SER Derivation and Power Optimization of a Two-Way Multi-Relay Cooperative Communication System

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ABSTRACT

In this paper, we consider Rayleigh fading based cooperative communication system with AaF (Amplify and Forward) relaying using multiple relays. We take spectrally efficient two-way model of cooperative communication terminals and formulate performance evaluation framework in terms of SER (Symbol Error Rate). We not only consider fading channel for this performance evaluation but also consider the effect of relay terminal location into our model which does not require any CSI (Channel State Information) at transmitting nodes. We have proposed power allocation framework for these nodes and analytically derived SER performance results. We have numerically evaluated this framework for power optimization as well as minimizing required SER. Significant performance improvement as compared with equal power sharing among the cooperating terminals is achieved using our proposed framework. It is shown that virtual cooperative antenna configurations is able to demonstrate up to 3dB gain as compared with co-located antenna configurations. Thus incorporating relay location information for performance evaluation results significant power savings.

Key Words: Symbol Error Probability, Power Allocation, Relay Channels, Two-Way Relay Channel, Bidirectional Relay Channel.

1. INTRODUCTION

Although MIMO (Multiple Input Multiple Output) communication systems have many advantages over SISO (Single Input and Single Output) communication system their implementation is difficult to realize due to size, cost and hardware limitations. In order to realize the benefits of MIMO without paying extra cost, cooperative communication techniques have been proposed [1-3]. In cooperative communication system in wireless communication environment we makes use of diversity technique due to inherent broadcast wireless transmission by using cooperative node as a virtual antenna which enables us to achieve spatial diversity. This diversity gain provides us performance efficiency in terms of SER.

Cooperation schemes are mainly of two kinds. AaF (Amplify-an-Forward) cooperation or non-regenerative relaying in this scheme the relaying node just amplify or scales the received signal. In AaF neither the received signal is regenerated nor it is decoded, relay just forwards

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the signal as or what it receives . The second type is DaF (Decode and-Forward) or regenerative relaying, in DaF relay terminal not only decodes the received signal and then also encodes it using different coding schemes before transmitting it to destination terminal. There are also some hybrid cooperation schemes which use both AaF and DaF types of relaying.

Cooperation schemes usually use one-way mode for data transfer between terminals and but it is less spectrally efficient because of repetitive transmissions from relays. Two-way relaying which is also called bi-directional relaying [5-6], on the other hand has proved to recover the spectral loss inherent in traditional one-way data transfer mode used in relay-based cooperative communication systems. In bidirectional relaying two terminals exchange their mutual data which usually does not have their direct link with each other. In this scheme in firstly both terminals transmit their data simultaneously to relay terminal, the relay receives them as a superposition of the two signals. In the second phase of the two-way mode relay transmits the signal received in the first phase, now the two terminals can get the information of the other terminal through subtracting their own signal. In this way bidirectional or two-way communication consumes two time slots as compared with one-way communication which takes four time slots for type of each other's data sharing between two terminals.

Shannon, [7] introduced the two-way communication channel and he described idea how two-way channel can work to achieve maximum possible data rates. Now two-way communication channel has become focus of many researchers with the introduction of idea of relay for the exchange of information between the two communicating terminals. The model consists of two data terminals wants to exchange data through relay in between can them, in this way the spectral loss can also be recovered as compared with half duplex relaying one way models. Rankov and Wittneben, [8-9], have considered two-way relaying and two-path relaying protocols and have shown

that it is possible to recover the spectral loss of half-duplex communication by using two-way communications. They have considered AaF and DaF relaying strategies and evaluated the achievable rates for these relaying schemes.

Cui, et. al. [4] considered two-way cooperative communication system for an AWGN channel. They have optimized bit error rates curve for different values of SNRs but without considering the effect of fading and relay location. They classify their various relaying schemes into abs-based schemes, where the relay first takes the absolute value of the received signal. They have proposed EaF (Estimate and Forward) relaying technique optimized for bit error rate for all SNR regimes.

Han et. al. [5] uses AaF relaying and derived average sum rate of the two-way half duplex system with upper and lower bounds. They have derived PEP (Pairwise Error Probability) and the bounds for the sum rate assuming perfect CSI at all terminals. They have shown higher spectral efficiency as compared to conventional one-way AaF system and extended their system model for Alamouti's OSTBC (Orthogonal Space Time Block Code) having multi-antenna source and destination terminals with relay having a single antenna. Furthermore, they also obtained analytical results for optimal power allocation with and without OSTBC. The theoretical and numerical results also achieve full diversity order.

Cui et. al. [6] considered different relaying strategies for memory-less two-way relay channels. They used binary antipodal signaling using higher order constellation sizes and derived the generalized probability of error for different SNR values but considered deterministic channel only and allocated more power for relay terminal. They used two types of relaying strategies; i.e. absolute and non absolute, and also optimized the performances of AaF, DaF, and EaF relaying schemes using average power constraint, for both these types.

The SER based performance analysis in MIMO is challenging research area which contributed many

research papers. Derivation of average SER analytical formula requires multiple integrals consisting of product of exponentials with SNR probability distribution function for each fading channels branches. Conventionally each integral is evaluated for its variable of integration and its single integral derivation requires convolving over every fading channel branch path for joint PDF of SNR. Converting this convolution to multiplication sum using Laplace transform is a way to analytical derivation. Most SER analytical derivation results solutions which cannot be solved numerically due to infinite integral limits in Gaussian function. For cases which do not converge to any solution some authors compare their results with some well known bounds are UB (Union Bound) and Chernoff Bound. Unified frame work approach using MGF based technique [10] which we used offers BER probability performance for almost all types of modulations and fading channel types.

We consider similar model as in [4] with AaF relaying but APS (Average Power Scaling) [11] for our analytical derivation. Contrary to [4], we have considered relay location into our derivation and power allocation framework with objective of SER performance analysis, this type of model is applicable to moving nodes for mobile, laptops and also for orbiting satellites at far. We derive SER performance using finite range integrals and show that our analytical result perfectly matches with simulation results. We also formulate numerical optimization problem for power allocation and compare it with EP (Equal Power) allocation. The presented OP (Optimized Power) allocation is providing 3dB gain and without requiring channel state information at transmitting nodes it only depends upon location information of the relay. The paper presents in depth analysis as compared with [12] to check optimized results in different configuration or parameters of interest and to compare it with one-way cooperative communication environment.

The remainder of the paper is organized as follows. In the next section we describe our system model. In Section 3,

we describe performance analysis of the model. In Section 4, we describe optimum power allocation schemes and its related results using optimization. In Section 5, we compare the performance of one-way and two-way cooperative communication system. In Section 6, we present an in depth analysis and finally Section 7, concludes the paper.

Notations: $(.)^*$ and $E_x[.]$ denote the conjugate operation and expectation carried over variable x, respectively.

2. TRANSMISSION MODEL

We consider cooperative communication system model consisting of two data terminals T_1 and T_2 which are out of reach of each other i.e. cannot receive each other's data directly, we also suppose that there is one third terminal which is lying in between these terminals which can act as cooperative data relay node and all these nodes are half duplex nodes and all nodes have only one transmit and receive antennas. As shown in Fig. 1 we have two terminals T_1 and T_2 that want to share their own data with the help of N cooperative relay terminals R_i, and $i=1, 2, \cdots ,N$. All these N+2 terminals are located in a two-dimensional plane. Let $d_{T1,Ri}$ denote the distance of the first terminal T_1 to relay R_i and $d_{T2,Ri}$ is distance of the second terminal T_2 to R_i. We have considered channel model which considers both fading small scale as well as large scale into our performance analysis which also evaluates position of terminal nodes or the relay nodes on for symbol error rate derivation. As we know that the path loss between transmitter and receiver separated at a distance d is directly proportional to $d^{-\alpha}$ where α is path loss coefficient which depends upon different environment types and its different values can be found in [13]. Let we denote the path loss between T_1 and relay R_i, by $G_{T1,Ri}$ and by $G_{T2,Ri}$ for T_2 and relay R_i. We have defined ratio of two these two parameters of path losses by $G_{Ri}=G_{T1,Ri}/G_{T2,Ri}=(d_{T2Ri}/d_{TiRi})^{\alpha}$. This ratio depicts position of the relay R_i relative to the two terminals T_1 and T_2. Negative value of this ratio corresponds to the location of the relay when it is closer to T_2 compared to T_1. While positive value corresponds to the terminal T_1 when it is closer to relay terminal. In broadcasting phase which

is also first time slot, two terminals T_1 and T_2 transmit their data which is received by all the relays. In the second phase which is relaying phase, relays terminals transmit after amplifying the information received in the broadcast phase and this phase consists of N time slots as shown in Figs. 1-2.

Since each node has knowledge of its transmitted data, like both terminals T_1 and T_2 knows their own data so they both cancel their own data from the received signal through the relay in order to extract the other terminals data. Let x_i and x_2 symbols are transmitted using MPSK modulation in broadcasting phase by the two terminals T_1 and T_2 respectively. Considering the effects of both types of fading i.e. long term and short term fading effects, the received signals at the relay R_i is as given in [14]:

$$r_{R_i} = \sqrt{\gamma_{i1}}\, h_{T_1,R_i} x_1 + \sqrt{\gamma_{i2}}\, h_{T_1,R_i} x_2 + n_{R_i} \qquad (1)$$
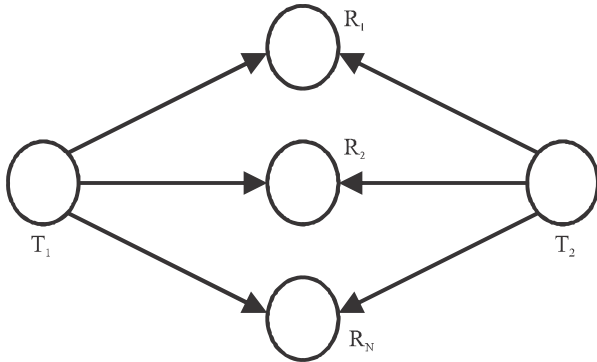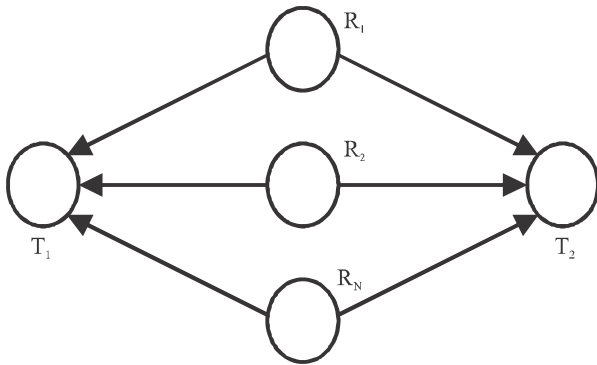

FIG. 1. DATA TRANSMISSION PHASE (BROADCASTING PHASE

FIG. 2. RELAYING PHASE

where $\gamma_{i1}=G_{Ti,Ri}K_{Ti}P$ and $\gamma_{i2}=G_{T2Ri}K_{T2}P$. We suppose that the total power needed for the transmission is P. K_T and K_{T2} are control parameters for controlling power usage in both phases i.e. in broadcasting and relaying phases. As stated Earlier $G_{Ti,Ri}$ denotes path loss between T_1 and relay R_i and similarly $G_{T2,Ri}$ denotes path loss between T_2 and relay R_i. Each relay uses the following normalization coefficient on r_{Ri}:

$$\sqrt{E_{n_{R_i},h_{T_1,R_i},h_{T_2,R_i}}\left[\left|r_{R_i}\right|^2\right]} = \sqrt{\gamma_{i1}+\gamma_{i2}+N_0} \qquad (2)$$

Where we use

$$E\left[\left|h_{T,R_k}\right|^2\right]= \sigma_{ik}^2 = 1$$

$\forall i=1,2,...N$ and $k=1,2$. This ensures the unity of average transmit energy. Relay takes normalization and conjugation of its received signal having power $K_{Ri}P$ using N orthogonal time slots for every relayed signal. $K_{Ri}S$ values are chosen in a way that satisfies the following power equation $\left(K_{T_i}+K_{T_2}+\Sigma_{i=1}^{N}K_{R_i}\right)P = P$. We assume reciprocal channels between all our cooperative communication system nodes [4] (i.e. $h_{Tj,Ri}=h_{Ri,Tj}$, $\forall_j=1,2$ and $i=1,2,...N$).In other words the uplink channel gain is the same as downlink channel gain. The received signals at the T_1 from R_i are:

$$r_{T_i,R_i} = \sqrt{\gamma_{R_{i1}}}\, h_{T_i,R_i} \frac{r_{R_i}^*}{\sqrt{E_{n,h_{T_1,R_i},h_{T_2},h_{R_i}}\left[\left|r_{R_i}\right|^2\right]}} + n_{T_1,R_i} \qquad (3)$$

$i = 1,2,.....N$

with $\gamma R_{i1}=G_{Ti,Ri}K_{Ri}P$. In Equations (1-3), $n_{T1,Ri}$ and $n_{Ri}=1,2,...N$, are the both independent random variable having probability distribution of ZMCG (Zero Mean Complex Gaussian) with variance 0.5 N_0 per dimension, which models the additive white noise. $h_{Tj,Ri}$, $\forall_i=1,2$ and

$j=1,2$ is fading channel gain parameter having zero-mean complex Gaussian with 0.5 variances each, which results that the fading to conclude that fading type is Rayleigh distributed. As we know that both terminals T_1 and T_2 knows their own data which can cancelled as self-interference, then the received signal at T_1 from R_i is:

$$
\hat{r}_{T_1,R_i} = \sqrt{\frac{\gamma_{R_i}\gamma_{12}}{\gamma_{i1} = \gamma_{12} + N_0}} h_{T_1,R_i} h^*_{T_2,R_i}, x^*_2
$$
$$
+ \sqrt{\frac{\gamma_{R_i}1}{\gamma_{i1} + \gamma_{i2} + N_0}} h_{T_1,R_i} n^*_{R_i} + \widetilde{n}_{T_1,R_i}
\tag{4}
$$

If $h_{T1,Ri}$ and $h_{T2,Ri}$ are given then $\widetilde{n}_{Ti,Ri}$ will be complex Gaussian. We assume that the T_1 terminal normalizes the received signal given by Equation (4) with

$$
\sqrt{\frac{\gamma_{Ri1}}{\gamma_{i1} + \gamma_{i2} + N_0} |h_{T1,Ri}|^2 + N_0}
\tag{5}
$$

resulting in

$$
r'_{T_1,R_i} = \sqrt{A_i} h_{T_1,R_i} h^*_{T_2,R_i} x^*_2 + n'_{T1,R_i}
\tag{6}
$$

$n'_{T1,Ri}$ denotes the noise term and in Equation (6) equation A_i can be written as given:

$$
A_i = \frac{\gamma_{R_i}\gamma_{i2}}{\gamma_{R_i1}|h_{i1}|^2 + (\gamma_{i1} + \gamma_{i2} + N_0)N_0}
\tag{7}
$$

Similarly for T_2, the received signal after subtracting their own data and then using normalization from R_i is:

$$
r'_{T_2,R_i} = \sqrt{B_i} h_{T_2,R_i} h^*_{T_1,R_i} x^*_1 + n'_{T_2,R_i}
\tag{8}
$$

where n'_{D2} is also complex Gaussian variable having mean zero and variance $N_0/2$. Now B_i can be written as follows:

$$
B_i = \frac{\gamma_{R_i}\gamma_{i1}}{\gamma_{R_i2}|h_{T_2,R_i}|^2 + (\gamma_{i1} + \gamma_{i2} + N_0)N_0}
\tag{9}
$$

3. Performance Analysis

Equations (6) and (8) represent the received signals at T_1 and T_2 respectively. In these equations we used APS constraint which ensures that an average output power is maintained but an instantaneous output power can be greater. Using MRC (Maximum Ratio Combining) technique signals received from all the relays at T_1 using QPSK modulation, SER at T_1 terminal can be written as follows:

$$
P^1_e = \frac{1}{\pi} \int_0^{\phi_0} E_h \left[\exp \left(\frac{g \sum_{i=1}^N A_i |h_{T_1,R_i}|^2 |h_{T_2,R_i}|^2}{N_0 \sin^2 \varphi} \right) \right] d\varphi
\tag{10}
$$

where $g=sin^2(\pi/M)$ and $\phi_0=(M-1)\pi/M$. Using the same steps as done in [15], and some further mathematical manipulation, we get the following:

$$
P^1_e = \frac{1}{\pi} \int_0^{\phi_0} \prod_{i=1}^N \left[\delta_{i1} E_{h_{T_1,R_i}} \left(1 + \frac{\alpha_{i1}}{|h_{T_1,R_i}|^2 + \lambda_{i1}} \right) \right] d\phi
\tag{11}
$$

where δ_{i1} and λ_{i1} and α_{i1} are defined, respectively, as:

$$
\delta_{i1} = \left(1 + \frac{g\gamma_{i2}}{N_0 \sin^2 \varphi} \right)^{-1}
\tag{12}
$$

$$
\lambda_{i1} = \mu_{i1}\delta_{i1}
\tag{13}
$$

$$
\alpha_{i1} = \mu_{i1}(1-\delta_{i1})
\tag{14}
$$

with

$$
\mu_{i1} = \frac{(\gamma_{i1} + \gamma_{i2} + N_0)N_0}{g_{R_i1}}
\tag{15}
$$

Equation (11) can be simplified by using [16] as:

$$P_e^1 = \frac{1}{\pi} \int_0^{\phi_0} \prod_{i=1}^{N} \left[\delta_{i1} + \delta_{i1} \alpha_{i1} \exp(\lambda_{i1}) \Gamma(0, \lambda_{i1}) \right] d\phi \qquad (16)$$

where $\Gamma(.,.)$ is incomplete Gamma function as given in [12]. Similarly SER at T_2 terminal using the same derivation steps can be written as after MRC and with some mathematical manipulation we can write as follows:

$$P_e^2 = \frac{1}{\pi} \int_0^{\phi_0} \prod_{i=1}^{N} \left[\delta_{i2} + \delta_{i2} \alpha_{i2} \exp(\lambda_{i2}) \Gamma(0, \lambda_{i2}) \right] d\phi \qquad (17)$$

where

$$\delta_{i2} = \left(1 + \frac{g \gamma_{i2}}{N_0 \sin^2 \phi} \right)^{-1} \qquad (18)$$

$$\lambda_{i2} = \mu_{i2} \delta_{i2} \qquad (19)$$

$$\alpha_{i2} = \mu_{i2} (1 - \delta_{i2}) \qquad (20)$$

with

$$\mu_{i2} = \frac{(\gamma_{i1} + \gamma_{i2} + N_0) N_0^{-1}}{\gamma_{R_i 2}} \qquad (21)$$

The SER for over all transmission can be calculated by adding the SER at Terminal T_1 and T_2 i.e. as:

$$P_e = P_e^1 + p_e^2 \qquad (22)$$

In Fig. 3 we plotted analytically derived SER in Equation (22) as well as the results obtained through Monte carlo simulation for different number of relays i.e. for N=1, 2 3, and 4 relays. Adding more relays we get more diversity gain and vice versa. In order to show the effect of increasing the symbol error rate performance as we increase from BPSK to 16PSK we have plotted the these results in Fig. 4 as shown we have also increased the SNR resolution from -30dB to 30dB in steps of 5dB in order to shows the effects in more details.

4.   OPTIMUM POWER ALLOCATION

In order to get full benefits of relay based cooperative communication system, optimization of power allocated to each cooperative node is promising technique. We formulate and solve the OP allocation problem for our system model with the goal to minimize the SER requirement. We minimize the sum of SER expressions in Equations (16-17) given by Equation (22) with respect to optimization control parameters K_T, K_T and K_{Ri} having the following constraint for all relays i.e.
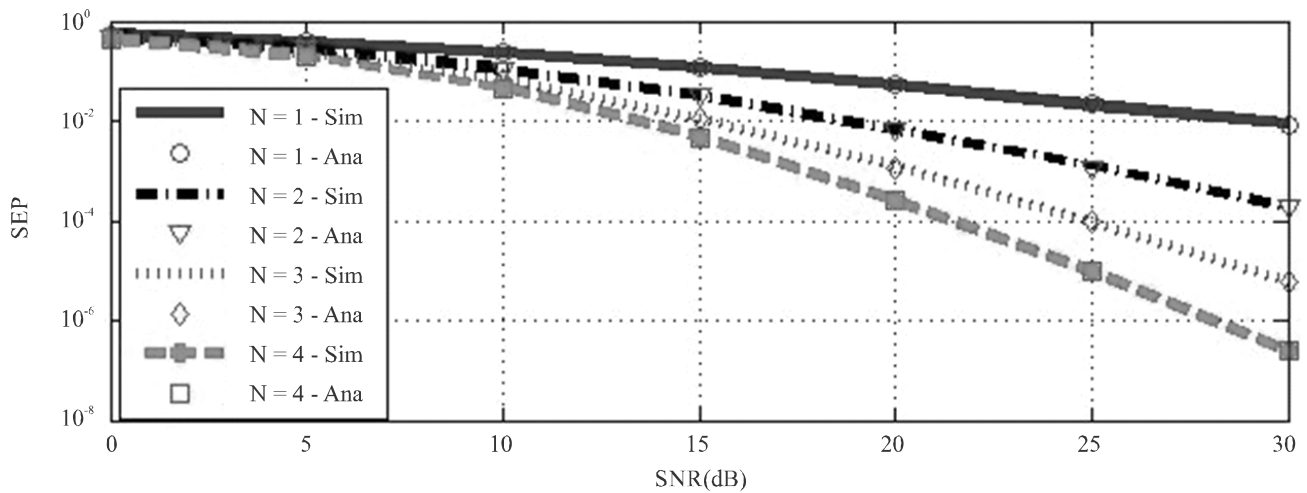

FIG. 3. COMPARISON OF SIMULATED AND DERIVED SER PERFORMANCE UPTO FOUR RELAYS FOR QPSK

$$\forall_i = 1,2,...,N, K_{T1} + K_{T2} + \sum_{i=1}^{N} K_{Ri} \leq 1$$

$$K_{T_1} + K_{T_2} + \sum_{i=1}^{\min^N} K_{R_i \leq 1} \left(\psi \left(K_{T_1}, K_{T_2}, K_{R_i} \right) \right) \tag{23}$$

In Equation (23) $\psi(K_{T}, K_{T2}, K_{Ri})$ is the objective function to be minimized and given by Equation (22). We have used MATLAB's optimization toolbox for numerical optimization using fmincon function.

In Table 1 we have tabulated different optimized values for different position of the relay using its path loss parameter G_{R1} and K_{T1} for T_1, K_{T2} for T_2, and K_{Ri}, where $i=1,2,...N$ using. It be concluded from the Table 1 when the relay is closer to T_1 we get positive values of G_{R1} while when it closer to T_2 we get its negative values.

■ *T_2 Closer to Relay (G_{R1}=-30dB)*: When T_2 is closer to relay we get Optimum value of K_{T1} is 0.5552 and optimum value for K_{T2} is zero. It can be concluded from the above values that we can use maximum power in broadcasting while the
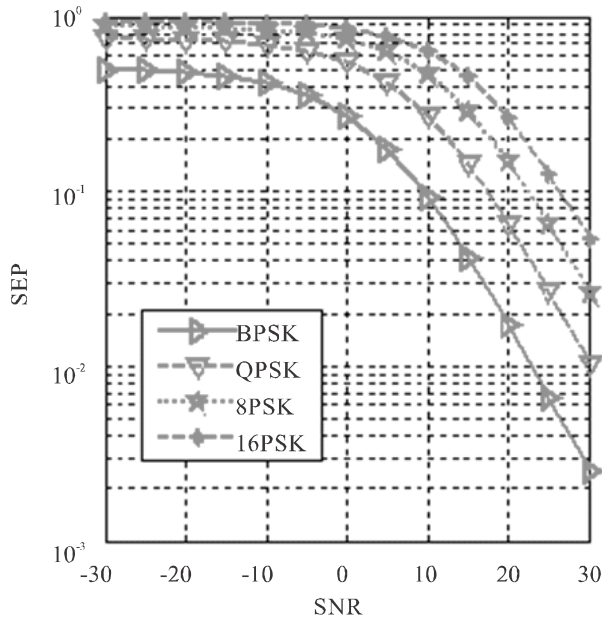
remaining power should be saved for relaying. In other words terminal T_1 and relay terminal get large fraction of the power while terminal T_2 gets smaller proportions.

■ *Relay is at Equal Distance from T_1 and T_2 (G_{R1}=0dB)*: Optimum value of K_{T1} and K_{T2} both start with 0.25 at lower SNR values but, decrease with increasing value of SNR. Most power is allocated to relay terminal while data terminals get small power.

■ *T_1 is Closer to Relay (G_{R1}=30dB)*: Terminal T_2 and relay terminal get large fraction of the power while terminal T_1 gets a smaller power.

FIG. 4. SER PERFORMANCE OF TWO-WAY FOR DIFFERENT MODULATION

TABLE 1. POWER OPTIMIZATION PARAMETERS AND THEIR OPTIMIZED VALUES FOR DIFFERENT RELAY LOCATIONS

SNR[dB]	K_{T_1}	K_{T_2}	K_{R_2}
$G_{R_1} = -30$dB			
0	0.5552	0.0127	0.4321
5	0.5146	0.0105	0.4749
10	0.4575	0.0096	0.5329
15	0.4034	0.0090	0.5876
20	0.3592	0.0085	0.6323
25	0.3249	0.0081	0.6670
$G_{R_1} = 0$dB			
0	0.2506	0.2506	0.4987
5	0.2328	0.2328	0.5343
10	0.2114	0.2114	0.5772
15	0.1908	0.1908	0.6185
20	0.1731	0.1731	0.6537
25	0.1588	0.1588	0.6824
$G_{R_1} = 30$dB			
0	0.0127	0.5552	0.4321
5	0.0105	0.5146	0.4749
10	0.0096	0.4575	0.5329
15	0.0090	0.4034	0.5876
20	0.0085	0.3592	0.6323
25	0.0081	0.3249	0.6670

5.   ONE-WAY VERSUS TWO-WAY COMMUNICATION

In one-way only one terminal acts as source (S), and sends information to destination (D), with the help of relays (R_i, $i=1,2,...,N$). The power is divided only between sources and relays i.e.

$$K_s + \sum_{i=1}^{N} K_{R_i} = 1$$

The SER at (D) for one-way communication has similar form:

$$P_e^D = \frac{1}{\pi} \int_0^{(M-1\pi)/M} \prod_{i=1}^{N} [\delta_{iD} + \delta_{iD}\alpha_{iD} \exp(\lambda_{iD})\Gamma(0,\lambda_{iD})] d\varphi \quad (24)$$

where

$$\delta_{iD} = \left(1 + \frac{gK_s G_{sRi} P}{N_0 \sin^2 \delta}\right)^{-1} \quad (25)$$

$$\lambda_{iD} = B_{iD} = \delta_{iD} \quad (26)$$

$$\alpha_{iD} = B_{iD}(1-\delta_{iD}) \quad (27)$$

with

$$B_{iD} = \frac{(K_s G_{sRi} P + N_0)N_0^{-1}}{K_R G_{RiD} P} \quad (28)$$

Fig. 5 presents gain achieved between sending data using One-Way technique or using Two-Way protocols with equal sharing of power i.e. with EP and using optimized allocation of power. In order to transfer mutual data between participating terminals one way technique uses 4 time slots while two way technique uses 2 time slots which proves that it can be used as time efficient data transfer technique in back bone or long haul communication networks. Because of different time shared protocols it is required to make a fair comparison between these two protocols, through considering 16-PSK for one way and QPSK for Two-Way. It can be observed that for a fixed *SNR=25dB*, Two-Way Protocol is always better than One-Way Protocol.

6.   SIMULATION RESULTS AND DISCUSSION

Monte Carlo technique is used to verify the optimized results as compared with equal shared power among the data terminals in different scenarios. SER performance of a multi-relay AaF based protocols using both EP and OP power allocations is shown in Fig. 6, for QPSK modulation. We assume that all the terminals lie in the two dimensional plane. In Fig. 6 SER_1 denotes the SER at terminal T_1. SER_2 denotes SER at terminal T_2 and SER_{12} denotes the total SER for over all transmission for single relay scenario. We observe that SER performance improvement of 3dB at target SER of 10^{-2} for $G_{Ri}=30dB$ is achieved.

In Fig. 7, we have shown improvement in terms of lower SNR required for targeted SER of 10^{-3} (shown by our derived SER expressions) achieved by OP allocation using for QPSK modulation scheme. We observe that about 1.2dB less SNR is required at $G_{Ri}=0dB$ and also about 4dB less SNR is required for $G_{Ri}=20dB$, using the optimization of derived SER expressions. It can be depicted that the optimization is more beneficial for positive values
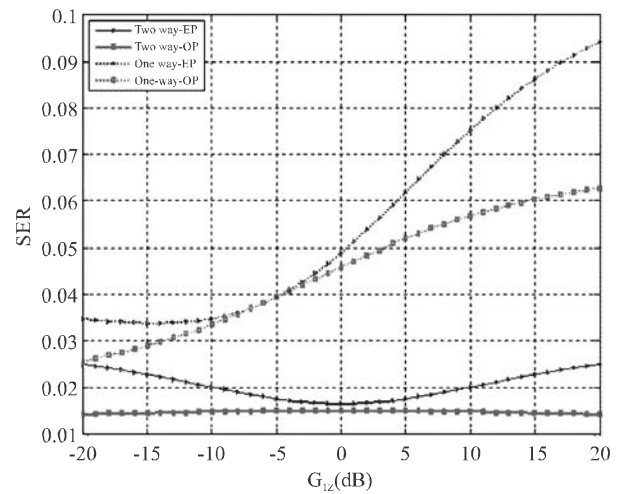

FIG. 5. SER PERFORMANCE OF TWO-WAY (QPSK) AND ONE-WAY (16-PSK) WITH EP AND OP FOR SNR=25dB

of G_{Ri} For example, almost 4dB lesser SNR is required for $G_{Ri}=30dB$. In Fig. 8, we have shown performance in power efficiency of our OP allocation framework for a fixed

$SNR=25dB$. We presented gain achieved for relay for different relay locations for constant amplitude modulation or in general for any PSK schemes.
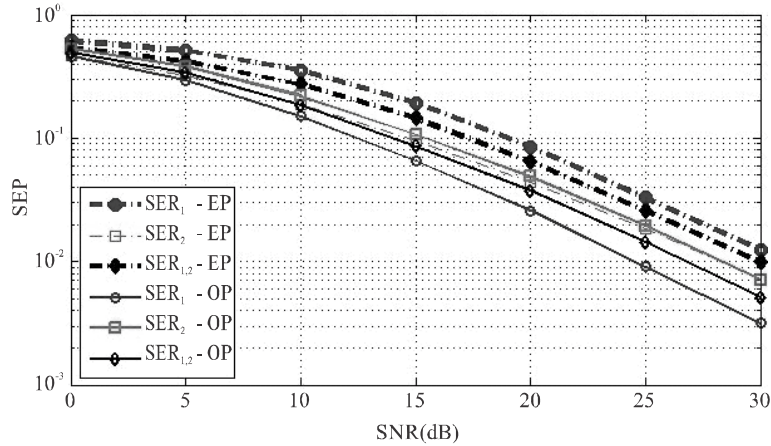

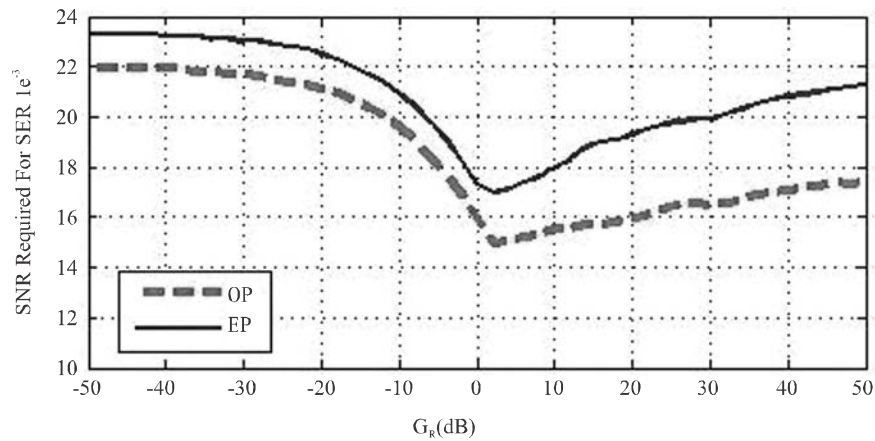FIG. 6. SER PERFORMANCE OF TWO-WAY (QPSK) WITH EP AND OP FOR $G_{Ri}=30dB$

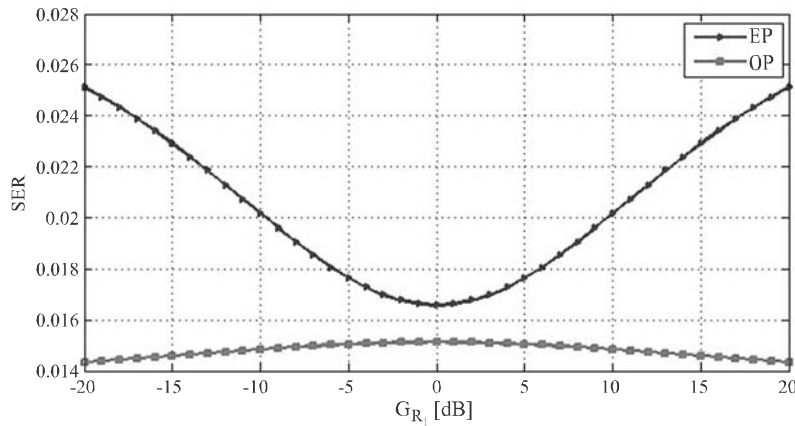FIG. 7. SNR REQUIRED FOR FIXED SER OF 10^{-3} AS COMPARED WITH RELAY LOCATION

FIG. 8. SER PERFORMANCE VERSES RELAY LOCATION FOR SNR=25dB

It is can be concluded that these results or the gains is being achieved in all scenarios irrespective of the relay position but gain is highly pronounced when relay is closer to any data terminals either T_1 or T_2.

7.   CONCLUSION

In this paper, we have derived SER expressions for APS scaling in terms of finite range integrals for Rayleigh fading channels. We have shown that our simulation results perfectly match with our analytical results achieving full diversity order. We proposed a framework for two way cooperative system model using amplify forward technique in this technique transmitter side only need to know the distance or location of the relay with respect to data terminals. Performance gains have been simulated and concluded versus different relay geometry, targeted SNR rates and for different path loss ratios. In comparison to EP, OP demonstrates significant performance gains depending on the relay position.

ACKNOWLEDGEMENTS

REFERENCES

[1]   Sendonaris, A., Erkip, E., and Aazhang, B., "User Cooperation Diversity Part-I: System Description", IEEE Transaction on Communications, Volume 51, No. 11, pp. 1927-1938, USA, November, 2003.

[2]   Sendonaris, A., Erkip, E., and Aazhang, B., "User Cooperation Diversity Part-II: Implementation Aspects and Performance Analysis", IEEE Transaction on Communications, Volume 51, No. 11, pp. 1939-1948, USA, November, 2003.

[3]   Laneman, J.N., and Wornell, G.W., "Distributed Space Time Coded Protocols for Exploiting Cooperative Diversity in Wireless Networks", IEEE Transactions on Information Theory, Volume 49, No. 10, pp. 2415-2425, USA, October, 2003.

[4]   Cui, T., Gao, F., Ho, T., and Arumugam, N., "Distributed Space-Time Coding for Two-Way Wireless Relay Networks", IEEE Transactions on Signal Processing, Volume 57, No. 2, pp. 658-671, USA, February, 2009.

[5]   Han, Y., Ting, S.H., Ho, C.K., and Chin, W.H., "Performance Bounds for Two-Way Amplify-and-Forward Relaying", IEEE Transactions on Wireless Communication, Volume 8, No. 1, pp. 432-439, USA, January, 2009.

[6]   Cui, T., Ho, T., and Kliewer, J., "Memoryless Relay Strategies for Two-Way Relay Channels", IEEE Transactions on Communications, Volume 57, No. 10, pp. 3132-3143, USA, October, 2009.

[7]   Shannon, C.E., "Two-Way Communication Channels", Proceedings of 4th Berkeley Symposium on Probability and Statistics, Volume 1, pp. 611-644, Berkeley CA, USA, 1961.

[8]   Rankov, B., and Wittneben, A., "Spectral Efficient Protocols for Half-Duplex Fading Relay Channels", IEEE Journal on Selected Areas in Communications, Volume 25, No. 2, pp. 379-3890, USA, February, 2007.

[9]   Rankov, B., and Wittneben, A., "Achievable Rate Regions for the Two-Way Relay Channel", IEEE International Symposium on Information Theory, USA, July, 2006.

[10]   Simon, M.K., and Slim, M., "Alouini, Digital Communication Over Fading Channels", John Wiley & Sons, [ISBN 0-471-31779-9], USA, 2000.

[11]   Chen, M., and Yener, A., "Multiuser Two-Way Relaying: Detection and Interference Management Strategies", IEEE Transactions on Wireless Communications, Volume 8, No. 8, pp. 4296-4305, USA, August, 2009.

[12]   Fareed, M.M., Rehman, S., and Uysal, M., "Performance Analysis of Multi-Relay Two-Way Cooperative Communication System over Rayleigh Fading Channels", IEEE PACRIM, Victoria, British Columbia, Canada, August, 2009.

[13]   Unger, T., and Klein, A., "Maximum Sum Rate for Non-Regenerative Two-Way Relaying in Systems of Different Complexities", Proceedings of 19th IEEE PIMRC, Cannes, France, September, 2008

[14]   Ho, C.K., Zhang, R., and Liang, Y.C., "Two-Way Relaying Over OFDM: Optimized Tone Permutation and Power Allocation", Proceedings of IEEE ICC, pp. 3908-3912, USA, May, 2008.

[15]   Fareed, M.M., and Uysal, M., "BER-Optimized Power Allocation for Fading Relay Channels", IEEE Transactions on Wireless Communication, Volume 7, No. 6, pp. 2350-2359, USA, June, 2008.

[16]   Gradshteyn, I.S., and Ryzhik, I.M., "Table of Integrals, Series and Products", Academic Press, 2nd Edition, USA, 1980.