions, such as Meijer's G functions. The computation of such functions can be difficult. To avoid mathematical difficulties, some further approximations have to be used. In [8], the Padé approximant method has been employed to obtain the ABER/ASER. In [11], the authors only obtained the analytical upper and lower bounds of the ergodic capacity for dual-hop relaying systems, and these expressions of capacity bounds still keep complicated and intractable.

In the analysis in composite fading channels, the prevalent model is the Nakagami-m/lognormal (NL) model, which has been extensively used to approximate the fading fluctuations in radar and radio-frequency communication systems. Recently, the authors in [12] developed a new approach to approximate the NL distribution by using the Mixture Gamma (MG) distribution. This distribution is composed of a weighted sum of gamma distribution, and can avoid the above-mentioned problems. Some exact results obtained are possible by adjusting the number of gamma distributions. In [13], we studied the end-to-end performance of multi-node cooperative networks over composite NL fading channels using MG distribution, and found it is more precise and amenable to approximate the NL distribution using MG distribution than the KG distribution from two aspects of the expression complexity and the analytical accuracy in the performance analysis of cooperative networks.

However, to the best of our knowledge, results concerning the performance of AF systems with fixed-gain relays operating over composite NL fading channels using MG distribution are not available in the open literature. In this paper, we focus on AF dual-hop systems with fixed-gain relays and analyze their end-to-end performance over independent non-identical composite NL fading channels using MG distribution. The main contribution of this paper is to derive the closed form expressions for the outage probability, the ASER, and the nth moment of the end-to-end SNR for this dual hop system. Also, two expressions for the parameter Z which describes the semi-blind fixed gain is derived and discussed. With these results, various numerical and simulation results are shown to demonstrate the validity of the proposed analysis under different scenarios, such as varying average SNR per hop, fading parameters, and the location of relaying nodes.

This paper is organized as follows. Section 2 describes the system and channel models. In section 3, some exact expressions of several important performance criteria are obtained. The performance evaluations and conclusions are presented in section 4 and 5, respectively.

2. System and Channel Models

We consider a wireless dual-hop AF relaying system over composite NL fading environments. The source node (S) communicates with the destination node (D) via a relaying node (R).The whole transmission is divided into two phases. In the first phase, S only transmits its signals to R, and in the second phase, R amplifies the received signals by a gain factor β and then forwards their amplified versions to D. Thus, the instantaneous end-to-end SNR, γ_{SRD}, at the destination can be expressed as in [2]

$$\gamma_{SRD} = \frac{(P_1|h_1|^2/N_0)(P_2|h_2|^2/N_0)}{(P_2|h_2|^2/N_0)+(1/N_0\beta^2)} \tag{1}$$

Where P_1 and P_2 are the transmit power at S and R respectively, $|h_i|$ is the fading amplitude of the i^{th} hop link, $i \in \{1,2\}$ N_0 is the power of the additive white Gaussian noise (AWGN) component. If β is selected according to the fixed relay gain, which is defined as $\beta^2 = P_1/ZN_0$ as in [2], then γ_{SRD} in (1) can be re-expressed as

$$\gamma_{SRD} = \frac{\gamma_1\gamma_2}{\gamma_2+Z} \tag{2}$$

Where $\gamma_i=\rho_i|h_i|^2$ is the instantaneous SNR of the i^{th}-hop link, $\rho_i=P_i/N_0$ denotes the un-faded SNR, Z is a constant for a fixed gain β. Without loss of generality, we assume $P_1=P_2=P$ in this paper, then $\overline{\gamma_i} = \rho\mathbf{E}[|h_i|^2] = \rho\Omega_i$ denotes the average SNR of the i^{th}-hop link, **E** [•] is the statistical expectation, Ω_i denotes the deviation of $|h_i|$.

Due to assuming the i^{th}-hop link experiences NL fading, γ_i is a composite Gamma-lognormal distribution variable with the PDF given by [14]

$$f_{\gamma_i}(x) = \int_0^\infty \frac{m_i^{m_i}x^{m_i-1}}{\Gamma(m_i)(\rho y)^{m_i}}\exp[-\frac{m_i x}{\rho y}]\frac{1}{\sqrt{2\pi}\lambda_i y}\exp[-\frac{(\ln y-\mu_i)^2}{2\lambda_i^2}]dy \tag{3}$$

where m_i is fading parameter in Nakagami-m fading, μ_i and λ_i are the mean and the standard deviation of lognormal shadowing, respectively, $\mu_i=\ln\Omega_i$, $\lambda_i=(\ln 10/10)\sigma$, σ denotes the standard deviation in dB. Due to considering the path-loss effect, we define the local mean power $\Omega_i = (d_0/d_i)^\varepsilon$, d_0 denotes the direct distance between S and D, d_i is the distance of the i^{th} hop link, and ε is the path-loss exponent.

Since a closed-form expression of eq.(3) is not available in the published literatures, the performance metrics of digital communication systems over composite NL distribution is intractable or difficult, some approximations or simple forms of (3) have been given great attention recently, such as KG, $\mathcal{G}$ and MG fading models. In this paper, we use MG distribution in [12] to approximate the composite NL distribution. Thus, the PDF of γ_i can be expressed as [12]

$$f_{\gamma_i}(x) = \sum_{j=1}^N T_j x^{m_i-1}\exp(-M_j x) \tag{4}$$

Where $T_j = c_j a_j/2\rho^{m_i}$, $M_j = b_j/\rho$, $a_j = 2m_i^{m_i}w_j\exp[-m_i(\sqrt{2}\lambda_i t_j+\mu_j)]/\sqrt{\pi}\Gamma(m_i)$, $c_j = \sqrt{\pi}/\sum_{j=1}^N w_j$, is the normalization factor, $b_j = m_i\exp[-(\sqrt{2}\lambda_i t_j+\mu_i)]$, w_j and t_j are abscissas and weight factors for Gaussian-Hermite integration w_j and t_j for different N values are available in [15, Table(25.10)].

Based on the definition of the CDF, $F_\gamma(\gamma)=\int_0^\gamma f_\gamma(x)dx$ in [14], where $f_\gamma(\cdot)$ is the PDF of the instantaneous SNR (γ), the CDF of γ_i can be obtained as

$$F_{\gamma_i}(\gamma)=1-\sum_{j=1}^{N}R_j\Gamma(m_i,M_j\gamma) \tag{5}$$

Where $R_j=c_ja_j/2b_j^{m_i}$, $\Gamma(\cdot,\cdot)$ is the incomplete gamma function defined in [16, eq.(8.350.2)].

3. Performance Analysis

3.1. Outage Probability

The outage probability is an important performance measure that is commonly used to characterize a wireless communication system. It is defined as the probability that the instantaneous end-to-end SNR falls below a given threshold (γ_{th}) in [14], this is

$$P_{out}=F_\gamma(\gamma_{th})=\Pr(\gamma\le\gamma_{th})=\int_0^{\gamma_{th}}f_\gamma(\gamma)d\gamma \tag{6}$$

For the dual-hop system with fixed gain, the end-to-end outage probability can be expressed as in [2]

$$P_{out}(\gamma_{th})=\Pr(\gamma_{SRD}\le\gamma_{th})=\int_0^\infty \Pr[\frac{\gamma_1+y}{Z+y}\le\gamma_{th}\mid y]f_{\gamma_2}(y)dy=\int_0^\infty \Pr[\gamma_1\le\frac{(Z+y)\gamma_{th}}{y}\mid y]f_{\gamma_2}(y)dy \tag{7}$$

By using (4) and (5), and substituting them into (7), and with the help of the series expression of $\Gamma(\cdot,\cdot)$ defined in [16, eq.(8.352.2)] and the binomial expansion defined in [16, eq.(1.111)], after applying some algebraic manipulations, eq.(7) can be rewritten as

$$P_{out}(\gamma_{th})=1-\sum_{i=1}^{N}\sum_{j=1}^{N}\sum_{k=0}^{m_1-1}\sum_{l=0}^{k}\binom{k}{l}\frac{R_iT_j\Gamma(m_1)}{k!Z^{l-k}M_i^{-k}}\gamma_{th}^k\exp[-M_i\gamma_{th}]\int_0^\infty y^{m_2+l-k-1}\exp[-M_jy-\frac{M_iZ\gamma_{th}}{y}]dy \tag{8}$$

With the help of eq. (6.621.3) in [16], we can obtain the outage probability as

$$P_{out}(\gamma_{th})=1-\sum_{i=1}^{N}\sum_{j=1}^{N}\sum_{k=0}^{m_1-1}\sum_{l=0}^{k}\binom{k}{l}\frac{2R_iT_j\Gamma(m_1)Z^{(m_2+k-l)/2}}{k!M_j^{(m_2+l-k)/2}M_i^{-(m_2+k+l)/2}}\gamma_{th}^{(m_1+l+k)/2}\exp\left[-M_i\gamma_{th}\right]K_{m_2+l-k}[2\sqrt{M_iM_jZ\gamma_{th}}] \tag{9}$$

Where $K_\alpha(*)$ is the second kind modified Bessel function of order α.

3.2. Average Symbol Error Rate

The ASER is a useful measurement for investigating the performance of wireless communication systems. For several modulations with Gray bit mapped constellations, a uniform expression of the ASER can be written as [14]

$$P_s=E[aQ(\sqrt{2b\gamma})]=\int_0^\infty aQ(\sqrt{2b\gamma})f_\gamma(\gamma)d\gamma \tag{10}$$

Where Q (•) is the Gaussion Q-funtion, the parameters a and b change by specific modulation scheme. Eq. (10) provides exact SER results for binary PSK (a=1, b=1), binary frequency shift keying (BFSK) (a=1, b=0.5) and M-ary pulse amplitude modulation (M-PAM) (a=2(M-1)/M, b=3/(M^2-1)). Furthermore, eq.

(10) also provides approximate SER results for other modulations such as M-PSK (a=2, b=sin^2 (π/M)). After integration by parts, eq. (10) can be rewritten, by using the CDF of γ_{SRD}, as

$$P_s = \frac{a\sqrt{b}}{2\sqrt{\pi}}\int_0^\infty \frac{\exp(-bx)}{\sqrt{x}} F_{\gamma_{SRD}}(x)dx \tag{11}$$

Where $F_{\gamma_{SRD}}(x)$ can be obtained by substituting γ_{th}=x into (9).

Therefore, by expressing $\exp(-x) = G_{0,1}^{1,0}[x|_{0}^{-}]$ and $K_v(2\sqrt{x}) = (1/2)G_{0,2}^{2,0}[x|_{v/2,-v/2}^{-}]$ as a Meijer's G function form defined in [17, eq. (01.03.26.0004.01)] and [17, eq. (03.04.26.0009.01)], and using [17, eq. (07.34.21.0011.01)], one can get the analytical expression of ASER as

$$P_s = \frac{a}{2} - \sum_{i=1}^{N}\sum_{j=1}^{N}\sum_{k=0}^{m_1-1}\sum_{l=0}^{k}\binom{k}{l}\frac{R_i T_j \Gamma(m_1) a\sqrt{b}}{2k!Z^l M_j^{m_2+l}\sqrt{\pi(M_i+b)}} G_{1,2}^{2,1}\left[\frac{M_i M_j Z}{M_i+b}\middle|\begin{matrix}0.5\\ m_2+l,k\end{matrix}\right] \tag{12}$$

Where G [•|•] is the Meijer's G-function defined in [16, eq. (9.301)].

3.3. Average End-To-End Snr and Amount of Fading (Aof)

The average end-to-end SNR is a useful performance measure serving as an excellent indicator of the overall system's fidelity. The nth moment of the end-to-end SNR can be derived by using CDF as

$$\mu(\gamma^n) = \int_0^\infty \gamma^n f_{\gamma_{SRD}}(\gamma)d\gamma = n\int_0^\infty \gamma^{n-1}[1-F_{\gamma_{SRD}}(\gamma)]d\gamma \tag{13}$$

By using (9) and with the help of [17, eq. (07.34.21.0011.01)], eq. (13) can be re-expressed as

$$\mu(\gamma^n) = \sum_{i=1}^{N}\sum_{j=1}^{N}\sum_{k=0}^{m_1-1}\sum_{l=0}^{k}\binom{k}{l}\frac{nR_i T_j \Gamma(m_1)}{k!Z^l M_j^{m_2+l} M_i^n} G_{1,2}^{2,1}\left[M_j Z\middle|\begin{matrix}1-n\\ m_2+l,k\end{matrix}\right] \tag{14}$$

Therefore, the average end-to-end SNR can be derived by setting n=1 in (14).

The AoF is a unified measure of the severity fading, which is typically independent of the average fading power and is defined as $AoF = \mu(\gamma^2)/\mu^2(\gamma) - 1$ in [14]. The AoF of dual-hop relaying system with fixed gain can be obtained by setting n=1 and 2 in (14) over MG fading channels.

3.4. The Choice of the Fixed Relay Gain

For the dual-hop system using fixed relay gain, the semi-blind relay gain is determined by the channel statistics at the first hop. In general, there are two major schemes to calculate the relay gain as in [18].

In the first scheme, the fixed-gain relaying factor β is chosen equal to the average of CSI assisted gain, as [2]

$$\beta^2 = \rho\mathbf{E}[1/(\gamma_1+1)] = \rho\int_0^\infty f_{\gamma_1}(\gamma_1)/(\gamma_1+1)\,d\gamma_1 \tag{15}$$

Since the first-hop link undergoes NL fading, the constant Z is given by

$$Z_1 = \frac{2\rho^{m_1}}{\sum_{i=1}^{N} c_i a_i \exp(b_i/\rho)\Gamma(m_1)\Gamma(1-m_1, b_i/\rho)} \tag{16}$$

In the second scheme, the fixed-gain relaying factor β is chosen as in [1]

$$\beta^2 = \rho/(\mathbf{E}[\gamma_1]+1) = \rho/(\bar{\gamma}_1+1) \tag{17}$$

Thus, the constant Z is determined by the average SNR of the first-hop, and obtained as

$$Z_2 = 1+\sum_{i=1}^{N} R_i\Gamma(m_1+1)/M_i \tag{18}$$

4. Numerical Results and Discussion

In this section, we present some numerical and simulation results to evaluate the performance of the dual hop system with fixed gain in composite fading channels by using the MG distribution.

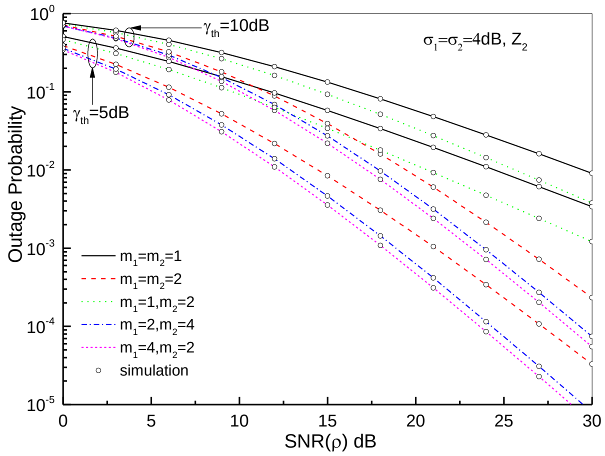

Figure 1. Outage Probability for the Dual-Hop Fixed Gain System versus the Un-Faded SNR (P) Under Different Multipath Fading Parameters

Figure 1 and Figure 2 illustrate the outage probability in (9) versus the un-faded SNR (ρ) under different fading scenarios. In this case, a symmetric network geometry is assumed, this is, d_0=1, d_1=d_2=0.5, ε=4, N =10 for MG distribution. From these figures, it is can be seen that the outage performance is improved with ρ increases. Figure 1 shows the impact of the multipath fading parameter (m) and the outage threshold (γ_{th}) on the outage probability where σ_1=σ_2=4dB and the constant Z_2 in (18) is used. As expected, it can be seen from Figure 1 that the outage performance is improved when the multipath fading level of either hops improves, and the slopes of the curves are dependent on the minimum value between m_1 and m_2. Moreover, the system performance is degraded when the outage threshold increases. These results are similar as the conclusions reported in [18] and the references therein. Figure 2 shows the impact of the shadowing parameter (σ) and the constant (Z) on the outage probability where m_1=m_2=2, and γ_{th}=5dB. As expected, it can be seen from Figure 2 that the outage performance is decreased when the shadowing deviation (σ) increases. When the shadowing deviation in dual hop system is asymmetric, for example, σ_1=4dB, σ_2=8dB, the case with the light shadow for the first hop shows better performance. For the choice of fixed gain factor, the case using (16) shows better performance than the case using (18). This is due to the fact that the calculation of the relay gain in (15) and (17) differs only in the position of the expectation operator and the function $1/(\gamma_1+1)$ is a strictly convex function, such that Z_2 in (18) is always greater than Z_1 in (16). At the same time, the simulation results coincide perfectly with the analytical results of (9) and verify the mathematical accuracy.

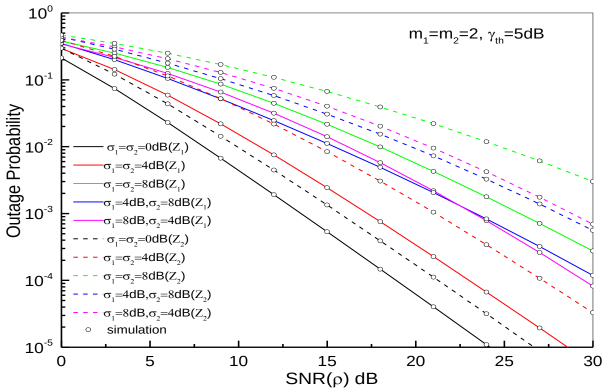

Figure 2. Outage Probability for the Dual-Hop Fixed Gain System versus the Un-Faded SNR (P) Under Different Shadowing Fading Parameters

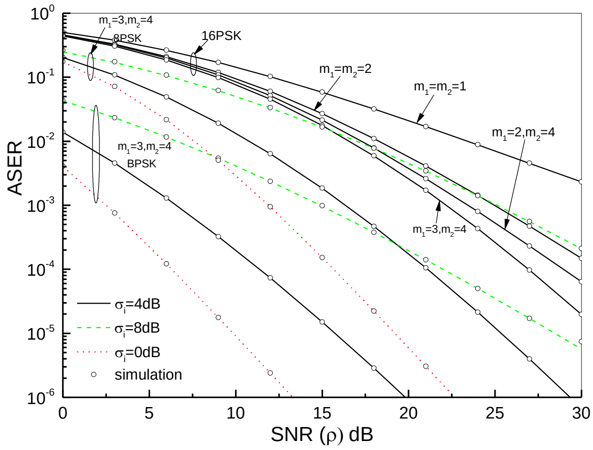

Figure 3. ASER of MPSK for the Dual-Hop Fixed Gain System versus the Un-Faded SNR (P)

Figure 3 shows the ASER of MPSK in (12) versus the un-faded SNR (ρ) under different fading scenarios. In this case, the symmetric network geometry is assumed as in Figure 1. It can be seen from Figure 3 that ASER of MPSK is improved with ρ increases. The impact of fading parameters on ASER shows agreement with the ones on outage probability in Figure 1 and Figure 2 by adjusting multipath and shadowing parameters. As expected, the performance of MPSK shows better when the value of M is smaller. At the same time, the simulation results still agree perfectly with the analytical results of (12).

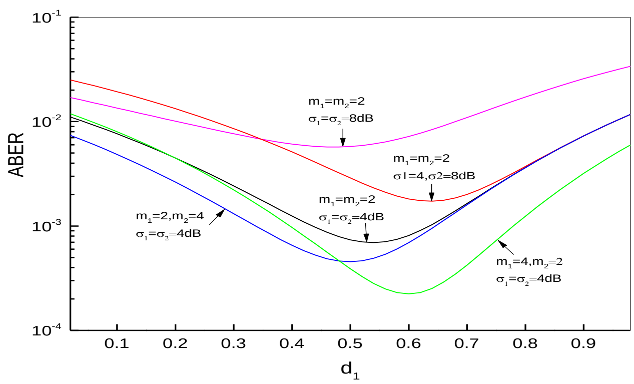

Figure 4. ABER Of BPSK For The Dual-Hop Fixed Gain System Versus D_1

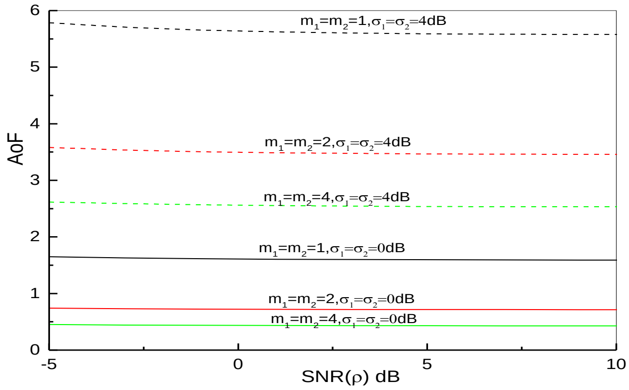

Figure 5. A of The Dual Hop Fixed Gain System Versus The Un-Faded SNR (P)

In Figure 4, we show the impact of the relay location on the ABER of BPSK for the dual-hop system. In this section, the asymmetric network geometry is examined where R is moved on a straight line between S and D, d_1 denotes the distance between S and R. Each hop has different fading parameters, ρ=10dB, N=10 for MG distribution. From Figure 4, it can be seen that the performance of the dual-hop system is symmetric about the middle of the line between S and D, the optimum performance is located near the middle when the fading parameters of per hop are same. On the other hand, the optimum performance moves toward the weaker hop when the fading parameters of per hop are different. When R is closer to S, the system performance is determined by the channel condition of the second hop, for example, if the fading parameter increases (m_2=2→m_2=4), the performance is improved and the location of the optimum performance moves toward S, and if the shadow deviation increases (σ_2=4dB→σ_2=8dB), the performance is degraded. When R is closer to D, the system performance is determined by the channel condition of the first hop. If the fading parameter increases (m_1=2→m_1=4), the performance is improved and the location of the optimum performance moves toward D. It can also be explained that they show the same performance when R is closer to D if only the channel conditions of the second-hop change. These results are helpful to the selection of relaying nodes in cooperative networks.

Figure 5 plots the AoF of the dual hop system versus the un-faded SNR (ρ) over composite fading channels. It can be seen that the AoF changes slightly with ρ increases. However, the AoF decreases with the multipath fading levels improve, and it increases with the shadowing deviation increases.

5. Conclusions

In this paper, we investigated the end-to-end performance of a dual-hop AF wireless communication system with fixed gain relays over the composite NL fading channels approximated by using MG distribution. Based on MG fading model, some novel closed-form expressions of the outage probability, the ASER of MPSK and the nth moments for the dual-hop AF system are derived, respectively. Then, we showed numerical and simulation results to verify the accuracy of the analytical results, and discussed the effect of the multipath, shadowing parameters and the location of relaying nodes on the performance of the dual-hop fixed gain system.

References

[1] J.N. Laneman, D.N.C. Tse, and G.W. Wornell, “Cooperative diversity in wireless networks: efficient protocols and outage behavior,” IEEE Transactions Information Theory, vol. 50, no. 12, Dec. (**2004**).

[2] M. O. Hasna and M. S. Alouini, ”A Performance Study of Dual Hop Transmissions With Fixed Gain Relays”, IEEE Trans. Wireless Commun., vol. 3, no. 6, Nov. (**2004**).

[3] G. K. Karagiannidis, ”Performance bounds of multihop wireless communications with blind relays over generalized fading channels”, IEEE Trans. Wireless Commun., vol. 5, no. 3, Mar. (**2006**).

[4] D. B. da Costa and M. D. Yacoub, ”Dual-hop transmissions with semi-blind relays over Nakagami-m fading channels”, Electron. Lett., vol. 44, no. 3, Dec. (**2007**).

[5] H. Shin and J. B. Song, “MRC analysis of cooperative diversity with fixed-gain relays in Nakagami-m fading channels,”IEEE Trans. Wireless Commun., vol. 7, no. 6, Jun. (**2008**).

[6] K. Peppas, A. Mansour, and G. T Tombras, “Dual-hop transmissions with fixed-gain relays over generalized gamma fading channels,” Journal Telecomm., vol. 1, no. 1, Feb. (**2010**).

[7] Osamah S. Badarneh and Michel Kadoch, “Performance Analysis of Dual-Hop systems with Fixed Gain Relays over Generalized η-μ Fading Channels”, IEEE Globecom (**2012**).

[8] L. Wu, 1. Lin, K. Niu, and Z. He, "Performance of dual-hop transmissions with fixed gain relays over generalized-K fading channels," IEEE ICC, (**2009**).

[9] T. Imène, A. Sofiène, and S. Alex, “On the performance of dual-hop fixed gain relaying systems over composite multipath/shadowing channels, ” IEEE 72nd VTC (Fall), Sept. (**2010**).

[10] O. Waqar, M. A. Imran and M. Dianati. On the Error Analysis of Fixed-gain Relay Networks over Composite Multipath/Shadowing Channels, IEEE 77th VTC (Spring), June 2-5, (**2013**).

[11] Caijun Zhong Michail Matthaiou, George K. Karagiannidis, Aiping Huang and Zhaoyang Zhang, “Capacity Bounds for AF Dual-hop Relaying in $\mathcal{G}$ Fading Channels”, IEEE Trans. on Vehicular Technology, vol.61, no.4, May (**2012**).

[12] S. Atapattu, C. Tellambura, and H. Jiang, “Representation of composite fading and shadowing distributions by using mixtures of gamma distributions,” Proc. IEEE Wireless Commun. Network. Conf., (**2010**).

[13] Weijun Cheng, “On the performance of multi-node cooperative networks over composite nakagami-lognormal fading channels using mixture gamma distribution”, Journal of Computers (Finland), vol.8, no.10, (**2013**).

[14] M.K. Simon, and M.S. Alouini, Digital Communication over Fading Channels, 2nd edition. New York: Wiley; (**2005**).

[15] M. Abramowitz, and I.A. Stegun, Handbook of Mathematical Functions: With Formulas, Graphs, and Mathematical Tables. Dover Publications, (**1965**).

[16] I.S. Gradshteyn, and I.M. Ryzhik, Table of Integrals, Series, and Products, 6th Edition. New York: Academic; (**2000**).

[17] The Wolfram functions site. URL http://functions.wolfram.com.

[18] M. Xia, C. Xing, Y.-C. Wu, and S. Aissa, “Exact performance analysis of dual-hop semi-blind AF relaying over arbitrary Nakagami-m fading channels,” IEEE Trans. Wireless Commun., vol. 10, no. 10, Oct. (**2011**).

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