Outage Probability Evaluation of Land Mobile Satellite Cooperative Diversity Communication System

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***Abstract*—In this paper, a dual-hop cooperative diversity land mobile satellite system (LMSS) respectively adopted amplify-and-forward (AF), decode-and-forward (DF), and coded cooperation (CC) relaying protocols is proposed, and the outage probability behaviors of the three protocols have been analyzed. We use the signal to noise ratio (SNR) of each path to derive the closed-form expressions of outage probability for each protocol. The accurately approximated expressions in favor of computation simplicity have also been derived applying trapezoidal integration. The Monte Carlo simulations show good match with the proposed analytical results under different shadowing environments, showing that CC is the best strategy for low terminal transmitting SNR. For high transmitting SNR, AF protocol outperforms the high cooperation level CC and DF, while the low cooperation level CC turns out to be better than the other two protocols.**

Keywords-land mobile satellite system; cooperative diversity communication; amplify-and-forward; decode-and-forward; coded cooperation

I. INTRODUCTION

The success of Multiple Input Multiple Output (MIMO) technology in terrestrial systems enormously stimulates the intensive research on its application in satellite communications [1]. In the new generation of satellite systems with strictly restricted available spectrum and power, high transmission speed and spectral efficiency are demanded, therefore, giving rise to more urge to utilize the spatial resources provided by MIMO technology. However, due to the limit of size, power and hardware complexity, it is difficult to employ multiple antennas both on ground terminals and satellite, especially at the mobile terminal. The installation of only one antenna at each user terminal tremendously hampers the development of MIMO technology. Recently, cooperative diversity technique, which is based on user cooperation and relaying cooperation, has emerged as a promising technique and received considerable interests[2][3].The spirit of this technique lies in that single-antenna terminals in a multi-user scenario are allowed to share their antennas and other resources through distributed transmission and processing, so that a virtual multi-antenna transmitter is formed, hence achieving the spatial diversity benefits of the virtual MIMO system.

When one mobile terminal travels in a large area, severe channel conditions, like trees or buildings obstructing signals transmitting directly from terminal to satellite might happen, resulting in complete blockage of line-of-sight (LOS) path. In such situation, cooperative relaying to satellite from other terminals under better propagation environments may offer an effective way to combat channel fading, enable better reliability of communications, as well as reduce the burden of transmitting power for the terminal. This kind of cooperative relaying communication does not rely on the assistance of other terrestrial facilities, making it particularly suitable for the gap-filler-less scenario.

A LMSS is a communication system that provides communications to terrestrial mobile users using satellite. There have been papers focusing on the outage performance under LMSS environments with AF relaying protocol (e.g., [4][5]). But, to the best of our knowledge up to now, there has been few works on the outage probability analysis on DF and CC protocol of LMSS in the literature. However, these two protocols can be incorporated with different channel coding schemes, having the potential to decrease bit error rate, as well as enhance the system feasibility under different channel conditions. So, it is also of great importance to investigate the outage performance of DF and CC in LMSS.

In this paper, we are interested in proposing an uplink mobile terminal assisted cooperation diversity LMSS using AF strategy, DF strategy, and CC strategy, respectively. We derive the closed-form expressions of accurately approximated outage probabilities for the three protocols. The outage performances of these protocols are compared when signal from direct terminal to satellite path is undergoing different degree of shadowing. The analytical results are verified by Monte Carlo simulations.

The remainder of this paper is organized as follows. Section II presents the system models and the channel fading models. In section III we derive the closed-form expressions of approximated outage probabilities for the three relaying protocols. The simulation results are presented in section IV. Finally, conclusion remarks are made in section V.

II. SYSTEM MODELS

A. *System Models*

We provide the simple frequency nonselective fading system for AF protocol and DF protocol consisting of a source terminal, a cooperative relaying terminal, and the land mobile satellite (LMS) represented by a GEO satellite, as shown in Fig. 1. The source can transmit signal to the relay and the satellite at the same time with different frequency bands using

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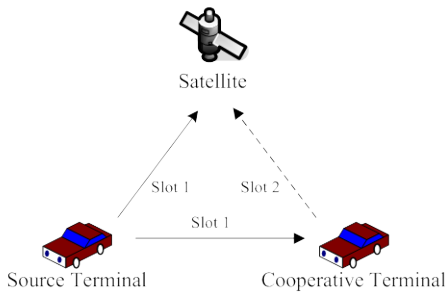

Figure 1. A three node LMS cooperative diversity system for AF and DF.

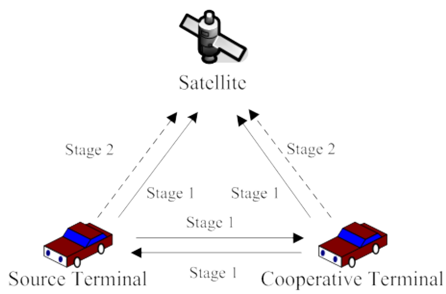

Figure 2. A three node LMS cooperative diversity system for CC.

two sets of antennas. But the relay node cannot transmit and receive signal using the same frequency at the same time, so the half duplex mode is adopted. The time scheduling consists of two time slots. In the first time slot, the source transmits its signal both to satellite and the cooperative terminal with transmitting power p_1. During the second time slot, the scaled version of the signal for AF or regenerated version of the signal for DF at the cooperative terminal is transmitted to the satellite with transmitting power p_2. At the satellite, signals from source and relay nodes are combined through maximum ratio combining (MRC) algorithm.

Based on Fig. 1, the cooperative diversity system for the CC protocol is provided in Fig. 2, where the cooperation process is divided into two stages, during which the source terminal and its cooperative terminal each transmits a total length of N bits containing K information bits. In the first stage, both terminals transmit the information bits to each other and to the satellite in N_1 bits code word with rate $R_1 = K / N_1$. Again, two pairs of antennas are used for terrestrial communication and satellite communication, respectively. If the source node or the relay node cannot correctly decode its partner's code word in the first stage, then it transmits $N_2 = (N - N_1)$ bits code word of its own parity bits to the satellite in the second stage, or its partner's parity bits are transmitted. An important parameter of the protocol is the cooperation level, defined by N_2 / N.

B. Channel Models

Channel fading coefficient from the source to the satellite h_{sd} is assumed to be shadowed Rician fading, and N_0 is the corresponding noise power. The probability density function (PDF) of the instantaneous SNR $\gamma_{sd} = |h_{sd}|^2 p_1 / N_0$ per symbol is expressed as [6]

$$p_{\gamma_{sd}}(\gamma) = \exp(-\gamma / 2b_0\bar{\gamma}_{sd})[2b_0 m / (2b_0 m + \Omega)]^m \times {}_1F_1(m, 1, \Omega\gamma / [2b_0\bar{\gamma}_{sd} \times (2b_0 m + \Omega)]) / 2b_0\bar{\gamma}_{sd} \tag{1}$$

where b_0 is the average power of the multipath component, $\bar{\gamma}_{sd} = \sigma_{sd}^2 p_1 / N_0$ is the average SNR between the source and satellite with variance σ_{sd}^2, m is Nakagami parameter, Ω is the average power of the LOS component, and ${}_1F_1(\cdot)$ is the confluent hypergeometric function.

The cumulative distribution function (CDF) of γ_{sd} is

$$\begin{aligned} P_{\gamma_{sd}}(\gamma) &= (2b_0 m)^m / 2b_0\bar{\gamma}_{sd}(2b_0 m + \Omega)^m \\ &\times \sum_{l=0}^{\infty} (2b_0\bar{\gamma}_{sd})^{(l+1)} \Gamma(l+1, \gamma / 2b_0\bar{\gamma}_{sd}) \\ &\times (m)_l \Omega^l / (1)_l l! [2b_0\bar{\gamma}_{sd} \times (2b_0 m + \Omega)]^l \end{aligned} \tag{2}$$

where $\Gamma(\cdot,\cdot)$ is the incomplete gamma function according to (8.350.1) [7], $(\cdot)_l$ is the Pochhammer symbol.

Channel fading coefficients of the source to cooperative relay h_{sr} and the relay to source h_{rs} are assumed to be Rayleigh fading, with the corresponding noise power N_0. The PDFs of the instantaneous SNR $\gamma_{sr} = |h_{sr}|^2 p_1 / N_0$ and $\gamma_{rs} = |h_{rs}|^2 p_2 / N_0$ per symbol are expressed as

$$p_{sr}(\gamma) = \exp(-\gamma / \bar{\gamma}_{sr}) / \bar{\gamma}_{sr} \tag{3}$$

$$p_{rs}(\gamma) = \exp(-\gamma / \bar{\gamma}_{rs}) / \bar{\gamma}_{rs} \tag{4}$$

The CDF of γ_{sr} and γ_{rs} is given as

$$P_{\gamma_{sr}}(\gamma) = 1 - \exp(-\gamma / \bar{\gamma}_{sr}) \tag{5}$$

$$P_{\gamma_{rs}}(\gamma) = 1 - \exp(-\gamma / \bar{\gamma}_{rs}) \tag{6}$$

where $\bar{\gamma}_{sr} = \sigma_{sr}^2 p_1 / N_0$ is the average SNR from the source to the cooperative relay with variance σ_{sr}^2, and $\bar{\gamma}_{rs} = \sigma_{rs}^2 p_2 / N_0$ is the average SNR from the relay to the source with variance σ_{rs}^2.

We assume that there is always a relay terminal having a clear sight of the satellite, so the channel fading coefficient h_{rd} can be modeled as Rician fading, with the corresponding noise power N_0. And how to find the proper cooperative terminal is left for future work. The PDF of the instantaneous SNR $\gamma_{rd} = |h_{rd}|^2 p_2 / N_0$ per symbol is expressed as

$$p_{\gamma_{rd}}(\gamma) = [(1 + K_{rd}) / \bar{\gamma}_{rd}] \exp[-K_{rd} - (1 + K_{rd})\gamma / \bar{\gamma}_{rd}] \times I_0(2\sqrt{K_{rd}(1 + K_{rd})\gamma / \bar{\gamma}_{rd}}) \tag{7}$$

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where $\overline{\gamma}_{rd} = \sigma_{rd}^2 p_2 / N_0$ is the average SNR between the relay and the satellite with variance σ_{rd}^2, K_{rd} is the channel Rician K-factor, and $I_0(\cdot)$ is the zero-order modified Bessel function of the first kind.

The CDF of γ_{rd} is given by

$$P_{\gamma_{rd}}(\gamma) = 1 - Q(\sqrt{2K_{rd}}, \sqrt{2(1+K_{rd})\gamma / \overline{\gamma}_{rd}}) \quad (8)$$

where $Q(\cdot,\cdot)$ is the first-order Marcum Q function [8].

III. OUTAGE PROBABILITY ANALYSIS

When spectral efficiency is set to R, the whole communication system is in outage state when the maximum average mutual information $I_D < R$. From the perspective of information theory, I_D depends on the instantaneous SNR γ_d of the combined signal at the satellite. The outage probability of the source node is

$$P_{out} = \Pr\{\gamma_d < \gamma_{th}\} \quad (5)$$

where γ_{th} is the threshold decided by R.

For AF relaying protocol, the instantaneous SNR of the combined signal at the satellite is given as [2]

$$\gamma_d = \gamma_{d\_AF} = \gamma_{sd} + \gamma_{sr}\gamma_{rd} / (\gamma_{sr} + \gamma_{rd} + 1) \quad (6)$$

The outage probability of γ_{d_AF} is derived as

$$\begin{aligned} P_{out\_AF} &= \Pr\{\gamma_{d\_AF} < \gamma_{th}\} = \Pr\{\gamma_{d\_AF} < \gamma_{th\_AF}\} \\ &= \int_0^{\gamma_{th\_AF}} p_{\gamma_{AF}}(\gamma_1) \int_0^{\gamma_{th\_AF}-\gamma_1} p_{\gamma_{sd}}(\gamma_2) d\gamma_2 d\gamma_1 \quad (7) \\ &= \int_0^{\gamma_{th\_AF}} p_{\gamma_{AF}}(\gamma_1) P_{\gamma_{sd}}(\gamma_{th\_AF} - \gamma_1) d\gamma_1 \end{aligned}$$

where $p_{\gamma_{AF}}(\cdot)$ denotes the PDF of the SNR $\gamma_{AF} = \gamma_{sr}\gamma_{rd} / (\gamma_{sr} + \gamma_{rd} + 1)$. Using the method in [9]

$$\begin{aligned} p_{\gamma_{AF}}(\gamma) &= (1+K_{rd}) / (\overline{\gamma}_{sr}\overline{\gamma}_{rd}) \exp[-K_{rd} - (1+K_{rd})\gamma / \overline{\gamma}_{rd} - \gamma / \overline{\gamma}_{sr}] \\ &\times \{ \sum_{t=0}^{\infty} [K_{rd}(K_{rd}+1) / \overline{\gamma}_{rd}]^t \\ &\times \sum_{k=0}^{t+1} 2\gamma^t \binom{t+1}{k} (\gamma+1)^k [(\beta/\eta)^{(1-k)/2} K_{(1-k)}(2\sqrt{\eta\beta}) \\ &+ \gamma(\beta/\eta)^{-k/2} K_{-k}(2\sqrt{\eta\beta})] / (t!)^2 \} \end{aligned} \quad (8)$$

where $\beta = \gamma(\gamma+1)(K_{rd}+1) / \overline{\gamma}_{rd}$, $\eta = 1/\overline{\gamma}_{sr}$, and $K_\nu(\cdot)$ denotes the νth order modified Bessel function of the second kind.

For DF relaying protocol, the instantaneous SNR of the combined signal at the satellite is given as [2]

$$\gamma_d = \gamma_{d\_DF} = \min\{\gamma_{sr}, \gamma_{sd} + \gamma_{rd}\} \quad (9)$$

where $\min(\cdot)$ returns the minimum value.

So the outage probability of γ_{d_DF} is derived as

$$\begin{aligned} P_{out\_DF} &= \Pr\{\gamma_{d\_DF} < \gamma_{th}\} = \Pr\{\gamma_{d\_DF} < \gamma_{th\_DF}\} \\ &= P_{\gamma_{sr}}(\gamma_{th\_DF}) + [1 - P_{\gamma_{sr}}(\gamma_{th\_DF})] \quad (10) \\ &\times \int_0^{\gamma_{th\_DF}} p_{\gamma_{sd}}(\gamma_1) \int_0^{\gamma_{th\_DF}-\gamma_1} p_{\gamma_{rd}}(\gamma_2) d\gamma_2 d\gamma_1 \\ &= P_{\gamma_{sr}}(\gamma_{th\_DF}) + [1 - P_{\gamma_{sr}}(\gamma_{th\_DF})] \\ &\times \int_0^{\gamma_{th\_DF}} p_{\gamma_{sd}}(\gamma_1) P_{\gamma_{rs}}(\gamma_{th\_DF} - \gamma_1) d\gamma_1 \end{aligned}$$

For CC relaying protocol, the instantaneous SNR of the combined signal at the satellite is much more complicated. Here we simply give the source node outage probability expression based on [10] as below

$$\begin{aligned} P_{out\_CC} &= [1 - P_{\gamma_{rs}}(2^{R/\alpha} - 1)][1 - P_{\gamma_{sr}}(2^{R/\alpha} - 1)] \\ &\times \int_0^{2^{R/\alpha}-1} p_{\gamma_{sd}}(\gamma_1) P_{\gamma_{rd}}(u_1) d\gamma_1 \\ &+ P_{\gamma_{rs}}(2^{R/\alpha} - 1) P_{\gamma_{sr}}(2^{R/\alpha} - 1) P_{\gamma_{sd}}(2^R - 1) \\ &+ [1 - P_{\gamma_{rs}}(2^{R/\alpha} - 1)] P_{\gamma_{sr}}(2^{R/\alpha} - 1) \quad (11) \\ &\times \int_0^{2^R-1} p_{\gamma_{sd}}(\gamma_1) P_{\gamma_{rd}}(u_2) d\gamma_1 \\ &+ P_{\gamma_{rs}}(2^{R/\alpha} - 1)[1 - P_{\gamma_{sr}}(2^{R/\alpha} - 1)] P_{\gamma_{sd}}(2^{R/\alpha} - 1) \end{aligned}$$

where $(1-\alpha)$ is the cooperation level of the cooperative diversity system, and also $u_1 = 2^{R/(1-\alpha)} / (1+\gamma_1)^{\alpha/(1-\alpha)} - 1$, while $u_2 = 2^{R/(1-\alpha)} / (1+\gamma_1)^{\alpha/(1-\alpha)} - \gamma_1 - 1$. The channel condition of the three paths for different α is the same as in AF and DF.

The integral operations in (7), (10), and (11) are difficult to compute. In this paper, through the trapezoidal integration with reasonably unit spacing, the accurately approximated integrals can be obtained.

Set $W(\gamma_1) = p_{\gamma_{AF}}(\gamma_1) P_{\gamma_{sd}}(\gamma_{th\_AF} - \gamma_1)$, and the closed-form outage probability expression for AF is written as

$$\begin{aligned} P_{out\_AF} &\approx \sum_{n=1}^{q_{AF}-1} W(n\gamma_{th\_AF} / q_{AF}) \gamma_{th\_AF} / q_{AF} \quad (12) \\ &+ [W(0) + W(\gamma_{th\_AF})] \gamma_{th\_AF} / 2q_{AF} \end{aligned}$$

where q_{AF} is the number of the spacings for $W(\gamma_1)$.

Set $X(\gamma_1) = p_{\gamma_{sd}}(\gamma_1) P_{\gamma_{rd}}(\gamma_{th\_DF} - \gamma_1)$, and the closed-form expression of outage probability for DF protocol is written as

$$\begin{aligned} P_{out\_DF} &\approx P_{\gamma_{sr}}(\gamma_{th\_DF}) + [1 - P_{\gamma_{sr}}(\gamma_{th\_DF})] \\ &\times \{ \sum_{n=1}^{q_{DF}-1} X(n\gamma_{th\_DF} / q) \gamma_{th\_DF} / q_{DF} \quad (13) \\ &+ [X(0) + X(\gamma_{th\_DF})] \gamma_{th\_DF} / 2q_{DF} \} \end{aligned}$$

where q_{DF} is the number of the spacings for $X(\gamma_1)$.

Set $Y(\gamma_1) = p_{\gamma_{sd}}(\gamma_1) P_{\gamma_{rd}}(2^{R/(1-\alpha)}/(1+\gamma_1)^{\alpha/(1-\alpha)} - 1)$, and $Z(\gamma_1) = p_{\gamma_{sd}}(\gamma_1) P_{\gamma_{rd}}(2^{R/(1-\alpha)}/(1+\gamma_1)^{\alpha/(1-\alpha)} - \gamma_1 - 1)$, so the closed-form expression of outage probability for CC protocol is written as

$$
\begin{aligned}
P_{out\_CC} \approx\ & [1 - P_{\gamma_{rs}}(2^{R/\alpha} - 1)][1 - P_{\gamma_{sr}}(2^{R/\alpha} - 1)] \\
& \times \{ \sum_{n=1}^{q_{CC1}-1} Y(n(2^{R/\alpha} - 1)/q_{CC1})(2^{R/\alpha} - 1)/q_{CC1} \\
& + [Y(0) + Y([2^{R/\alpha} - 1])][2^{R/\alpha} - 1]/2q_{CC1} \} \\
& + P_{\gamma_{rs}}(2^{R/\alpha} - 1)[1 - P_{\gamma_{sr}}(2^{R/\alpha} - 1)] P_{\gamma_{sd}}(2^{R} - 1) \\
& + [1 - P_{\gamma_{rs}}(2^{R/\alpha} - 1)] P_{\gamma_{sr}}(2^{R/\alpha} - 1) \\
& \times \{ \sum_{n=1}^{q_{CC2}-1} Z(n(2^{R} - 1)/q_{CC2})[2^{R} - 1]/q_{CC2} \\
& + [Z(0) + Z([2^{R} - 1])](2^{R} - 1)/2q_{CC2} \} \\
& + P_{\gamma_{sr}}(2^{R/\alpha} - 1)[1 - P_{\gamma_{rs}}(2^{R/\alpha} - 1)] P_{\gamma_{sd}}(2^{R/\alpha} - 1)
\end{aligned} \tag{14}
$$

where q_{CC1} is the number of the spacings for $Y(\gamma_1)$ and q_{CC2} is the number of the spacings for $Z(\gamma_1)$.

IV. SIMULATION RESULTS AND ANALYSIS

In this section, the Monte Carlo simulation results and the theoretical analysis of the three relaying protocols above are presented with each path experiences nonidentical fading. The relaying protocols are compared with the no cooperative direct transmission as well. Set the transmitting SNR at the source and the cooperative terminal $p_1/N_0 = p_2/N_0$, and $\sigma_{sd}^2 = \sigma_{sr}^2 = \sigma_{rs}^2 = \sigma_{rd}^2 = 1$. In a GEO LMSS, K_{rd} value ranges from 7 to 15 dB [11], so it is assumed that $K_{rd} = 11.14dB$. We set $R = 1b/s/Hz$, and the threshold $\gamma_{th} = \gamma_{th\_AF} = \gamma_{th\_DF} = 2^{2R} - 1$. For CC protocol, set the cooperation level to $0.1, 0.3, 0.5$ and 0.7, respectively. Set $q_{AF} = q_{DF} = q_{CC1} = q_{CC2} = 1000$ with the approximation accuracy of the outage probability. The parameters for different channel condition of the shadowed Rician model given in [6] are shown in Table Ⅰ.

Fig. 3, Fig. 4 and Fig. 5 compare AF, DF, CC and the no cooperation case in terms of the system outage probability

TABLE I. PARAMETERS FOR THE SHADOWED RICIAN UNDER DIFFERENT CHANNEL CONDITIONS

Channel Condition	b_0	m	Ω
Infrequent light shadowing	0.158	19.4	1.29
Average shadowing	0.126	10.1	0.835
Frequent heavy shadowing	0.063	0.739	0.000897

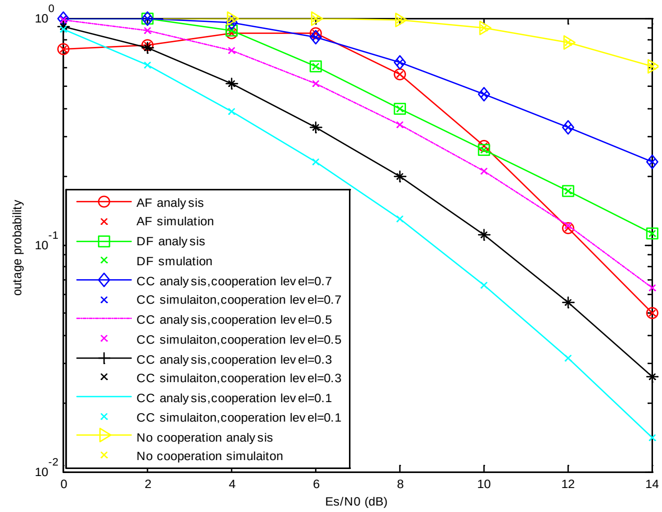

Figure 3. Outage probability for AF, DF and CC when shadowed Rician channel is in frequent heavy shadowing.

under different shadowed Rician channel conditions. The outage probabilities of the system are plotted versus the E_s/N_0 ($E_s/N_0 = p_1/N_0 = p_2/N_0$). It is evident from the figures that, the theoretical results excellently match with the simulation results, verifying the accuracy of the analysis.

Fig. 3 shows the outage probability comparisons between AF, DF, different cooperation level CC, and no cooperation transmission with the source to satellite path undergoing frequent heavy shadowing. In the figure, all three relaying protocols show diversity gain compared to no cooperation scenario. For CC protocol, as α gets lower, the slope of curves tends to get deeper, which means stronger channel coding algorithm for N_1 ensures better outage performance (also shown in Fig. 4 and Fig.5). It can be observed from the figure that when $E_s/N_0 > 6dB$, AF and DF outperform CC when α is high, $\alpha = 0.7$ for example, while the latter protocol is superior to the former two when its cooperation level is as low as 0.1. AF has higher outage probabilities than DF as E_s/N_0 is between $4dB$ and $10dB$. All protocols have high outage probabilities when E_s/N_0 is low, reaching more than 0.70 at $E_s/N_0 = 0dB$. The outage probability between $E_s/N_0 = 0dB$ and $E_s/N_0 = 6dB$ increases with transmitting SNR. This is due to the nonmonotone decreasing property of $p_{\gamma_{AF}}(\gamma)$ with respect to increasing SNR and the channel parameters of the heavy shadowing channel condition.

Fig. 4 shows the outage probability comparisons between the three protocols and no cooperation scenario when the source to satellite path is in average shadowing. Fig. 5 shows the comparisons in the infrequent light shadowing case. Combined with Fig. 3, the three figures illustrate that, the better shadowed Rician channel condition is, the lower the outage probabilities get, with the exception of DF. As a matter of fact, the outage probabilities for the DF protocol are almost the same at the same E_s/N_0 value under three different channel conditions. It can be also seen that, AF and CC outperform the no cooperation scenario except for CC

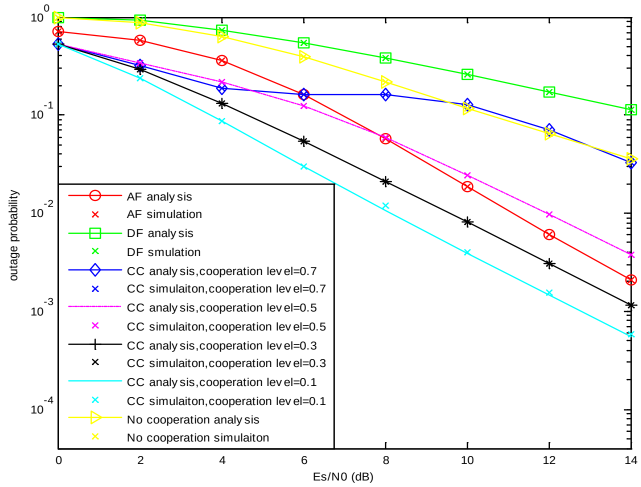

Figure 4. Outage probability for AF, DF and CC when shadowed Rician channel is in average shadowing.

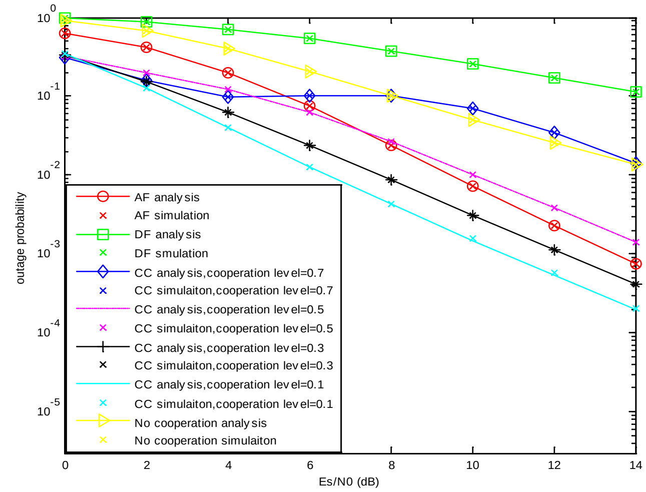

Figure 5. Outage probability for AF, DF and CC when shadowed Rician channel is in infrequent light shadowing.

with $\alpha = 0.7$, and DF protocol has the worst outage probability behavior in Fig. 4 and Fig. 5, even worse than the no cooperation scenario.

When comparisons are made between the AF and CC at $E_s / N_0 > 6dB$, similar illustration as in Fig. 3 is shown. But at low E_s / N_0 values, unlike Fig. 3, CC protocol with different cooperation levels all have the obvious advantage over the other two protocols, with the probabilities as low as 0.5 in Fig. 4 and 0.3 in Fig. 5 at $E_s / N_0 = 0dB$, while the probabilities of the others are still higher than 0.7 in both figures.

For CC protocol in Fig. 4 and Fig. 5, it may be noticed that curves of all α values have almost the same trend as in Fig. 3 except for the curve of $\alpha = 0.7$. This result can be explained as follows. It is found that at higher E_s / N_0, the outage probability in (14) is mainly determined by the second term and the fourth term of the addition operation, the former of which is monotonic decreasing while the latter one is convex, thanks to the monotonic increasing outage probability in Rayleigh channel at high cooperation level $\alpha = 0.7$. Therefore, makes it possible for the overall outage possibility to be nondecreasing, or even increasing within certain range of E_s / N_0.

I. CONCLUSIONS

In this paper, the outage performance of a dual-hop LMS cooperative diversity system is proposed. The closed-form expressions of approximated outage probability for three important and commonly used relaying protocols: amplify-and-forward, decode-and-forward, and coded cooperation, are derived. The simulation results verify the analytical results. The results show that for different shadowing conditions on source to terminal path, at high transmitting SNR, AF protocol is the preferable option to CC protocol with high cooperation level, but with low cooperation level, or at low transmitting SNR regardless of the cooperation level, CC protocol turns out to be the better option for the LMS cooperative diversity system. Both CC protocol and AF protocol show diversity gain over direct transmission. DF protocol is the last choice of the three protocols.

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