Asymptotic Performance Analysis of AF Relaying in Two-Wave with Diffuse Power Fading Channels

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***Abstract*—In the context of two-wave with diffuse power (TWDP) fading scenarios, this paper analyzes the outage probability and symbol error rate (SER) of single relay cooperative networks using amplify-and-forward (AF) relaying. Each channel in the network is assumed to be independently and non-identically distributed. The statistical result of the upper bound on the received signal-to-noise ratio (SNR) is derived. We derive the closed-form asymptotic expressions to approximate the outage probability and SER in the high SNR regime, respectively. Based on the asymptotic results, the diversity order and coding gain of the cooperative network is analyzed. Simulation results show that these asymptotic results are tight particularly in the high SNR regime for cooperative networks in different fading scenarios.**

***Index Terms*—Cooperative diversity, outage probability, symbol error rate, two-wave with diffuse power.**

I. Introduction

The technique of cooperative network is a promising approach to obtain spatial diversity in networks consisting of single-antenna nodes. To exploit the full cooperative diversity, two typical cooperative strategies including amplify-and-forward (AF) and decode-and-forward (DF) are proposed [1]. Specifically, the AF relaying strategy has gained considerable interest due to its simplicity. Over the past years, the performance of AF cooperative networks in the Rayleigh, Nakagami-*m*, and Rician fading cases has been extensively investigated [2–8].

However, such fading models mentioned above are unable to characterize certain practical situations, where the received signal contains two strong, specular multipath waves. Such situation is very common in practical fading environments. For instance, directional antenna and antenna array can amplify several multipath waves and attenuate the rest according to their arrival directions. Furthermore, receivers for wide-band signal separate specular multipath components from other diffuse multipath waves based on distinct propagation time delays. To accurately describe these scenarios, a more comprehensive and flexible channel model named two-wave with diffuse power (TWDP) was proposed [9]. It has been verified that TWDP fading can well represent frequency-selective fading in wireless sensor networks [10]. Over the past decades, the performance of point-to-point systems in TWDP fading channels was extensively analyzed [11–14]. However, to the authors' best acknowledge, few works have conducted a comprehensive investigation on the cooperative networks over TWDP fading channels.

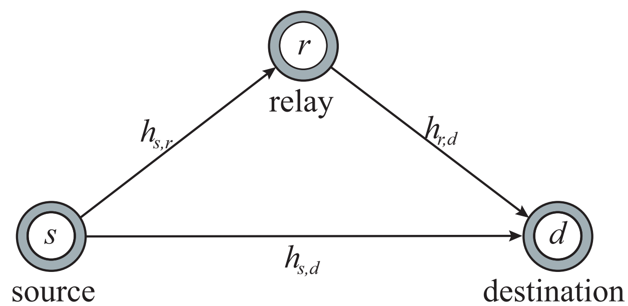

Fig. 1. Illustration of a cooperative relay network.

In this paper, we specifically investigate the outage probability and the symbol error rate (SER) of dual-hop AF relaying networks in independent and non-identical TWDP fading channels. We derive a closed-form asymptotic expression for the outage probability. In addition, the asymptotic SER expression for AF relaying networks modulated by M-ary phase shift keying (M-PSK) or M-ary quadrature amplitude modulation (M-QAM) is derived. The asymptotic results are validated by simulations, and it is shown that the asymptotic results are tight in the high signal-to-noise ratio (SNR) regime. Our proposed results can be used to investigate the performance and the power allocation strategy of AF relaying in TWDP fading channels.

II. System and Channel Model

A. System Model

We consider a cooperative network consisting of a source, a relay and a destination as shown in Fig. 1. The channel fading coefficients of the source-to-destination, source-to-relay, and relay-to-destination links denoted by $h_{s,d}$, $h_{s,r}$, and $h_{r,d}$ are subject to independent and non-identically distributed (i.n.i.d.) TWDP fading. Without any loss of generality, we assume that all additive white Gaussian noise (AWGN) terms have zero mean and equal variance N_0. The AF relaying consists of two transmission phases. In the first phase, the source broadcasts its signal $x(n)$ to the relay and the destination. The received signals at the relay and destination are respectively given by

$$y_{s,r}(n) = \sqrt{\varepsilon_s} h_{s,r} x(n) + \omega_1(n), \tag{1}$$

and

$$y_{s,d}(n) = \sqrt{\varepsilon_s} h_{s,d} x(n) + \omega_2(n), \tag{2}$$

where ε_s is the transmitted energy at the source, and ω_1 and ω_2 are additive white Gaussian noise (AWGN) signals with mean power of N_0. During the second phase, the relay forwards the amplified signal to the destination, and the received signal is given by

$$y_{r,d}(n) = \alpha h_{r,d} y_{s,r}(n) + \omega_3(n), \tag{3}$$

where ω_3 is a AWGN signal with mean power of N_0, and $\alpha = \sqrt{\frac{\varepsilon_r}{\varepsilon_s |h_{s,r}|^2 + N_0}}$ denotes the amplifying factor, with ε_r denoting the transmitted energy at the relay. At the destination, the maximal ratio combining (MRC) strategy is used to combine the signals received from the source and the relay. The total instantaneous SNR at the destination can be expressed as [2]

$$\gamma_d = \gamma_{s,d} + \frac{\gamma_{s,r}\gamma_{r,d}}{\gamma_{s,r} + \gamma_{r,d} + 1}, \tag{4}$$

where $\gamma_{s,d} = |h_{s,d}|^2 \gamma_s$, $\gamma_{s,r} = |h_{s,r}|^2 \gamma_s$, and $\gamma_{r,d} = |h_{r,d}|^2 \gamma_r$ respectively denote the instantaneous SNRs of the source-to-destination, source-to-relay, and relay-to-destination links, $\gamma_s = \varepsilon_s / N_0$ denotes the transmit SNR at the source, and $\gamma_r = \varepsilon_r / N_0$ denotes the transmit SNR at the relay. Moreover, the average SNRs of the source-to-destination, source-to-relay, and relay-to-destination links are denoted by $\bar{\gamma}_{s,d} = \mathbb{E}[\gamma_{s,d}]$ and $\bar{\gamma}_{s,r} = \mathbb{E}[\gamma_{s,r}]$, and $\bar{\gamma}_{r,d} = \mathbb{E}[\gamma_{r,d}]$, respectively, where $\mathbb{E}[\cdot]$ denotes the expectation.

B. Channel model

Since the exact closed-form probability density function (PDF) for TWDP fading is intractable to derive, the approximate PDF of $|h_{u,v}|$ with $u \in \{s, r\}$, $v \in \{r, d\}$ and $u \neq v$ is given by [9]

$$p_{|h_{u,v}|}(x) = \frac{x}{\sigma^2} e^{-K_{u,v} - \frac{x^2}{2\sigma^2}} \sum_{i=1}^{L} a_i D\left(\frac{x}{\sigma}; K_{u,v}, \alpha_{i_{u,v}}\right), \tag{5}$$

where $2\sigma^2$ is the average power of the diffuse waves, $K_{u,v}$ denotes the ratio of the total specular power to diffuse waves, $\alpha_{i_{u,v}} = \Delta_{u,v} \cos\left[(i-1)\pi/(2L-1)\right]$, $\Delta_{u,v}$ denotes the relative strength of the two specular components, $L \geq K_{u,v}\Delta_{u,v}/2$ is the order of the PDF, and $D(x; y, z) = \frac{1}{2} e^{yz} I_0\left(x\sqrt{2y(1-z)}\right) + \frac{1}{2} e^{-yz} I_0\left(x\sqrt{2y(1+z)}\right)$ with $I_0(\cdot)$ denoting the zeroth-order modified Bessel function of the first kind. The first five values of $\{a_i\}_{i=1}^{L}$ are given in Table II of [9]. When $K_{u,v} = 0$, the TWDP PDF represents the Rayleigh fading case, and when $K_{u,v} \neq 0$ and $\Delta_{u,v} = 0$, the TWDP PDF denotes the Rician fading case.

III. Asymptotic Performance

A. Approximate Outage Probability expression

For AF relaying networks, the instantaneous mutual information is given by [1]

$$\mathcal{I} = \frac{1}{2} \log_2 (1 + \gamma_d). \tag{6}$$

The outage probability is defined as $P_{\text{out}} = \Pr(\mathcal{I} < R)$ with R denoting the predetermined transmission rate. From (6), P_{out} can be expressed as $P_{\text{out}} = \Pr(\gamma_d < \gamma_{\text{th}})$ with $\gamma_{\text{th}} = 2^{2R} - 1$, thus the outage probability can be obtained by deriving the cumulative density function (CDF) of γ_d. However, analytical evaluation of the outage probability using γ_d is complicated. To make it tractable, γ_d is tightly approximated by [5]

$$\gamma_d \approx \gamma_b = \gamma_{s,d} + \gamma_{\min}, \tag{7}$$

where $\gamma_{\min} = \min(\gamma_{s,r}, \gamma_{r,d})$. This upper bound has been shown accurate enough in the high SNR regime [5], and is used here to evaluate the outage probability and the SER.

Armed with (5), the PDF of $\gamma_{u,v}$ can be derived as

$$p_{\gamma_{u,v}}(\gamma) = \frac{1}{2\sigma^2 \tilde{\gamma}_{u,v}} \sum_{l=1}^{2L} \frac{\tilde{a}_l}{2} e^{-\frac{\gamma + \kappa_{l_{u,v}} \tilde{\gamma}_{u,v}}{2\sigma^2 \tilde{\gamma}_{u,v}}} I_0\left(\sqrt{\frac{\kappa_{l_{u,v}} \gamma}{\sigma^2 \tilde{\gamma}_{u,v}}}\right), \tag{8}$$

where $\tilde{\gamma}_{u,v} = \bar{\gamma}_{u,v}/(1 + K_{u,v})$, $\kappa_{2i-1_{u,v}} = K_{u,v}\left(1 - \alpha_{i_{u,v}}\right) 2\sigma^2$, $\kappa_{2i_{u,v}} = K_{u,v}\left(1 + \alpha_{i_{u,v}}\right) 2\sigma^2$, and $\tilde{a}_{2i-1} = \tilde{a}_{2i} = a_i$, for $i = 1, 2, \cdots, L$. With the aid of (8), it is straightforward to obtain the CDF of $\gamma_{u,v}$ as

$$F_{\gamma_{u,v}}(\gamma) = 1 - \frac{1}{2} \sum_{l=1}^{2L} \tilde{a}_l \mathcal{Q}_1\left(\sqrt{\frac{\kappa_{l_{u,v}}}{\sigma^2}}, \sqrt{\frac{\gamma}{\sigma^2 \tilde{\gamma}_{u,v}}}\right), \tag{9}$$

where $\mathcal{Q}_p(a, b)$ is the pth order Marcum Q-function given by [15, eq. (86)]

$$\mathcal{Q}_p(x, y) = \frac{1}{x^{p-1}} \int_y^\infty t^p e^{-\frac{t^2 + x^2}{2}} I_{p-1}(xt) dt. \tag{10}$$

Hereafter, to alleviate the notation, we define $K \triangleq K_{s,d}$, $\hat{K} \triangleq K_{s,r}$, $\check{K} \triangleq K_{r,d}$, $\Delta \triangleq \Delta_{s,d}$, $\hat{\Delta} \triangleq \Delta_{s,r}$, $\check{\Delta} \triangleq \Delta_{r,d}$, $\kappa_l \triangleq \kappa_{l_{s,d}}$, $\hat{\kappa}_l \triangleq \kappa_{l_{s,r}}$, and $\check{\kappa}_l \triangleq \kappa_{l_{r,d}}$.

Applying the result in order statistics [16], the CDF of $\gamma_{\min}$ can be derived as

$$F_{\gamma_{\min}}(\gamma) = 1 - \left[\frac{1}{2} \sum_{l=1}^{2L} \tilde{a}_l \mathcal{Q}_1\left(\sqrt{\frac{\hat{\kappa}_l}{\sigma^2}}, \sqrt{\frac{\gamma}{\sigma^2 \tilde{\gamma}_{s,r}}}\right)\right] \times \left[\frac{1}{2} \sum_{l=1}^{2L} \tilde{a}_l \mathcal{Q}_1\left(\sqrt{\frac{\check{\kappa}_l}{\sigma^2}}, \sqrt{\frac{\gamma}{\sigma^2 \tilde{\gamma}_{r,d}}}\right)\right]. \tag{11}$$

Thus the PDF can be obtained by taking the derivative of (11) with respect to γ as

$$p_{\gamma_{\min}}(\gamma) = \left[\frac{1}{2}\sum_{l=1}^{2L}\tilde{a}_l \mathcal{Q}_1\left(\sqrt{\frac{\hat{\kappa}_l}{\sigma^2}}, \sqrt{\frac{\gamma}{\sigma^2\tilde{\gamma}_{s,r}}}\right)\right] p_{\gamma_{r,d}}(\gamma) + \left[\frac{1}{2}\sum_{l=1}^{2L}\tilde{a}_l \mathcal{Q}_1\left(\sqrt{\frac{\check{\kappa}_l}{\sigma^2}}, \sqrt{\frac{\gamma}{\sigma^2\tilde{\gamma}_{r,d}}}\right)\right] p_{\gamma_{s,r}}(\gamma). \tag{12}$$

By assuming that $\gamma_{s,d}$ and $\gamma_{\min}$ are independently distributed, the CDF for γ_b can be derived as

$$F_{\gamma_b}(\gamma) = \int_0^{\gamma}\int_0^{\gamma-\gamma_2} p_{\gamma_{\min}}(\gamma_1) p_{\gamma_{s,d}}(\gamma_2) d\gamma_1 d\gamma_2. \tag{13}$$

Deploying $F_{\gamma_b}(\gamma)$ in Maclaurin series yields

$$F_{\gamma_b}(\gamma) = F_{\gamma_b}(0) + \frac{\partial F_{\gamma_b}}{\partial\gamma}(0)\gamma + \cdots + \frac{\partial^n F_{\gamma_b}}{\partial\gamma^n}(0)\frac{\gamma^n}{n!} + \cdots. \tag{14}$$

Taking the derivative of $F_{\gamma_b}(\gamma)$ with respect to γ, the PDF of γ_b is given by

$$p_{\gamma_b}(\gamma) = \frac{\partial F_{\gamma_b}}{\partial\gamma}(0) + \cdots + \frac{\partial^n F_{\gamma_b}}{\partial\gamma^n}(0)\frac{\gamma^{n-1}}{(n-1)!} + \cdots. \tag{15}$$

Using $I_0(0) = 1$ and $\mathcal{Q}_1(x,0) = 1$, we have $F_{\gamma_b}(0) = 0$, $\frac{\partial F_{\gamma_b}}{\partial\gamma}(0) = 0$, and $\frac{\partial^2 F_{\gamma_b}}{\partial\gamma^2}(0) = p_{\gamma_{\min}}(0)p_{\gamma_{s,d}}(0)$. Thus, (15) can be rewritten as

$$p_{\gamma_b}(\gamma) = p_{\gamma_{\min}}(0)p_{\gamma_{s,d}}(0)\gamma^2 + o(\gamma), \tag{16}$$

where $o(x)$ is the function satisfying $\lim_{x\to 0} a(x)/x = 0$ with $a(x)$ denoting an arbitrary function.

From above, we note that AF relaying networks satisfy AS1–AS3 given in [17], and thus the propositions presented in [17] can be used to derive our closed-form asymptotic expressions. Armed with [17, Prop. 5], the outage probability can be approximated as

$$P_{\text{out}} \approx \frac{{\gamma_{\text{th}}}^2}{2} p_{\gamma_{\min}}(0)p_{\gamma_{s,d}}(0) = (O_c\gamma_t)^{-O_d}, \tag{17}$$

where the outage diversity order is

$$O_d = 2, \tag{18}$$

and the outage coding gain is

$$O_c = \left\{\frac{1}{2}\left(\frac{\gamma_{\text{th}}}{2\sigma^2}\right)^2 \Xi(\lambda_1,\lambda_2,\lambda_3)\right\}^{-\frac{1}{2}}, \tag{19}$$

where

$$\Xi(\lambda_1,\lambda_2,\lambda_3) = \left[\sum_{l=1}^{2L}\frac{\tilde{a}_l}{2}\left(\lambda_2 e^{-\frac{\hat{\kappa}_l}{2\sigma^2}} + \lambda_3 e^{-\frac{\check{\kappa}_l}{2\sigma^2}}\right)\right] \times \left(\sum_{l=1}^{2L}\frac{\tilde{a}_l}{2}\lambda_1 e^{-\frac{\kappa_l}{2\sigma^2}}\right) \tag{20}$$

with $\lambda_1 = (1+K)\gamma_t/\bar{\gamma}_{s,d}$, $\lambda_2 = (1+\hat{K})\gamma_t/\bar{\gamma}_{s,r}$, and $\lambda_3 = (1+\check{K})\gamma_t/\bar{\gamma}_{r,d}$.

TABLE I
PARAMETER CONFIGURATIONS FOR SEVERAL COHERENT MODULATION SCHEMES.

Modulation	P_E
BPSK	$\Psi(\mu,\nu,g;\gamma)$ with $\mu = \frac{1}{\pi}$, $\nu = \frac{1}{2}$, and $g = 2$
BFSK	$\Psi(\mu,\nu,g;\gamma)$ with $\mu = \frac{1}{\pi}$, $\nu = \frac{1}{2}$, and $g = \begin{cases} 1 & \text{orthogonal BFSK} \\ 1.43 & \text{minimum correlation}\end{cases}$
MPSK	$\Psi(\mu,\nu,g;\gamma)$ with $\mu = \frac{1}{\pi}$, $\nu = \frac{M-1}{M}$, and $g = 2\sin^2\left(\frac{\pi}{M}\right)$
MQAM	$\Psi(\mu_1,\nu_1,g_1;\gamma) + \Psi(\mu_2,\nu_2,g_2;\gamma)$ with $\mu_1 = \frac{4}{\pi}\left(1-\frac{1}{\sqrt{M}}\right)$, $\nu_1 = \frac{1}{2}$, and $g_1 = \frac{3}{(M-1)}$ $\mu_2 = -\frac{4}{\pi}\left(1-\frac{1}{\sqrt{M}}\right)^2$, $\nu_2 = \frac{1}{4}$, and $g_2 = \frac{3}{(M-1)}$

B. Asymptotic SER

It has been shown that when the transmit SNR is given by γ, the conditional SER can be obtained from the evaluation of

$$\Psi(\mu,\nu,g;\gamma) = \mu\int_0^{\nu\pi} e^{-\frac{g\gamma}{2\sin^2\theta}} d\theta, \tag{21}$$

where the values of μ, ν and g are determined by the type of modulation scheme. Specifically, we list the values of these parameters and the conditional error probability P_E in Table I for binary phase-shift keying (BPSK), binary frequency-shift keying (BFSK), multiple phase-shift keying (MPSK) and M-ary quadrature amplitude modulation (MQAM).

The average SER can be calculated by averaging P_E over p_{γ_b} as

$$P_{\text{SER}} = \int_0^{\infty} P_E(\gamma)p_{\gamma_b}(\gamma)d\gamma. \tag{22}$$

The integral can be solved using familiar mathematical software packages such as MATLAB, however, we derive the asymptotic SER which approximates the SER in the high SNR regime. Using the first order expansion of p_{γ_b} in (16), the average SER can be approximated as

$$P_{\text{SER}} \approx \int_0^{\infty} P_E(\gamma)p_{\gamma_{\min}}(0)p_{\gamma_{s,d}}(0)\gamma d\gamma. \tag{23}$$

From Table I, we note that for different modulation schemes (23) can be obtained by the evaluation of

$$\Phi(\mu,\nu,g) = \int_0^{\infty}\Psi(\mu,\nu,g;\gamma)p_{\gamma_{\min}}(0)p_{\gamma_{s,d}}(0)\gamma d\gamma. \tag{24}$$

Substituting (21) into (24), we have

$$\begin{aligned}\Phi(\mu,\nu,g) =& \mu\int_0^{\infty}\int_0^{\nu\pi} e^{-\frac{g\gamma}{2\sin^2\theta}} p_{\gamma_{\min}}(0)p_{\gamma_{s,d}}(0)\gamma d\theta d\gamma \\ =& \frac{\mu}{g^2}\left(\frac{3\nu\pi}{2} - \sin(2\nu\pi) + \frac{\sin(4\nu\pi)}{8}\right)\left(\frac{1}{2\sigma^2\gamma_t}\right)^2 \\ &\times \Xi(\lambda_1,\lambda_2,\lambda_3).\end{aligned} \tag{25}$$

Now using (25), the average SER can be approximated as

$$P_{\text{SER}} \approx (G_c\gamma_t)^{-G_d} \tag{26}$$

where the diversity order is

$$G_d = 2, \tag{27}$$

for BPSK, BFSK, and MPSK the coding gain is

$$G_c = \left\{ \frac{\mu}{g^2} \left(\frac{3\nu\pi}{2} - \sin(2\nu\pi) + \frac{\sin(4\nu\pi)}{8} \right) \times \left(\frac{1}{2\sigma^2} \right)^2 \Xi(\lambda_1, \lambda_2, \lambda_3) \right\}^{-\frac{1}{2}}, \tag{28}$$

and for MQAM the coding gain is

$$G_c = \left\{ \left[\frac{\mu_1}{g_1^2} \left(\frac{3\nu_1\pi}{2} - \sin(2\nu_1\pi) + \frac{\sin(4\nu_1\pi)}{8} \right) + \frac{\mu_2}{g_2^2} \left(\frac{3\nu_2\pi}{2} - \sin(2\nu_2\pi) + \frac{\sin(4\nu_2\pi)}{8} \right) \right] \times \left(\frac{1}{2\sigma^2} \right)^2 \Xi(\lambda_1, \lambda_2, \lambda_3) \right\}^{-\frac{1}{2}}. \tag{29}$$

IV. Simulation Results and Discussions

In this section, we provide asymptotic, analytical and simulation results to validate the theoretical analysis developed in previous section. The source-to-relay and relay-to-destination links are assumed to be equal, i.e., $\mathbb{E}[h_{s,r}] = \mathbb{E}[h_{r,d}] = 1$, and the direct source-to-destination has doubled distance of the others, which by assuming path-loss exponent 3, and $\mathbb{E}[h_{s,d}] = 1/8$. In all examples, the analytical outage probability is obtained by $P_{\text{out}} = F_{\gamma_b}(\gamma_{\text{th}})$, the asymptotic outage probability is obtained using (17), the analytical SER is obtained using (22), and the asymptotic SER is obtained using (26). The transmitted energy at the source is identical to the one at the relay, i.e. $\gamma_s = \gamma_r$. The analytical SER is obtained using (22), and the asymptotic SER is obtained using (26).

Example 1: In this example we investigate the outage probability and SER in independent and identically distributed (i.i.d) TWDP fading channels, i.e. $K = \hat{K} = \check{K}$, and $\Delta = \hat{\Delta} = \check{\Delta}$. We set $R = 1$ bps/Hz, and the symbols are modulated by binary phase shift keying (BPSK). To evaluate the performance of cooperative networks in typical fading channels, four different fading cases are considered here. Among these cases, *Case 1* ($K = 10$, $\Delta = 1$) describes practical frequency-selective fading for in-vehicle wireless sensor applications [10], *Case 2* ($K = 0$, $\Delta = 1$) describes Rayleigh fading, *Case 3* ($K = 4$, $\Delta = 0.5$) describes TWDP fading scenario where the total power of the specular waves is four times that of the diffuse component, and the power of one of the specular waves is approximately fourteen times that of the other one [12], and *Case 4* ($K = 4$, $\Delta = 0$) describes the Rician fading. Fig. 2 and 3 respectively depict the outage probability and SER versus γ_s of the AF relaying networks in the foru. Note that the analytical results match precisely with the Monte Carlo simulations in the medium and high SNR regimes. Such observation results from the fact that we used γ_b to approximate γ_d. Moreover, we note that *Case 1* performs poorer than *Case 2*. This observation results

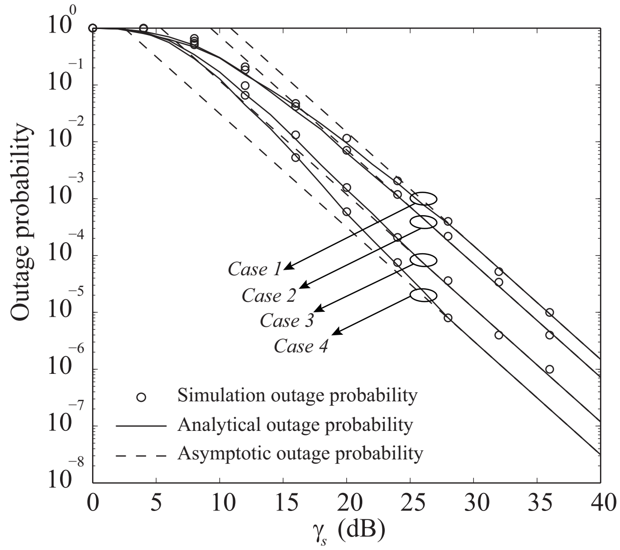

Fig. 2. Outage probability of AF relaying in different i.i.d fading scenarios including *Case 1*: $K = 10$ and $\Delta = 1$ (hyper-Rayleigh fading), *Case 2*: $K = 0$ and $\Delta = 1$ (Rayleigh fading), *Case 3*: $K = 4$ and $\Delta = 0.5$, and *Case 4*: $K = 4$ and $\Delta = 0$ (Rician fading). $R = 1$ bps/Hz

from the cancelation of the two specular waves when they are antiphase and the low power of the diffuse components when K-parameter is large enough. In addition, we observe that *Case 3* outperforms *Case 4*, which results from the fact that for fixed K, the performance becomes worse when the amplitudes of the two specular waves are closer to each other (i.e., Δ increases). It is shown that the asymptotic results are tight at high SNR in different fading conditions.

Example 2: In this example, we proceed to investigate the performance of AF relaying networks in i.n.i.d fading scenarios. We assume that the source-to-destination link experiences the four fading cases in the previous example. Fig. 4 depicts the simulation, analytical, and asymptotic results of SER versus γ_s. We observe that in different fading cases the diversity order remains constant, and the different performance is caused by the varieties of coding gain.

V. Conclusions

The exact closed-form outage probability and SER of AF relaying networks in TWDP fading channels is intractable to derive. In this paper we proposed the asymptotic solutions to approximate these two measures. The total SNR at the destination can be approximated by its upper bound. Based on the approximation, we derived the CDF for the upper bound. This statistical result was used to derive the asymptotic expressions for the outage probability and SER in the high SNR regime. According to the asymptotic expression, we obtained the diversity order and coding gain of the AF relaying networks in TWDP fading channels These asymptotic results can be applied to analyze the performance and investigate the power allocation scheme of AF relaying networks in TWDP fading channels including Rayleigh and Rician fading as special cases.

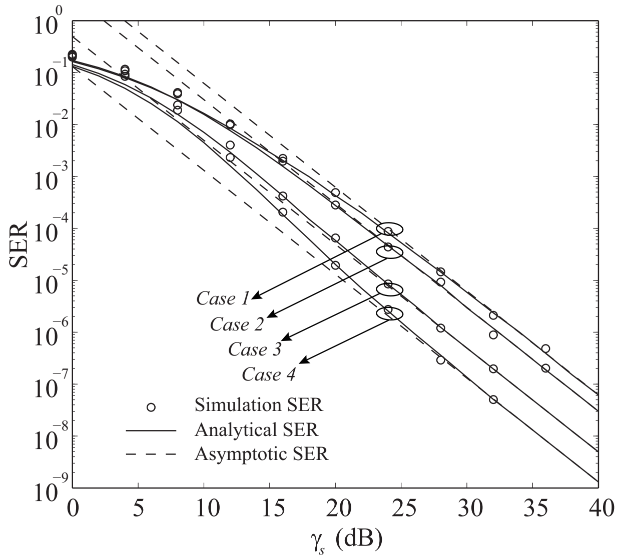

Fig. 3. SER of AF relaying in different i.i.d fading scenarios including *Case 1*, *Case 2*, *Case 3*, and *Case 4*, signals are modulated by BPSK.

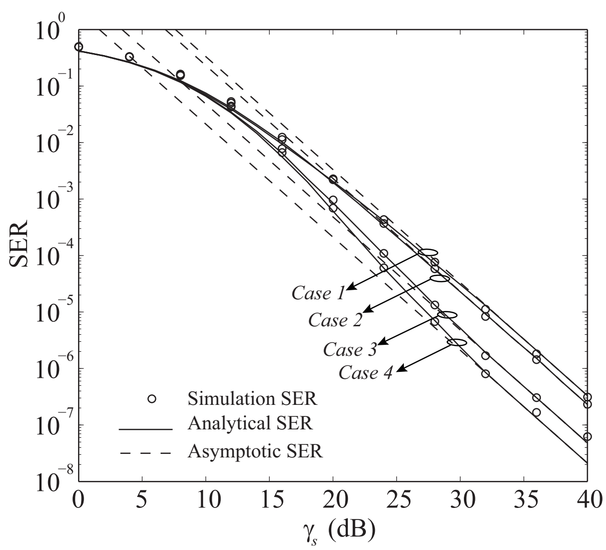

Fig. 4. SER of AF relaying in different i.n.i.d fading scenarios. The values of $\hat{K}$ and $\check{K}$ are uniformly distributed over $[0, 10]$, and $\hat{\Delta}$ and $\check{\Delta}$ are uniformly distributed over $[0, 1]$. The signals are modulated by 4QAM at the source.

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