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ADAPTIVE POWER ALLOCATION IN THRESHOLD-BASED HYBRID RELAYING SYSTEM

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Abstract

Performance of a single relay-based cooperative communication system in a wireless network is analyzed in this article. A single relay equipped with a single antenna employs a hybrid relay scheme. Based on the channel condition, either amplify or forward (AF) or adaptive decode and forward (ADF) scheme is employed in hybrid mode, which permits switching between the above mentioned dualistic schemes. The performance of the hybrid relay scheme has been examined in terms of symbol error rate (SER), outage probability and optimal power distribution for uncoded cooperative communication. A closed-form depiction for SER and outage probability for M-PSK signal has been derived, where the relay and the destination are considered to perform MRC combining of the message.

Keywords:

Amplify and forward (AD), Adaptive Decode and Forward (ADF), SNR-based Adaptive Decode and Amplify Forward (SNR-ADAF), Symbol Error Rate (SER), Outage Probability

1. INTRODUCTION

Cooperative communication is a satisfactory method to expand the communication range transmitting data to its final destination [1]. This technique can be used in such a scenario where the uninterrupted communication between the source and the sink; for relaying the information, in-between nodes of the source broadcast range can be used. The use of relays reduces signal power needed for source to destination transmission [2]. In [3]-[5], Decode-Forward (DF) and Amplify-Forward (AF) are suggested as two basic cooperative strategies. In DF scheme, the source signal is made to produce energy and interference from primary transmitter with the help of relays and use this energy to reach the received signal to the destination. The relays of the received signal help in amplification and it is then forwarded to the endpoint in case of AF scheme. We may categorize the DF strategy in two ways: (i) Fixed Decode-and-Forward (FDF) and (ii) Adaptive-Decode and Forward Relaying (ADF). In FDF, the relay decodes and forwards the expected signal always. In ADF, when the relay is properly decoded then it forwards the received symbol. AF is considered as the simplest protocol as it does not involve decoding technique at the relays though the noise amplification is its major drawback. The better performances have been observed for ADF over AF. In [6]-[11], benefits of AF and ADF protocols are used for proposed work and FDF protocols concerning symbol error probability. The authors have proposed that outcome of the decoding process depends on the performance of ADF or AF relay. They also showed that the symbol regeneration and retransmission can be possible with the help of successful decoding process of ADF relay. But in case of AF relay, when the decoding process fails to perform, then the signal is advanced to the destination. The limitation has been observed in their proposed work that either AF or ADF relay is chosen to decode the expected signal. In [12]-[13], authors suggested that the protocol depends on the received signal SNR. The moment SNR of the received signal exceeds a fixed threshold value, it is known as SNR based Hybrid Decode-Amplify-Forward (SNR-HDAF) relay and the ADF relaying technique is chosen. But in the case when the received signal SNR has a lower value, the AF relaying technique is preferred [12]. In [13], authors have proposed another relaying technique termed Threshold-based Adaptive Decode-Amplify-Forward (T-ADAF). In T-ADAF technique, once the SNR of the received signal gets below the average SNR, the ADF relay is selected else AF relay is selected. However, if the instant value of SNR is just above the low average SNR it is better to use the ADF scheme since the received signal is noisier.

To eliminate these problems, an adaptive relaying protocol with optimal adaptive power allocation is proposed, namely SNR-based adaptive decode and amplified forward (SNR- based ADAF) protocol. It gives the ideal power distribution depending on channel conditions (i.e. source-destination link, source-relay link, and relay-destination link) and modulation schemes. This method provides rigidity to the relay to implement maximum appropriate protocol based on the channel condition of the source-destination link, source-relay link, and relay-destination link. Furthermore, we focus on SNR-based adaptive decode-and-forward (SNR-ADF) network to investigate outage performance and symbol error rate (SER) above non-identical and independent distribution Rayleigh fading channels. A secured communication for outage probability and SER performance of M-PSK and M-QAM signal has been derived for SNR-based ADAF scheme. It has been observed that this process minimizes SER and outage probability under total and individual power constraints.

The total system model has been described in this paper in section 2. We develop the SER of the SNR-based ADAF protocol in section 3. Section 4 delivers methodical formulation for driving the outage possibility of the SNR-based ADAF protocol. Power portion optimization and the analytical solution for optimum power which minimizes SER and outage probability in SNR-based ADAF protocol under total power constraint are also deliberated in section 5. The numerical and simulation results depending on our formulation are represented in section 6 and the performance SNR-based ADAF protocol is compared with rest of the predictable cooperative schemes and on the basis of that, conclusions are described in section 7.

2. SYSTEM MODEL

The network configuration displayed in Fig.1 is represented as the system model. A cooperative communication technique with two segments in wireless network is considered here. In phase_1, each movable consumer in a wireless system directs data to the terminus, and other users also receive the data at the same interval. Whereas in phase_2, either AF or ADF protocol are used by the relay to forward the data depending on predetermined criterion on channel SNR. For both the cases, TDMA, FDMA or CDMA schemes are used to transfer signals over orthogonal channels [1]-[4]. In our work we have mainly focused on two-user cooperation scheme for better understanding of the concept of cooperation. Normally, in case of phase_1, user_1 directs information to the destination, user_2. After information is received, user_2 decrypts the same and directs user_1 to the information to other users in phase_2. Also when information is referred by user_2 to user_1 in phase_1, then user_1 collects and decodes the information and directs user_2 to the information to other users in phase_2. Thus the total system model can be understood by analyzing the performance of user_1 only as there is operational symmetry. A crisp model is shown in Fig1 where source and relay denote user_1 and user_2 respectively. In phase_1, information from the user source is sent to terminus through designed relay system model. The equations for the signals $y_{s,d}$ (source to destination) and $y_{s,r}$ (source to relay) are shown in Eq.(1) and Eq.(2), respectively

$$y_{s,d} = \sqrt{P_1} h_{s,d} x + \eta_{s,d} \tag{1}$$

$$y_{s,r} = \sqrt{P_1} h_{s,r} x + \eta_{s,r} \tag{2}$$

where P_1 is transmitted power (source), x is transmitted information, and $\eta_{s,r}$ and $\eta_{s,d}$ are additive noise. The channel coefficients are $h_{s,r}$ (source to relay) and $h_{s,d}$ (source to destination) respectively which are modelled as complex Gaussian, zero-mean distributed variables with variances $\delta_{s,r}^2$ and $\delta_{s,d}^2$ respectively. The noise terms $\eta_{s,r}$ and $\eta_{s,d}$ are complex Gaussian, zero-mean distributed variables with variance N_0.

In the second time slot (i.e. phase_2), either AF or ADF protocol are used by the relay to forward the data depending on predetermined criterion on channel SNR. Thus if the channel SNR exceeds a predetermined threshold, it uses the AF protocol i.e., basically strengthens the received signal and then it forwards its encoded version to the target place. Otherwise the ADF protocol is used, i.e., it transmits the signal with power P_2 to the destination after successful decoding. In case of failure in proper decoding the relay cannot refer or remains idle. According to the AF protocol, endpoint expected signal in phase_2 is represented as

$$y_{r,d} = \frac{\sqrt{P_2}}{\sqrt{P_1 \left|h_{s,r}\right|^2 + N_0}} h_{r,d} y_{s,r} + \eta_{r,d} \tag{3}$$

where, $h_{r,d}$ indicates the coefficient of the channel which exists between the relay and the destination and is identified as a complex Gaussian, zero-mean distributed variable which has a variance $\delta_{s,r}^2$. Also the noise term $\eta_{r,d}$ specifies a complex Gaussian, zero-mean distributed variable with variance N_0. More specifically, using Eq.(2), the received signal $y_{r,d}$ is further simplified to

$$y_{r,d} = \frac{\sqrt{P_1 P_2}}{\sqrt{P_1 \left|h_{s,r}\right|^2 + N_0}} h_{r,d} h_{s,r} x + \eta'_{r,d} \tag{4}$$

where

$$\eta'_{r,d} = \frac{\sqrt{P_2}}{\sqrt{P_1 \left|h_{s,r}\right|^2 + N_0}} h_{r,d} \eta_{s,r} + \eta_{r,d} \tag{5}$$

Assuming that $\eta_{s,r}$ and $\eta_{r,d}$ are self-determining noise terms, the resultant noise $\eta'_{r,d}$ indicates a complex Gaussian, zero-mean distributed variable with variance $\left(\frac{P_2 \left|h_{r,d}\right|^2}{P_1 \left|h_{s,r}\right|^2 + N_0} + 1\right) N_0$.

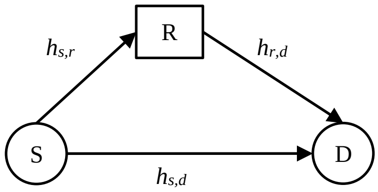


Fig.1. Single hybrid relay network

Under the ADF cooperation protocol, the relay decodes the symbol at transmitter. In the next phase (i.e. phase_2), when the relay helps in transferring the decoded symbol with power P_2 to destination, then in phase_2, the received signal at the end can be depicted as

$$y_{r,d} = \sqrt{\tilde{P}_2} h_{r,d} x + \eta_{r,d} \tag{6}$$

If relay decrypts the transmitted symbol properly then $\tilde{P}_2 = P_2$, otherwise $\tilde{p}_2 = 0$. Relay to destination channel coefficient $h_{r,d}$ is identified as a complex Gaussian, zero-mean distributed variable with variance $\delta_{r,d}^2$. The noise term $\eta_{r,d}$ specifies a complex Gaussian, zero-mean distributed variable with variance N_0. Maximum-ratio combining (MRC) accumulates the expected signal directly from the starting point at phase_1 with that from received relay in phase_2, and identifies the transmitted symbols. In all the supposed protocols, we consider a total power P (transmitted) such as $P = P_1 + P_2$.

3. SYMBOL ERROR RATE OF *M*-PSK IN SNR-BASED ADAF PROTOCOL

Here, we have evaluated the SER performance for the proposed SNR-based ADAF systems. A closed-form expression of SER is being developed for the proposed *M*-PSK and M-QAM modulation systems. Again two upper bounded SER are delivered to expose the asymptotic performance. We further obtain expression for AF and ADF to compare the performance of SNR-based ADAF with those two schemes. Now it is time to discuss AF and single-link ADF relay network in [11] that is the base of our work.

Assume that symbol x at transmitter in Eq.(1) and Eq.(2) has average energy of 1, MRC SNR output in ADF mode can be stated as:

$$\gamma = \frac{P_1 \left|h_{s,d}\right|^2 + \tilde{P}_2 \left|h_{r,d}\right|^2}{N_0} \tag{7}$$

SER for an un-coded *M*-PSK modulation system are given by [11]

$$\psi_{psk}\left(\rho\right)=\frac{1}{\pi}\int_{0}^{\frac{(M-1)\pi}{M}}\exp\left(-\frac{b_{psk}\rho}{\sin^{2}\theta}\right)d\theta \tag{8}$$

where ρ is SNR and $b_{psk}=\sin^{2}\left(\frac{\pi}{M}\right)$. (9)

Therefore, when *M*-PSK modulated system is used in the ADF cooperation system, with the immediate SNR γ in Eq.(7), the average system SER $p_{psk}^{h_{s,d}\,h_{s,r}\,h_{r,d}}$ with the channel coefficients $h_{s,d}$, $h_{s,r}$ and $h_{r,d}$ may be written as:

$$p_{psk}^{h_{s,d}\,h_{s,r}\,h_{r,d}}=\psi_{psk}\left(\frac{P_{1}\left|h_{s,d}\right|^{2}+\tilde{P}_{2}\left|h_{r,d}\right|^{2}}{N_{0}}\right) \tag{10}$$

Further in phase_2, it is expected that if the source transmitted symbol *x* is decoded by the relay properly, and the respective relay helps the decrypted symbol with power P_2 at the terminus, i.e. $\tilde{P}_2=P_2$, else the relay cannot direct, i.e. $\tilde{P}_2=0$. If an *M*-PSK signal is transmitted from the source, then most likely improper decoding is $\psi_{psk}\left(\frac{p_{1}\left|h_{s,r}\right|^{2}}{N_{0}}\right)$ at the relay and the probability of proper decoding is $1-\psi_{psk}\left(\frac{p_{1}\left|h_{s,r}\right|^{2}}{N_{0}}\right)$. Firstly, SER performance is emphasised in case of *M*-PSK modulation system. Taking into account two circumstances $\tilde{P}_2=P_2$ and $\tilde{P}_2=0$, the conditional SER is depicted in (11) as follows:

$$\begin{aligned}p_{psk}^{h_{s,d}\,h_{s,r}\,h_{r,d}}&=\psi_{psk}(\gamma)\Big|_{\tilde{P}_2=0}\,\psi_{psk}\left(\frac{p_{1}\left|h_{s,r}\right|^{2}}{N_{0}}\right)\\&+\psi_{psk}(\gamma)\Big|_{\tilde{P}_2=P_2}\left[1-\left(\frac{p_{1}\left|h_{s,r}\right|^{2}}{N_{0}}\right)\right]\end{aligned} \tag{11}$$

From the Eq.(8) we can establish the SER in Eq.(11) as follows

$$\begin{aligned}p_{psk}^{h_{s,d}h_{s,r}h_{r,d}}&=\frac{1}{\pi^{2}}\int_{0}^{(M-1)\pi/M}\exp\left(\frac{b_{psk}\,p_{1}\left|h_{s,d}\right|^{2}}{N_{0}\sin^{2}\theta}\right)d\theta\\&\int_{0}^{(M-1)\pi/M}\exp\left(\frac{b_{psk}\,p_{1}\left|h_{s,r}\right|^{2}}{N_{0}\sin^{2}\theta}\right)d\theta\\&+\frac{1}{\pi}\int_{0}^{(M-1)\pi/M}\exp\left(\frac{b_{psk}\,(p_{1}\left|h_{s,d}\right|^{2}+p_{2}\left|h_{r,d}\right|^{2})}{N_{0}\sin^{2}\theta}\right)d\theta\\&\times\left[1-\frac{1}{\pi}\int_{0}^{(M-1)\pi/M}\exp\left(\frac{b_{psk}\,p_{1}\left|h_{s,r}\right|^{2}}{N_{0}\sin^{2}\theta}\right)d\theta\right]\end{aligned} \tag{12}$$

We assume that all the links that exist between source to relay $h_{s,r}$, source to destination $h_{s,d}$ and relay to destination $h_{r,d}$ are Rayleigh faded with variances $\delta_{s,r}^{2}$, $\delta_{s,d}^{2}$ and $\delta_{r,d}^{2}$ respectively. Since the fading channel coefficients $h_{s,r}$, $h_{s,d}$ and $h_{r,d}$ are self-directed of each other, and

$$\int_{0}^{\alpha}\exp\left(-\frac{b_{psk}\,p_{1}z}{N_{0}\sin^{2}\theta}\right)p_{|h|^{2}}(z)dz=\frac{1}{1+\frac{b_{psk}\,p_{1}\delta^{2}{}_{h}}{N_{0}\sin^{2}\theta}} \tag{13}$$

Now the SER of M-PSK modulated ADF collaboration system can be written from [11]:

$$\begin{aligned}p_{M-PSK}^{ADF}&=F_{1}\left(1+\frac{b_{psk}\,p_{1}\delta_{s,d}^{2}}{N_{0}\sin^{2}\theta}\right)F_{1}\left(1+\frac{b_{psk}\,p_{1}\delta_{s,r}^{2}}{N_{0}\sin^{2}\theta}\right)+\\&F_{1}\left(\left(1+\frac{b_{psk}\,p_{1}\delta_{s,d}^{2}}{N_{0}\sin^{2}\theta}\right)\left(1+\frac{b_{psk}\,p_{1}\delta_{r,d}^{2}}{N_{0}\sin^{2}\theta}\right)\right)\\&\times\left[1-F_{1}\left(1+\frac{b_{psk}\,p_{1}\delta_{s,r}^{2}}{N_{0}\sin^{2}\theta}\right)\right]\end{aligned} \tag{14}$$

where,

$$F_{1}\left(x(\theta)\right)=\frac{1}{\pi}\int_{0}^{(M-1)\pi/M}\frac{1}{x(\theta)}d\theta \tag{15}$$

The SER of M-QAM modulated ADF cooperation system can be written from [11]

$$\begin{aligned}p_{M-QAM}^{ADF}&=F_{2}\left(1+\frac{b_{psk}\,p_{1}\delta_{s,d}^{2}}{2N_{0}\sin^{2}\theta}\right)F_{2}\left(1+\frac{b_{psk}\,p_{1}\delta_{s,r}^{2}}{2N_{0}\sin^{2}\theta}\right)+\\&F_{2}\left(\left(1+\frac{b_{psk}\,p_{1}\delta_{s,d}^{2}}{2N_{0}\sin^{2}\theta}\right)\left(1+\frac{b_{psk}\,p_{1}\delta_{r,d}^{2}}{2N_{0}\sin^{2}\theta}\right)\right)\\&\times\left[1-F_{2}\left(1+\frac{b_{psk}\,p_{1}\delta_{s,r}^{2}}{2N_{0}\sin^{2}\theta}\right)\right]\end{aligned} \tag{16}$$

where,

$$F_{2}\left(x(\theta)\right)=\frac{4K}{\pi}\int_{0}^{\frac{\pi}{2}}\frac{1}{x(\theta)}d\theta-\frac{4K^{2}}{\pi}\int_{0}^{\frac{\pi}{4}}\frac{1}{x(\theta)}d\theta \tag{17}$$

and $K=1-\frac{1}{\sqrt{M}}$

When all the channel link $h_{s,r}$, $h_{s,d}$ and $h_{r,d}$ are non-zero, i.e. $\delta_{s,r}^{2}\neq 0$, $\delta_{s,d}^{2}\neq 0$, and $\delta_{r,d}^{2}\neq 0$, then SER of the arrangements with M-PSK modulated system may be closely approximated in case $\frac{p_{1}}{N_{0}}$ as well as $\frac{p_{2}}{N_{0}}$ go to infinity (i.e. source transmitted SNR and relay transmitted SNR is high) is given as [11]

$$p_{SER,appro}^{ADF}=\frac{N_{0}^{2}}{b^{2}}\cdot\frac{1}{p_{1}\delta_{s,d}^{2}}\left(\frac{A^{2}}{p_{1}\delta_{s,r}^{2}}+\frac{B}{p_{2}\delta_{s,d}^{2}}\right) \tag{18}$$

where,

$$A=\frac{M-1}{2M}+\frac{\sin\frac{2\pi}{M}}{4\pi}\text{ and }B=\frac{3(M-1)}{8M}+\frac{\sin\frac{2\pi}{M}}{4\pi}-\frac{\sin\frac{4\pi}{M}}{32\pi}\quad(19)$$

If the transmitted signal *x* in Eq.(1) and Eq.(2) is assumed to have an average energy, then the MRC SNR output in AF mode can be stated as $\gamma=\gamma_1+\gamma_2$.

$$\gamma_1=\frac{p_1\left|h_{s,d}\right|^2}{N_0}\qquad(20)$$

and

$$\gamma_2=\frac{\frac{P_1P_2}{p_1\left|h_{s,r}\right|^2+N_0}\left|h_{s,r}\right|^2\left|h_{r,d}\right|^2}{\left(\frac{p_2\left|h_{r,d}\right|^2}{p_1\left|h_{s,r}\right|^2+N_0}+1\right)N_0}=\frac{1}{N_0}\frac{P_1P_2\left|h_{s,r}\right|^2\left|h_{r,d}\right|^2}{P_1\left|h_{s,r}\right|^2+P_2\left|h_{r,d}\right|^2+N_0}\quad(21)$$

The immediate SNR γ_2 in Eq.(21) is tightly upper constrained as

$$\gamma_2\le\overline{\gamma}_2=\frac{1}{N_0}\left(\frac{P_1P_2\left|h_{s,r}\right|^2\left|h_{r,d}\right|^2}{P_1\left|h_{s,r}\right|^2+P_2\left|h_{r,d}\right|^2}\right)\qquad(22)$$

Where the harmonic average of two exponential distributed variables are $\frac{p_1\left|h_{s,r}\right|^2}{N_0}$ and $\frac{p_2\left|h_{r,d}\right|^2}{N_0}$. If we approximate the SNR as $\gamma=\gamma_1+\overline{\gamma}_2$, then conditional SER of AF support schemes with *M*-PSK modulated system can be evaluated according to Eq.(8) and is expressed as follows:

$$p_{psk}^{h_{s,d}h_{s,r}h_{r,d}}=\frac{1}{\pi}\int_0^{(M-1)\pi/M}\exp\left(\frac{b_{psk}(\gamma_1+\overline{\gamma}_2)}{\sin^2\theta}\right)d\theta\qquad(23)$$

Now if we put the γ_1 and γ_2 from Eq.(20) and Eq.(21) respectively, the SER formula with M-PSK modulation in AF mode can be represent as [11]

$$p_{M-PSK}^{AF}\approx\frac{1}{\pi}\int_0^{(M-1)\pi/M}\frac{1}{1+\frac{b_{psk}}{\beta_0\sin^2(\theta)}}\left\{\begin{array}{l}\frac{(\beta_1-\beta_2)^2+(\beta_1+\beta_2)\frac{b_{psk}}{\sin^2(\theta)}}{\Delta^2}+\\ \frac{2\beta_1\beta_2b_{psk}}{\Delta^3\sin^2\theta}\ln\frac{\left(\beta_1+\beta_1+\frac{b_{psk}}{\sin^2\theta}+\Delta\right)^2}{4\beta_1\beta_2}\end{array}\right\}d\theta\qquad(24)$$

The SER formula with the M-QAM modulation in AF mode can be represent as [11]

$$p_{M-QAM}^{AF}\approx\frac{1}{\pi}\int_0^{(M-1)\pi/M}\frac{1}{1+\frac{b_{psk}}{2\beta_0\sin^2(\theta)}}\left\{\begin{array}{l}\frac{(\beta_1-\beta_2)^2+(\beta_1+\beta_2)\frac{b_{psk}}{2\sin^2(\theta)}}{\Delta^2}\\ +\frac{2\beta_1\beta_2b_{psk}}{\Delta^3 2\sin^2\theta}\ln\frac{\left(\beta_1+\beta_1+\frac{b_{psk}}{\sin^2\theta}+\Delta\right)^2}{4\beta_1\beta_2}\end{array}\right\}d\theta\qquad(25)$$

where $\beta_0=\frac{N_o}{p_1\delta_{s,d}}$, $\beta_1=\frac{N_o}{p_1\delta_{s,r}}$, $\beta_2=\frac{N_o}{p_2\delta_{r,d}}$ and

$\Delta^2=s^2+2(\beta_1+\beta_2)s+(\beta_1-\beta_2)^2$ with $s=\frac{b_{psk}}{\sin^2\theta}$ for both the modulation (M- QAM and M- PSK).

When each channel link $h_{s,r}$, $h_{s,d}$ and $h_{r,d}$ is present i.e. $\delta_{s,r}^2\neq0$, $\delta_{s,d}^2\neq0$, and $\delta_{r,d}^2\neq0$, then SER of the received M-PSK modulated system may be tightly approximated in case $\frac{p_1}{N_0}$ and $\frac{p_2}{N_0}$ are infinity (i.e. at high SNR) can be expressed as [11]

$$p_{SER,approx}^{AF}=\frac{BN_0^2}{b_{psk}^2}\cdot\frac{1}{p_1\delta_{s,d}^2}\left(\frac{1}{p_1\delta_{s,r}^2}+\frac{1}{p_2\delta_{r,d}^2}\right)\qquad(26)$$

where b_{psk} and *B* are specified in Eq.(9) and Eq.(19) for M-PSK respectively.

Here the hybrid forwarding system merges both the advantages of AF and ADF scheme which flexibly shifts in between AF and ADF according to channel condition to improve SER performance, outage probability as well as the decoding complexity in a wireless relay network. In practice, the switching decision is determined by checking immediate signal to noise ratio (γ_i) at the relay. If the instant value of signal to noise ratio (γ_i) at the relay surpasses an already defined switching limit (γ_{th}), the AF strategy is used, otherwise ADF scheme is used.

The probability of working in ADF mode at the relay (i.e. probability of γ_i is below threshold γ_{th}) may be stated as

$$P_{ADF}=P(\gamma_i<\gamma_{th})=1-e^{-\frac{\gamma_{th}}{\overline{\gamma}}}\qquad(27)$$

The probability of occupied in AF mode at the relay (i.e. probability of γ_i is above threshold γ_{th}) can be stated as

$$P_{AF}=P(\gamma_i>\gamma_{th})=e^{-\frac{\gamma_{th}}{\overline{\gamma}}}\qquad(28)$$

Hence, by using Eq.(14), Eq.(24), Eq.(27) and Eq.(28), the SER performance of SNR-based ADAF scheme with M-PSK modulation can be obtained as

$$p_{psk}^{ADAF}=P(\gamma_i<\gamma_{th})p_{psk}^{ADF}+P(\gamma_i>\gamma_{th})p_{psk}^{AF}\qquad(29)$$

$$=\left(1-e^{-\frac{\gamma_{th}}{\bar{\gamma}}}\right)\left|\begin{array}{l}F_1\left(1+\frac{b_{psk}\,p_1\delta^2{}_{s,d}}{N_0\sin^2\theta}\right)F_2\left(1+\frac{b_{psk}\,p_1\delta^2{}_{s,r}}{N_0\sin^2\theta}\right)+\\ F_1\left(\left(1+\frac{b_{psk}\,p_1\delta^2{}_{s,d}}{N_0\sin^2\theta}\right)\left(1+\frac{b_{psk}\,p_1\delta^2{}_{r,d}}{N_0\sin^2\theta}\right)\right)\\ \times\left[1-F_1\left(1+\frac{b_{psk}\,p_1\delta^2{}_{s,r}}{N_0\sin^2\theta}\right)\right]\end{array}\right|$$

$$+\left(e^{-\frac{\gamma_{th}}{\bar{\gamma}}}\right)\frac{1}{\pi}\int_0^{(M-1)\pi/M}\frac{1}{1+\frac{b_{psk}}{\beta_0\sin^2(\theta)}} \tag{30}$$

$$\left\{\begin{array}{l}\frac{(\beta_1-\beta_2)^2+(\beta_1+\beta_2)\frac{b_{psk}}{\sin^2(\theta)}}{\Delta^2}\\ +\frac{2\beta_1\beta_2 b_{psk}}{\Delta^3\sin^2\theta}\ln\frac{\left(\beta_1+\beta_1+\frac{b_{psk}}{\sin^2\theta}+\Delta\right)^2}{4\beta_1\beta_2}\end{array}\right\}d\theta$$

The SER performance of SNR-based ADAF scheme with M-QAM modulation as

$$p_{M-QAM}^{ADAF}=P(\gamma_i<\gamma_{th})p_{M-QAM}^{ADF}+P(\gamma_i>\gamma_{th})p_{M-QAM}^{AF}$$

$$=\left(1-e^{-\frac{\gamma_{th}}{\bar{\gamma}}}\right)\left|\begin{array}{l}F_2\left(1+\frac{b_{psk}\,p_1\delta^2{}_{s,d}}{2N_0\sin^2\theta}\right)F_2\left(1+\frac{b_{psk}\,p_1\delta^2{}_{s,r}}{2N_0\sin^2\theta}\right)+\\ F_2\left(\left(1+\frac{b_{psk}\,p_1\delta^2{}_{s,d}}{2N_0\sin^2\theta}\right)\left(1+\frac{b_{psk}\,p_1\delta^2{}_{r,d}}{2N_0\sin^2\theta}\right)\right)\\ \times\left[1-F_2\left(1+\frac{b_{psk}\,p_1\delta^2{}_{s,r}}{2N_0\sin^2\theta}\right)\right]\end{array}\right|$$

$$+\left(e^{-\frac{\gamma_{th}}{\bar{\gamma}}}\right)\frac{1}{\pi}\int_0^{(M-1)\pi/M}\frac{1}{1+\frac{b_{psk}}{\beta_0 2\sin^2(\theta)}} \tag{31}$$

$$\left\{\begin{array}{l}\frac{(\beta_1-\beta_2)^2+(\beta_1+\beta_2)\frac{b_{psk}}{2\sin^2(\theta)}}{\Delta^2}\\ +\frac{2\beta_1\beta_2 b_{psk}}{\Delta^3 2\sin^2\theta}\ln\frac{\left(\beta_1+\beta_1+\frac{b_{psk}}{\sin^2\theta}+\Delta\right)^2}{4\beta_1\beta_2}\end{array}\right\}d\theta$$

Similarly, by using Eq.(16), Eq.(24), Eq.(27) and Eq.(28), we can obtain the tightly approximated SER performance of SNR-based ADF arrangement with M-PSK modulation as

$$p_{psk,approx}^{ADAF}=P(\gamma_i<\gamma_{th})p_{psk,approx}^{ADF}+P(\gamma_i>\gamma_{th})p_{psk,approx}^{AF}$$

$$=\left(1-e^{-\frac{\gamma_{th}}{\bar{\gamma}}}\right)\frac{N_0^2}{b^2}\cdot\frac{1}{p_1\delta_{s,d}^2}\left(\frac{A^2}{p_1\delta_{s,r}^2}+\frac{B}{p_2\delta_{s,d}^2}\right)+$$

$$\left(e^{-\frac{\gamma_{th}}{\bar{\gamma}}}\right)\frac{BN_0^2}{b_{psk}^2}\cdot\frac{1}{p_1\delta_{s,d}^2}\left(\frac{1}{p_1\delta_{s,r}^2}+\frac{1}{p_2\delta_{r,d}^2}\right) \tag{32}$$

4. OUTAGE PROBABILITY ANALYSIS

Outage probability for hybrid relay scenario is presented below. If the instant value of signal to noise ratio (γ_i) exceeds a definite chosen switching limit (γ_{th}), the hybrid relay initiates in AF mode, otherwise, the relay follows in ADF mode. In ADF scheme, it is assumed that if a certain threshold $g(\bar{\gamma})$ (i.e. the relay is possibly capable of decoding the signal source properly) is exceeded by the received signal-to-noise ratio at the relay, the relay decrypts received signal and sends the decrypted information toward the destination. Again, concerning the source and the relay, if the channel endures a severe fading such that the signal-to-noise ratio drops below the threshold $g(\bar{\gamma})$ (i.e. the relay may not decrypt the source signal correctly), then the relay remains idle.

In source–relay link, if the SNR surpasses the threshold value, the source signal is being decoded by the relay properly. Here, at destination, the SNR of joint MRC signal is the amount of the expected from source SNR and relay SNR. Thus, the ADF relaying common information can be expressed by

$$\begin{aligned}I_{ADF}&=\frac{1}{2}\log\left(1+2\bar{\gamma}\left|h_{s,d}\right|^2\right)\text{ for }\left|h_{s,d}\right|^2<g(\bar{\gamma})\\ &=\frac{1}{2}\log\left(1+\bar{\gamma}\left|h_{s,d}\right|^2+\bar{\gamma}\left|h_{r,d}\right|^2\right)\text{ for }\left|h_{s,d}\right|^2\geq g(\bar{\gamma})\,.\end{aligned} \tag{33}$$

where the threshold value $g(\bar{\gamma})=\frac{\left(2^{2R}-1\right)}{\bar{\gamma}}$

Thus the selective relaying outage probability may be evaluated as follows, whether the source signal is advanced by the relay or not depending on the law of total probability, we have

$$\begin{aligned}P\left(I_{ADF}<R\right)&=P\left[I_{ADF}<R\middle|\left|h_{s,d}\right|^2<g(\bar{\gamma})\right]\Pr\left(\left|h_{s,d}\right|^2<g(\bar{\gamma})\right)\\ &+P\left[I_{ADF}<R\middle|\left|h_{s,d}\right|^2>g(\bar{\gamma})\right]\Pr\left(\left|h_{s,d}\right|^2>g(\bar{\gamma})\right)\end{aligned} \tag{34}$$

From Eq.(32), the ADF relaying outage probability is expressed

$$P\left(I_{ADF}<R\right)=P\left[\frac{1}{2}\log(1+2\bar{\gamma}\left|h_{s,d}\right|^2)<R\middle|\left|h_{s,d}\right|^2<g(\bar{\gamma})\right]$$

$$\Pr\left(\left|h_{s,d}\right|^2<g(\bar{\gamma})\right)+ \tag{35}$$

$$P\left[\begin{array}{l}\frac{1}{2}\log(1+\bar{\gamma}\left|h_{s,d}\right|^2+\\ \bar{\gamma}\left|h_{r,d}\right|^2)<R\left|\left|h_{s,d}\right|^2>g(\bar{\gamma})\right.\end{array}\right]\Pr\left(\left|h_{s,d}\right|^2>g(\bar{\gamma})\right)$$

The source can succeed diversity order two as in the above outline the first term indicates the multiplication of two possibilities of each account to diversity order one, and the second term also indicates a multiplication of two possibilities out of which the first term has diversity order two. Alternatively, we can say that so as to an outage event to happen, the ADF relaying scheme can succeed diversity order two. Either in the event of both the source to relay and source to destination relay, channels must be in outage or the combined relay to destination or source to destination channel may be in outage. In above expression, all the random variables are independent exponential distributed variables that make the outage probability calculation directly, and the outage expression at high SNR can be evaluated by [11],

$$P_{out,ADF} = \Pr\left[I_{AF} < R\right] \approx \frac{\delta_{s,r}^2 - \delta_{r,d}^2}{2\delta_{s,d}^2\left(\delta_{s,r}^2\delta_{r,d}^2\right)}\left(\frac{2^{2R}-1}{\bar{\gamma}}\right)^2 \tag{36}$$

At high SNR, both AF and ADF relaying has the same diversity gain. Since the outage probability of SNR-based ADAF is the mixture of AF and ADF schemes so the outage probability of SNR-based ADAF scheme is same AF and ADF cases. Therefore, the outage probability of SNR-based ADAF scheme is depicted as

$$P_{out,ADAF} = \Pr\left[I_{AF} < R\right] \approx \frac{\delta_{s,r}^2 - \delta_{r,d}^2}{2\delta_{s,d}^2\left(\delta_{s,r}^2\delta_{r,d}^2\right)}\left(\frac{2^{2R}-1}{\bar{\gamma}}\right)^2 \tag{37}$$

where the multiplicative element of 2 in 2R ascends due to the bandwidth loss in co-operation.

1. ADAPTIVE POWER DISTRIBUTION

Here we have defined an asymptotic optimal power sharing for SNR-based ADAF cooperation system depending on the fitted SER approximation in Eq.(33) in high SNR environment. For a static entire transmitted power $P_1+P_2=P$, we need to improve P_1 and P_2 such that the asymptotically fitted SER estimation in Eq.(32) is reduced. Consistently, we attempt to lessen

$$G\left(P_1,P_2\right) = \frac{1}{P_1\delta_{s,d}^2}\left[\begin{array}{l}\left(1-e^{-\frac{\gamma_{th}}{\bar{\gamma}}}\right)\left(\dfrac{A^2}{P_1\delta_{s,r}^2}+\dfrac{B}{P_2\delta_{s,d}^2}\right)+\\ \left(e^{-\frac{\gamma_{th}}{\bar{\gamma}}}\right)\left(\dfrac{B}{P_1\delta_{s,r}^2}+\dfrac{B}{P_2\delta_{r,d}^2}\right)\end{array}\right] \tag{38}$$

Taking derivative in terms of P_1 and setting the derivation to 0. For necessarily high SNR, the optimum power distribution in SNR-based ADFA cooperation systems, with M-PSK modulation is:

$$P_1^{ADAF} = \left(\begin{array}{r}\left(1-e^{-\frac{\gamma_{th}}{\bar{\gamma}}}\right)\dfrac{\delta_{s,r}^2+\sqrt{\delta_{s,r}^2+8\left(\dfrac{A^2}{B}\right)\delta_{r,d}^2}}{3\delta_{s,r}^2+\sqrt{\delta_{s,r}^2+8\left(\dfrac{A^2}{B}\right)\delta_{r,d}^2}}\\ +\left(e^{-\frac{\gamma_{th}}{\bar{\gamma}}}\right)\dfrac{\delta_{s,r}^2+\sqrt{\delta_{s,r}^2+8\delta_{r,d}^2}}{3\delta_{s,r}^2+\sqrt{\delta_{s,r}^2+8\delta_{r,d}^2}}\end{array}\right)P \tag{39}$$

$$P_2^{ADAF} = \left(\begin{array}{r}\left(1-e^{-\frac{\gamma_{th}}{\bar{\gamma}}}\right)\dfrac{2\delta_{s,r}^2}{3\delta_{s,r}^2+\sqrt{\delta_{s,r}^2+8\left(\dfrac{A^2}{B}\right)\delta_{r,d}^2}}\\ +\left(e^{-\frac{\gamma_{th}}{\bar{\gamma}}}\right)\dfrac{2\delta_{s,r}^2}{3\delta_{s,r}^2+\sqrt{\delta_{s,r}^2+8\delta_{r,d}^2}}\end{array}\right)P \tag{40}$$

Since SNR-based ADAF cooperation scheme is a mixture of AF and ADF schemes depending on switching threshold (γ_{th}), the optimum power allocation in SNR-based ADAF not only depend on the total transmitted power (*P*) but also it depends on switching threshold (γ_{th}). Moreover, in ADF scheme, we can understand that at the source the optimal ratio of the transmitted power P_1 to the total power *P* is in between 0.5 and 1, while at the relay the optimal ratio of the power P_2 to the total power *P* is in between 0.5 and 0 i.e., $\frac{1}{2} < \frac{P_1}{P} < 1$ and $0 < \frac{P_2}{P} < \frac{1}{2}$

It indicates that we must place additional source power compared to less relay power.

5. RESULTS AND DISCUSSIONS

In this segment, we have presented some results based on analytical framework and highlighted the comparative performance of AF, ADF and SNR-based ADAF schemes. We also carry out simulation based on MATLAB to validate our analytical formulation. In this section, simulation outcomes are symbolized by distinct marks on the curves, while numerical outcomes are denoted by curves. We have compared the performance of AF, ADF and SNR-based ADAF cooperation system under the optimum power distribution scheme with equivalent power scheme systems. We also compare the SER performance for ADF, AF and SNR-based ADAF schemes in Eq.(14), Eq.(24) and Eq.(30) respectively with the simulated SER curves for M-PSK modulation.

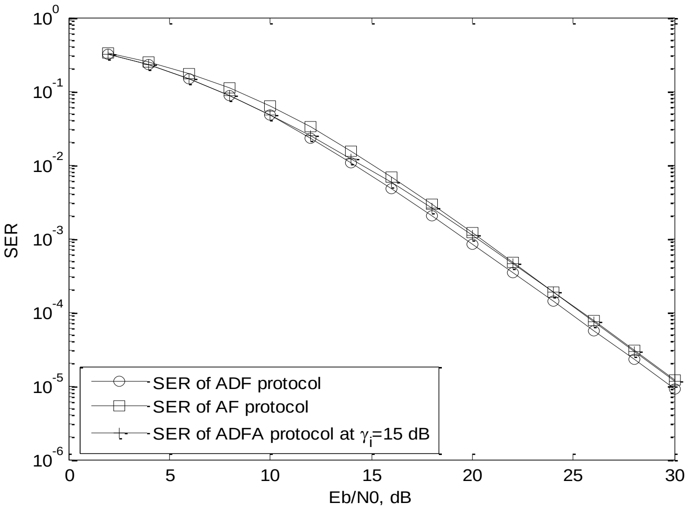


Fig.2. Performance of AF, ADF and ADAF cooperation with QPSK signal for equal power distribution

The Fig.2 displays the SER performance of the SNR-based ADAF strategy for a switching threshold of γ_{th} =15dB. It has been observed that the performance of SNR-based ADAF lies in among that of AF and ADF strategy. The SER performance of SNR-based ADAF and ADF are moderately parallel in the low SNR range. However, SER performance of ADAF degrades as SNR increases and finally reaches to the level of AF. Where the BER of ADF separates the AF/ADF curve, that point is determined by the switching threshold value γ_{th} selected at the relay.

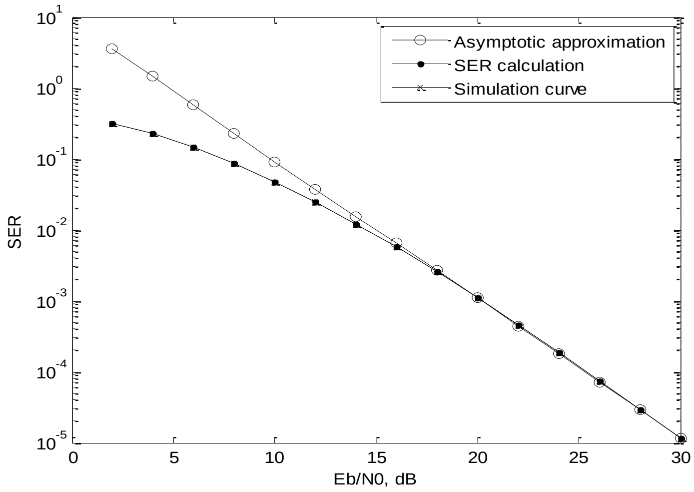
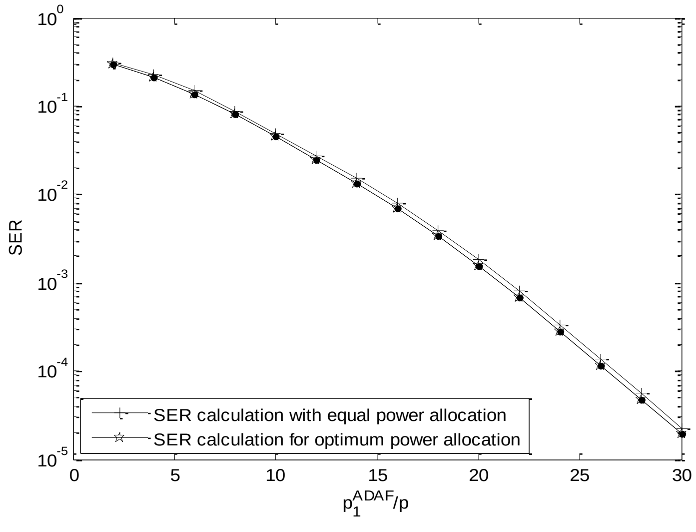
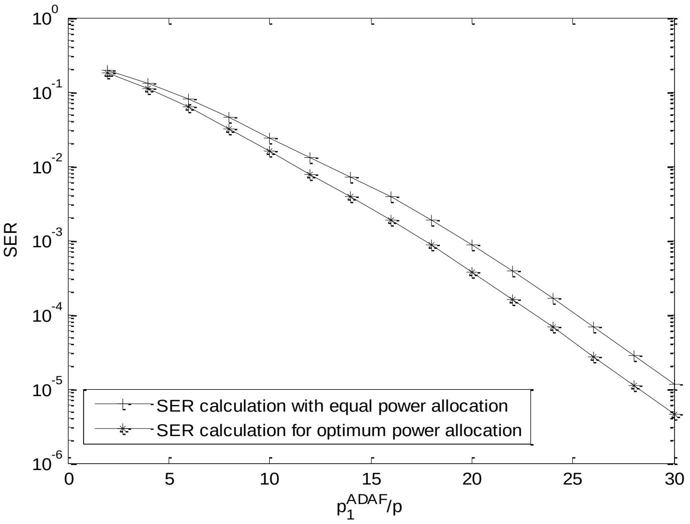


Fig.3. cooperation between the SER approximations and the exact SER calculation for ADF scheme with QPSK signal

The comparison between analytical and simulated values of SER in SNR-based ADAF cooperation system with QPSK modulation is shown in Fig.3. It is observed that SER as per analytical expression in Eq.(30) perfectly matches with the simulation result. Moreover, the simple SER estimation in Eq.(32) is fitted at high value of SNR that is better to display the asymptotic presentation of the SNR-based ADAF support system.



(a)



(b)

Fig.4. Performance of ADF collaboration systems with QPSK signals: adaptive optimal power distribution versus equivalent power pattern. (a) $\delta^2 s,r=\delta^2{}_{r,d}=1$ (b) $\delta^2 s,r=\delta^2{}_{r,d}=10$

The simulation results of SNR-based ADAF collaboration systems with QPSK modulation are shown in Fig.4. In the case of ($\delta_{s,r}^2=\delta_{r,d}^2$ = 1, $\bar{\gamma}$ = 20dB and γ_{th} = 15dB) in Fig.4(a), the finest power ratios are $\frac{P_1^{ADAF}}{P}$ = 0.6467 and $\frac{P_2^{ADAF}}{P}$ = 0.3533 that are the same as those for the BPSK modulation. In Fig.4, the optimum power distribution performance is improved than identical power case system, while the SER guesses are matched with simulation curves. In case of ($\delta_{s,r}^2=\delta_{r,d}^2$ = 10, $\bar{\gamma}$ = 20dB and γ_{th} = 15dB), the finest power ratios are $\frac{P_1^{ADAF}}{P}$ = 0.8128 and $\frac{P_2^{ADAF}}{P}$ = 0.1872 according to Eq.(38) and Eq.(39). From Fig.3(b), we have observed that the optimal power distribution arrangement overtakes the identical power arrangement with about 2 dB performance enhancement. If the channel link quality ratio $\frac{\delta_{r,d}}{\delta_{s,r}}$ increases, we expect a greater improvement in the optimal power allocation performance above the equal power case. Furthermore, it is seen that in all of the above simulations, the SER calculations are fitted enough throughout the entire the SNR range.

The Fig.5 shows the optimum power distribution for the pure AF and ADF along with the mixed AF/ADF (i.e. SNR-based ADAF) strategies in a single relay link. We realize that the asymptotic optimal power distribution for AF and ADF schemes is only determined by the source-relay link and relay-destination link. It does not depend on source-destination link. In SNR-based ADAF scheme the asymptotic optimal power allocation not only varies on source-relay link and relay- destination link, but depends on average SNR. Optimum power distribution of the ADF scheme for several levels of switching threshold is between that of AF and ADF.

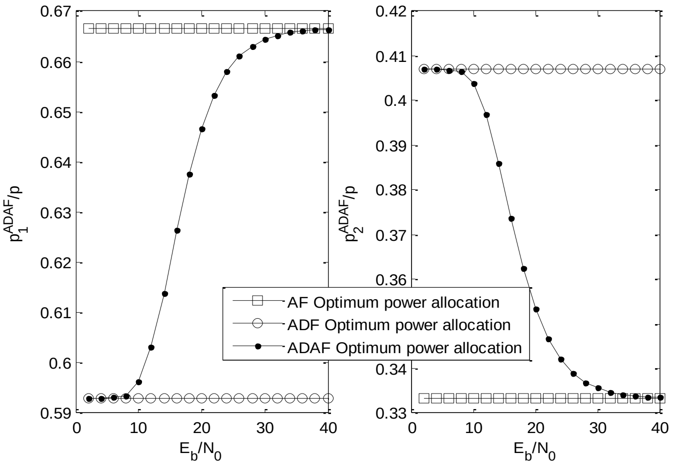


Fig.5. Asymptotic optimum power distribution for AF, DF and ADF cooperation systems with $\delta_{s,r}^2 = \delta_{r,d}^2 = 1$

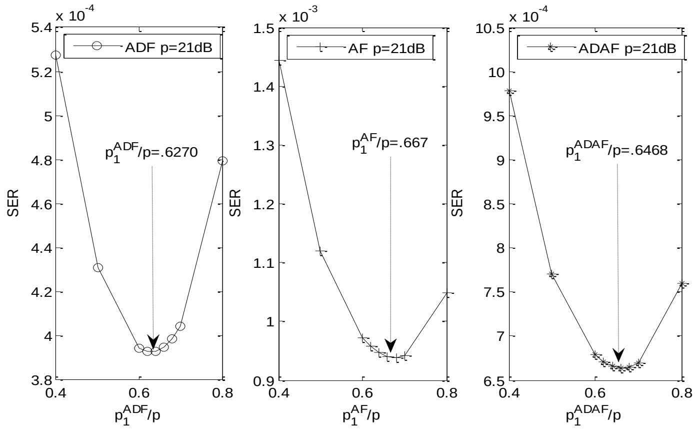


Fig.6. Comparative study of optimum power allocation with $\delta^2 s,r = \delta^2{}_{r,d} = 1$ and $\delta^2{}_{s,d} = 1$

In Fig.6, exact SER have been designed as a function of ratio $\frac{p_1}{p}$ for different schemes (i.e. AF, ADF and SNR-based ADAF schemes) with QPSK modulation and different fading scenarios i.e. $\delta_{s,r}^2 = \delta_{r,d}^2 = 1$. The asymptotic optimum power distribution for AF and ADF schemes are $\frac{P_1^{AF}}{P} = 0.667$ and $\frac{P_1^{DAF}}{P} = 0.6270$ respectively. But in SNR-based ADAF scheme the optimum power allocation $\frac{P_1^{ADAF}}{P} = 0.6468$ with a switching threshold of $\gamma_{th} = 15$dB. In case of ($\delta_{s,r}^2 = \delta_{r,d}^2 = 10$, $\bar{\gamma} = 21$dB and $\gamma_{th} = 15$dB), the optimum power ratio of ADF, AF and SNR-based ADAF scheme are $\frac{P_1^{ADF}}{P} = 0.627$, $\frac{P_2^{AF}}{P} = 0.667$ and $\frac{P_1^{ADAF}}{P} = 0.6468$ respectively according to Eq.(38) which is match with simulated SER results.

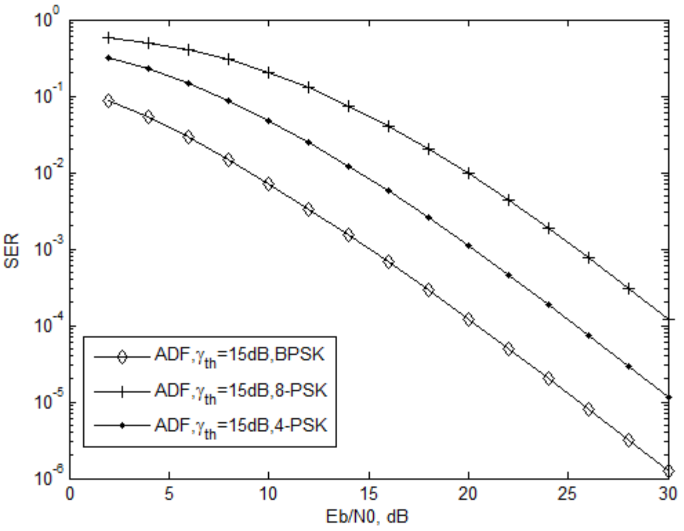


Fig.7. Comparative study of different modulation schemes

The Fig.7 displays the SER performance of SNR-based ADAF for different modulation schemes. It is seen that BPSK modulation schemes is better than QPSK modulation in terms of SER performance.

6. CONCLUSION

In this paper, the functioning of AF, ADF and SNR-based ADAF cooperation systems are compared under the optimum power distribution scheme with that of equal power scheme. SER performance of ADAF degrades as SNR increases and finally meets to that of AF. The SER performance of SNR-based ADAF and ADF are comparable in the low SNR range. The comparison between analytical and simulated values of SER in SNR-based QPSK modulated ADAF cooperation system is shown. It is observed that the analytical expression of the SER perfectly matches with the simulation results. Also, the simple SER calculation is fitted at high value of SNR, which is better to display the asymptotic presentation of the SNR-based ADAF collaboration system. It has been noticed that the optimal power distribution performance is improved than equal power case system, while approximations of SER are matched with that of simulation curves. The asymptotic optimal power distribution for AF and ADF schemes are mostly dependent on the source-relay link and relay-destination link.

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