Performance Analysis of Dual Hop Amplify And Forward Relaying Over Time Varying Fading Channel

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Abstract- *In this paper, full-duplex (FD) relay networks with one source, one destination and N FD amplify-and-forward (AF) relays is proposed. Each FD relay is equipped with two antennas, one for transmitting and other for receiving. End-to-end error performance is optimized using a joint antenna and relay selection scheme. In proposed system, each relay adaptively selects the transmit antenna and receive antenna based on the instantaneous channel conditions, and the optimal single relay with the optimal Tx/Rx antenna is selected to optimize the end-to-end performance of the system transmission which differ from the conventional FD relay selection, where the Tx and Rx FD antenna of each relay are fixed. Extra space diversity is also obtained due to the antenna selection at the relay nodes, which improves the system performance. In this paper outage probability and SER is derived and analytical results are verified by MATLAB simulations. Results show that the proposed scheme is better than the conventional full-duplex relay selection scheme with fixed relay Tx and Rx antennas.*

Keywords- Full-duplex, antenna mode selection, relay selection, amplify and-forward relaying.

I. INTRODUCTION

Full-duplex (FD) transmission has been shown to be a promising technology to improve the capacity of wireless transmissions by allowing simultaneously transmitting and receiving on the same channel [1]. Recently, FD has been applied to the relay networks [2]–[4]. COGNITIVE radio (CR) systems allow a secondary user to share the spectrum of the primary user. This arrangement is known as spectrum sharing [1]. Theoretically, spectrum sharing offers a way of improving spectrum utilization without affecting legacy systems [2].In addition, the use of a relay node between the source and destination offers the added benefit of reducing the overall path loss [3]. Basically, relay systems fall into one of two categories: half duplex relaying (HDR), where the relay receives and retransmits the signal on orthogonal channels [4]-[6], and full duplex relaying (FDR), where the reception and the retransmission at the relay occur at the same time on the same channel [4]-[6].

The introduction of HDR nodes into the system means that additional resources are required. This degrades the resource efficiency, especially temporal efficiency [5][6]. FDR represents a viable option for addressing this problem because it obviates the need for the additional resources required for HDR [5]. However, the use of FDR nodes introduces interference problems that are inherent to the full duplex approach [6]. Therefore, choosing the proper relay type based on the system environment is crucial to improving performance.

On one side, the FD relaying efficiently uses the channel bandwidth, but on the other side, it suffers from the self-loop interference caused by the signal leakage between the relay transmit (Tx) and receive (Rx) antennas [5], [6].Several self-loop interference cancellation schemes have been proposed by isolating the Tx/Rx antennas [7], using directional antennas [8] or employing the time-domain interference cancellation [9]. However, these methods still suffer from residual interference in practice due to the imperfect cancellation. In [10], the authors model the residual interference as a Rayleigh distributed variable, and the outage performance of dual-hop FD relaying was analyzed. [11] further extended the work to a multihop FD relay system by taking into account the path loss factor. It is shown that the FD relaying with effective self-loop interference cancellation outperforms the HD relaying. The symbol error rate (SER) performance of the FD decode-and-forward (DF) relay networks was analyzed in [12], and the capacity of the FD amplify-and-forward(AF) relaying was derived for multiple-input multiple-output (MIMO) relay systems in [13].For the system with multiple FD relays, relay selection is an efficient and simple approach to achieve the spatial diversity. In [14], several relay selection scheme were proposed to optimize/sub-optimize the end-to-end signal to interference and noise ratio (SINR) in the cooperative FD relay networks after taking into account the residual self-loop interference.

The authors analyze the outage probability for the proposed relay selection schemes. Results showed that the residual self-loop interference is the main drawback of the FD relay system. To reduce the effect of the self-loop interference, some novel relaying schemes were proposed. A hybrid relaying strategy was proposed in [15] by adaptively switching between FD and HD relaying according to the instantaneous channel conditions. In [16], [17], several antenna selection schemes have been investigate to maximize the end-to-end performance of the multiple antenna relay systems. Results showed that these relaying schemes can effectively improve the performance compared to the conventional FD relay system. In [18],the authors analyzed the multiple two-way FD relay system with AF protocol, and proposed the optimal relay selection scheme to maximize the effective signal-to-interference and noise ratio. However, all the existing works in FD relaying assume that the roles of the Tx/Rx antennas are unchanged in the relaying process. When the channel link from the source to the relay receive antenna and/or from the relay transmit antenna to the destination falls into a deep fading, the system performance will be seriously degraded. In this thesis, we consider a FD relay network which consists of one source node, one destination node and multiple FD AF relay nodes. Each FD relay is equipped with two antennas and two RF chains (one for transmitting the signal and the other for receiving). We study the joint relay and Tx/Rx antenna mode selection scheme (RAMS), where the optimal relay with its optimal Tx and Rx antenna configuration is selected jointly based on the instantaneous channel conditions. Only the optimal relay is active to forward the information from the source to the destination. Different from the conventional FD relay node, where the Tx and Rx antennas of each relay are fixed, in the proposed scheme, each antenna of the FD relay is able to transmit/receive the signal. Therefore, the relay node needs to include a flexible connection switches between the antennas and the RF chains, which can flexibly connect or disconnect the switches between the two antennas and two RF chains [19], [20]. The FD relay adaptively configures the Tx/Rx mode of the two antennas, and selects the optimal Tx/Rx antenna configuration for receiving and forwarding. The best FD relay with the optimal Tx/Rx antenna configuration is finally selected to optimize the end-to-end performance of the system transmission. The proposed scheme provides an additional dimension of selection process by adaptively configuring the Tx/Rx antenna mode, which brings an extra degree of freedom compared to the conventional FD relay selection with fixed Tx/Rx antenna configuration, thus significantly improving the system performance.

In this paper, we derived outage probability for the FD relay systems. The derived CDF expressions are fundamentally different from existing work in [5], [17]. Multi-hop communication via relay nodes is an attractive solution for hotspot capacity enhancement, network coverage extension and gap filling in next generation cellular systems. In mobile relays, simultaneous transmission and reception on the same frequency, or full-duplex (FD) transmission, is not feasible because all practical implementations suffer from a significant level of loop interference, i.e., signal leakage between transmission and reception at the relay.

The main contributions of this paper are summarized as follows:

1) A joint relay and Tx/Rx antenna mode selection scheme is studied for the multiple FD relay networks and Comparing it to the conventional relay selection scheme
2) Considering the variance of the loop interference, the CDF of the end-to-end SINR for the proposed RAMS scheme is studied.
3) Based on the CDF expression, the closed-form expressions of the outage probability is derived and verified it by the Monte-Carlo simulations.

II. SYSTEM MODEL

We consider a multiple relay system, which consists of one source node (S), one destination node (D), and N AF relay nodes, as shown in Fig.3.1.

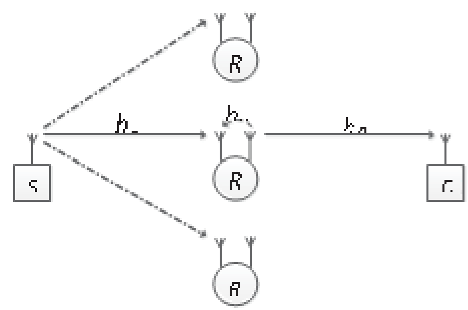

Fig. 1. System model of the multiple AF relay system

We assume that there is no direct channel link between the source and the destination due to shadowing conditions or the transmit power limitation, and thus the information needs to be forwarded through the relay nodes in the networks. Both source and relay nodes use the same time-frequency resource blocks and the relay nodes work in the full-duplex mode with two antennas (one receive antenna and one transmit antenna). In the proposed antenna selection and optimal relay selection (ASORS) scheme, the optimal relay with the optimal configuration of FD Tx and Rx antennas is selected to forward the signals from the source to the destination. Note that for each relay, the transmit/receive mode configuration of the two antennas is adaptively determined based on the instantaneous SNR of the channels between the source/destination node and the two antennas of the FD relay node. Assuming that the ith relay node Ri is selected to forward the signal, the received signal at Ri is given as

$$y_i[n] = h_{S,i}x[n] + h_{LI,i}x_i[n] + n_i[n] \quad (1)$$

where $h_{S,i}$ is the channel link between the source and the relay Ri, and $h_{LI,i}$ is the loop interference channel between the transmit antenna and the receive antenna of the relay Ri. x[n] and xi[n] are the nth transmit signal of the source and the Ri relay node with a transmit power Pt in a transmit slot. ni is the additive white Gaussian noise with the power σ2. Upon receiving the signal from the source, the relay uses AF protocol to forward the following signal. The retransmit signal at the FD relay node can be expressed as

$$x_i[n] = \beta y_i[n - \tau] \quad (2)$$

where β is the power amplification factor and τ is the processing delay. Under the transmit power constraint, the amplification factor β ensures that the average power of signal $x_i[n]$ satisfies the following power constraint

$$E[|xi[n]|^2] = \beta^2(|h_{S,i}|^2P_t + |h_{LI,i}|^2P_t + \sigma^2) \leq P_t \quad (3)$$

Therefore, the factor β can be obtained as

$$\beta = \sqrt[2]{\frac{P_t}{|h_{S,i}|^2P_t + |h_{LI,i}|^2P_t + \sigma^2}} \quad (4)$$

The received signal at the destination is given by

$$y_D[n] = h_{i,D}x_i[n] + n_D[n] \quad (5)$$

where $h_{i,D}$ is the channel link from relay R_i to destination, and n_D is the Gaussian noise with power σ^2.The end-to-end SINR can be obtained as

$$\gamma = (|h_{S,i}|^2 |h_{i,D}|^2 \beta^2)/ (|h_{LI,i}|^2 |h_{i,D}|^2 \beta^2 + |h_{i,D}|^2 \beta^2 \sigma^2 + \sigma^2) \quad (6)$$

Substituting the amplification factor β into (6), the end-toend SINR is given by

$$\gamma = \gamma_{Sri}\gamma_{RiD} /(\gamma_{SRi} + (\gamma_{RiD} + 1)(\gamma_{Ri} + 1)) \quad (7)$$

where $\gamma_{SRi} = P_t|h_{S,i}|^2/\sigma^2$, $\gamma_{RiD} = P_t|h_{i,D}|^2/\sigma^2$, and $\gamma_{Ri} = P_t|h_{LI,i}|^2/\sigma^2$.

In this thesis, we consider all the channel links are block Rayleigh fading channels. The channel links remain stationary during a transmit slot, and change independently from one slot to another. Therefore, the instantaneous channel SNR γ_{SRi}, γ_{RiD} and $\gamma_{R,i}$ can be modeled as the exponential random variable with the expectation λ_{SRi}, λ_{RiD} and $\lambda_{R,i}$ respectively. In this paper, we assume that the network links are independent identically distributed (i.i.d.). The channel links between the relay and source/destination nodes equip the same distribution,

$$f_{SRi}(x) = f_{RiD}(x) = (1/\lambda)e^{-x/\lambda} \quad (8)$$

The loop interference channels of N relay nodes also follow the similar distribution,

$$f_{R,i}(x) = (1/\lambda_R)\, e^{-x/\lambda_R} \quad (9)$$

One antenna is used to receive the signal from the source node, and the other is to forward the signal at the same time. In the earlier work [12], the transmit/receive modes of these two antennas are fixed, even when the channel link from the source to the relay receive antenna or from the relay transmit antenna to the destination is in the deep fading. However, there are two available channel links between the relay and source/destination nodes. To improve the system performance, in this thesis, we propose to adaptively select the transmit antenna and receive antenna for each relay. The antenna selection procedure for the FD relay is expressed as

$$m_{i,AS} = \arg\max\{\gamma_i, T_1\to T_2, \gamma_i, T_2\to T_1\} \quad (10)$$

where T_1 and T_2 denote the two antennas of the ith relay node, and $\gamma_i,T_1\to T_2$ denotes the end-to-end SINR when the ith relay node chooses the antenna T_1 as the receive antenna and T_2 as the transmit antenna in the next transmission $\gamma_i,T_2\to T_1$ is the end-to-end SINR when the antenna T_2 is used to receive the signal from the source node, and T1 is used to retransmit the signal to the destination. In this scheme, the optimal relay with the optimal Tx/Rx antenna configuration is selected to optimize the end to-end error performance. Therefore, AS-ORS scheme can be formulated as

$$k_{AS-ORS} = \arg \underbrace{max}_{i} \{ \gamma_i\} \quad (11)$$

where $\gamma_i = \max\{\gamma_i,T_1\to T_2, \gamma_i,T_2\to T_1\}$

The asymptotic CDF expression of the end-to end SINR via the *i*th relay node for the i.i.d. case, γi, can be calculated as

$$F_i(x) = 1- \frac{2}{1+\eta x} I(x) + \frac{2}{1+2\eta x} I(x)^2 \quad (12)$$

$$\text{where } I(x) = \exp\left(-\frac{2}{\lambda}x\right)\frac{2\sqrt[2]{x^2+x}}{\lambda}\, k_1\left(\frac{2\sqrt[2]{x^2+x}}{\lambda}\right) \quad (13)$$

and *K*1(.) is the first order modified Bessel function of the second kind [14]

According to the description of the antenna selection criterion in (10), there are two possible antenna configurations. According to the permutation theorem, the CDF of the received SINR is

$$F_i(x) = P_r(\gamma_i,T_1\rightarrow T_2 < x,\gamma_i,T_2\rightarrow T_1 < x)$$
$$= 1-P_r(\gamma_i,T_1\rightarrow T_2 > x)-P_r(\gamma_i,T_2\rightarrow T_1 > x)$$
$$+ P_r(\gamma_i,T_1\rightarrow T_2 > x,\gamma_i,T_2\rightarrow T_1 > x) \qquad (14)$$

After some mathematical manipulations, the end-to-end SINR in (7) can be written as

$$\gamma_i,T_1\rightarrow T_2 = \frac{\frac{\gamma_{SR_{i,1}}}{\gamma_{R_i}+1}\gamma_{R_iD,2}}{\frac{\gamma_{SR_{i,1}}}{\gamma_{R_i}+1}+\gamma_{R_iD,2}+1} = \frac{X_{i,1}\gamma_{R_iD,2}}{X_{i,1}+\gamma_{R_iD,2}+1} \qquad (15)$$

where $\gamma_{SRi,1}$ denotes the instantaneous SNR between the source node and the antenna T_1 of the ith relay node, $\gamma_{RiD,2}$ denotes the instantaneous SNR between the antenna T_2 of the ith relay node and the destination node, and $X_{i,1} = \gamma_{SRi,1}/\gamma_{Ri}+1$.This is similar as the SNR expression of the half-duplex relay networks [13].

The distribution of $X_{i,1}$, as mentioned in [12] is given by

$$F_{X,1} = 1 - \frac{2}{1-\eta_{i,1}x}\, e^{-\frac{1}{\lambda_{SRi,1}}x} \qquad (16)$$

where $\eta_{i,1} = \lambda_{Ri}/\lambda_{SRi,1}$.

For i.i.d. case, $\lambda_{SRi,1} = \lambda_{RiD,1} = \lambda_{Ri}/\eta_{i,1} = \lambda$, $\eta_{i,1} = \eta_{i,2} = \eta$, and the channel links between the source/destination node and the relay antennas are independent. The CDF of the end-to-end SINR via the ith relay node with the relaying mode $T_1 \rightarrow T_2$ is expressed as

$$P_r(\gamma_i,T_1\rightarrow T_2 > x) = P_r\{(\frac{\gamma_{SRi,1}}{\gamma_{Ri}+1} - x)(\gamma_{RiD,2} - x) > x2+x\}$$

$$= \frac{1}{\gamma_{RiD,2}}\int_x^{\infty} \frac{e^{-\frac{1}{\lambda_{SRi,1}}\left(x+\frac{x^2+x}{\gamma_{RiD,2}-x}\right)-\frac{1}{\lambda_{RiD,2}}\gamma_{RiD,2}}}{1+\eta_{i,1}(x+\frac{x^2+x}{\gamma_{RiD,2}-x})}\, d\gamma_{RiD,2}$$

$$= \frac{1}{\lambda}\int_x^{\infty} \frac{1}{1+\eta(x+\frac{x^2+x}{\gamma_{RiD,2}-x})}\, e^{-\frac{1}{\lambda}(x+\frac{x^2+x}{\gamma_{RiD,2}-x}+\gamma_{RiD,2})}\, d\gamma_{RiD,2} \qquad (17)$$

To the best of the author's knowledge, the integral of the exact CDF distribution does not have a closed-form solution. The value of the integral is primarily decided by the exponent item, especially in the high SNR region. We ignore the variance of the fraction $\frac{1}{1+\eta(x+\frac{x^2+x}{\gamma_{RiD,2}-x})}$ and simplify to a constant factor $1/(1 + \eta x)$.Using this simplification and with the help of formula [15], the integral (17) is written as

$$P_r(\gamma_i,T_1\rightarrow T_2 > x) \approx \frac{1}{1+\eta x}\frac{2\sqrt[2]{x^2+x}}{\lambda} k_1\left(\frac{2\sqrt[2]{x^2+x}}{\lambda}\right) e^{-\frac{2}{\lambda}x} \qquad (18)$$

For the symmetry of the received SINR, $P_r(\gamma_i,T_2\rightarrow T_1 > x)$ can be calculated by the similar expression.

$$P_r(\gamma_i,T_1\rightarrow T_2 > x, \gamma_i,T_2\rightarrow T_1 > x) =$$
$$\int_0^{\infty}\int_x^{\infty}\int_x^{\infty} \frac{1}{\lambda_{RiD,1}\lambda_{RiD,2}\lambda_{Ri}} e^{-\frac{\gamma_{Ri}+1}{\lambda_{SRi,1}}\left(x+\frac{x^2+x}{\gamma_{RiD,2}-x}\right)-\frac{1}{\lambda_{RiD,2}}\gamma_{RiD,2}}$$
$$\times e^{-\frac{\gamma_{Ri}+1}{\lambda_{SRi,2}}\left(x+\frac{x^2+x}{\gamma_{RiD,1}-x}\right)-\frac{\gamma_{RiD,1}}{\lambda_{RiD,1}}} e^{-\frac{\gamma_{Ri}}{\lambda_{Ri}}}\, d\gamma_{RiD,1}\, d\gamma_{RiD,2}\, d\gamma_{Ri}$$
$$= \int_0^{\infty}\int_0^{\infty} \frac{1}{1+\eta_{i,1}\left(x+\frac{x^2+x}{\gamma_{RiD,2}-x}\right)+\eta_{i,2}\left(x+\frac{x^2+x}{\gamma_{RiD,1}-x}\right)}$$
$$\times \frac{1}{\lambda_{RiD,1}\lambda_{RiD,2}} e^{-\frac{1}{\lambda_{SRi,1}}\left(x+\frac{x^2+x}{\gamma_{RiD,2}-x}\right)-\frac{1}{\lambda_{RiD,2}}\gamma_{RiD,2}}$$
$$\times e^{-\frac{1}{\lambda_{SRi,2}}\left(x+\frac{x^2+x}{\gamma_{RiD,1}-x}\right)-\frac{\gamma_{RiD,1}}{\lambda_{RiD,1}}} e^{-\frac{\gamma_{Ri}}{\lambda_{Ri}}}\, d\gamma_{RiD,1}\, d\gamma_{RiD,2} \qquad (19)$$

Similar to the approximation in (18), we simplify the fraction item to a constant value $1/(1 + \eta_{i,1}x + \eta_{i,2}\, x)$. The integral can be separated into two independent integrals. After some mathematical transformations, (19) is given by

$$P_r(\gamma_i,T_1\rightarrow T_2 > x, \gamma_i,T_2\rightarrow T_1 > x) = \frac{4x^2+4x}{(1+2\eta x)\lambda^2} K_1^2\left(\frac{2\sqrt[2]{x^2+x}}{\lambda}\right) e^{-\frac{4}{\lambda}x} \qquad (20)$$

Substituting (18) and 20) into (14), we can obtain the CDF expression.

When the transmit power is sufficiently large, $I(x) \rightarrow 1$. The distribution of the received SINR for the ith relay is

$$F_{i,\infty}(x) = 1- \frac{2}{1+\eta x}+ \frac{1}{1+2\eta x} \qquad (21)$$

As the optimal relay of the multiple relay networks which can provide the largest end-to-end SINR is selected to forward the signal. Therefore, the outage probability of AS-ORS scheme of the N relay networks is

$$P_{out}(x) = \left(1 - \frac{2}{1+\eta x}I(x) + \frac{2}{1+2\eta x}I^2(x)\right)^N \qquad (22)$$

In high SNR region, the outage probability can be written as

$$P_{\infty}(x) = \left[1 - \frac{2}{1+\eta x} + \frac{1}{1+2\eta x}\right]^N \qquad (23)$$

This is the asymptotic outage probability. From this asymptotic value, the outage probability is determined only by the loop interference level η, and thus the diversity order is zero when SNR approaches to infinity. Moreover, in the high SNR region, the function I(x) approaches to exp(−2x/λ) [13]. When the loop interference is very small, the outage probability can be written as

$$P_{out}(x) = \left[(1 - e^{-\frac{2}{\lambda}x})^2 + 2\eta x(e^{-\frac{2}{\lambda}x} - e^{-\frac{4}{\lambda}x})\right]^N \qquad (24)$$

When $\eta \to 0$, $(1 - e^{-\frac{2}{\lambda}x})^2 \gg 2\eta x(e^{-\frac{2}{\lambda}x} - e^{-\frac{4}{\lambda}x})$ in medial SNR region, and thus $P_{out}(x) \to (\frac{2x}{\lambda})^{2N}$. Therefore, in the small loop interference condition, AS-ORS scheme can achieve a diversity order of 2N before reaching the performance floor.

In the wireless communication system with linear modulations, the average SER of the proposed scheme can be calculated as follows [77]

$$\overline{SER} = \alpha e\left[Q\sqrt{\beta\gamma}\right] = \frac{\alpha}{\sqrt{2\pi}}\int_0^{\infty} F\left(\frac{t^2}{\beta}\right) e^{t^2/2} dt \qquad (3.25)$$

where F(·) is the CDF function of the end-to-end SINR given in Eq. (3.12), and Q(·) is the Gaussian Q-Function [78]. The parameters (α, β) are decided by the modulation formats, e.g., α = 1, β = 1 for the orthogonal binary frequency-shift keying (BFSK) modulation [77], and α = 1, β = 2 for the binary phase-shift keying (BPSK) modulation [77]. To compute the average SER, we define a set S = {1, 2, · · · , N} representing the N relay nodes in the system, and the sets A and B are the subset of S. Moreover, let the sets A_1, A_2 and A3 be the subsets of A, and the sets B_1, B_2, B_3 and B_4 be the subsets of B. The average SER of the proposed RAMS scheme can be expressed as follows,

$$\overline{SER} = \sum_{\substack{A\cup B\subseteq S\\ A\cap B=\emptyset}} \sum_{\substack{A1\cup A2=A\\ A1\cap A2=\emptyset}} \sum_{A3\subseteq A} \sum_{\substack{B1\cup B2=B\\ B1\cap B2=\emptyset}} \sum_{\substack{B3\cup B4\subseteq B\\ B3\cap B4=\emptyset}} \frac{\prod_{i_2\in A2}\eta_{i_2}^2 \prod_{j_2\in B2}\eta_{j_2}^2}{\prod_{i_3\in A3}\sqrt{\lambda_{S,i_3}\lambda_{i_3,D}}\prod_{j_3\in B3}\sqrt{\lambda_{S,j_3}\lambda_{j_3,D}}\prod_{j_4\in B4}\sqrt{\lambda_{S,j_4}\lambda_{j_4,D}}} \times \frac{\alpha\sqrt{\beta}(-1)^{N(A)}2^{a-1}(2b-1)!!}{(P_S P_R)^d(\beta+2c)^{b+1/2}} \qquad (3.26)$$

where

a = N(A₁) + N(A₃) + N(B₂) + 2N(B₃)+ 2N(B₄) ,

b = 2N(A₂) + N(A₃) + 2N(B₂) + N(B₃)+ 2N(B₄),

$$c = \sum_{i1\in A1}\eta_{i_1}^2 + \frac{5}{3}\sum_{i2\in A2}\eta_{i_2}^2 + 2\sum_{j1\in B1}\eta_{j_1}^2 + \frac{10}{3}\sum_{j2\in B2}\eta_{j_2}^2 + \sum_{i\in A}\left(\sqrt{\frac{1}{P_S\lambda_{S,i}}} + \sqrt{\frac{1}{P_R\lambda_{R,i}}}\right)^2 + 2\sum_{j\in B}\left(\sqrt{\frac{1}{P_S\lambda_{S,j}}} + \sqrt{\frac{1}{P_R\lambda_{R,j}}}\right)^2,$$

$$d = \frac{1}{2}N(A_3) + \frac{1}{2}N(B_3) + N(B_4)$$

The function N (·) denotes the size of one set, and ∅ denotes the empty set. If the set A_i or B_j is empty, the value of the product operation ∏ is one. Since the average SER is calculated by the integral of the CDF expression (3.12), the approximate SER expression (3.26) approach the exact SER performance in the high link SNR region. When the link SNRs increase, $P_S\lambda_{S,i} \to \infty$ and $P_R\lambda_{i,D} \to \infty$, the parameter c approaches a constant value, and the items of the nonempty set A_3, B_3 and B_4 in Eq. (3.26) approach zero. Therefore, the error floor of the average SER can be simplified as

$$\overline{SER} = \sum_{\substack{A\cup B\subseteq S\\ A\cap B=\emptyset}} \sum_{\substack{A1\cup A2=A\\ A1\cap A2=\emptyset}} \sum_{\substack{B1\cup B2=B\\ B1\cap B2=\emptyset}} \alpha\sqrt{\beta}(-1)^{N(A)}2^{a-1} \times \prod_{i2\in A2}\eta_{i_2}^2 \prod_{j2\in B2}\eta_{j_2}^2 \frac{(2b-1)!!}{(\beta+2c)^{b+1/2}} \qquad (3.27)$$

where

a = N(A₁) + N(B₂),

b = 2N(A₂) + 2N(B₂) ,

$$c = \sum_{i1\in A1}\eta_{i_1}^2 + \frac{5}{3}\sum_{i2\in A2}\eta_{i_2}^2 + 2\sum_{j1\in B1}\eta_{j_1}^2 + \frac{10}{3}\sum_{j2\in B2}\eta_{j_2}^2,$$

Eq. (3.27) is independent from the link SNR, and indicates that there is an error floor in the high SNR region representing the minimal value of the achievable average SER for our proposed RAMS scheme. The error floor is only determined by the loop interference of the relays in the FD relay system.

III. RESULT ANALYSIS

The outage probability analysis is carried out on the system model while varying various parameters. Through these means, the performance of the FD relay system with ARS scheme in analyzed. The parameters and the values that each parameter holds, in different scenarios, in Outage Probability analysis is listed below.

Transmit Power	0 – 30 dB
Self-Interference (η)	0 -1 dB
No. of Relay (M)	1-3
Transmission Rate (Rt)	1-10 bps

The outage probability for various values of transmit power is obtained by retaining the number of relays as 1 and varying the SI factor η in Fig 2

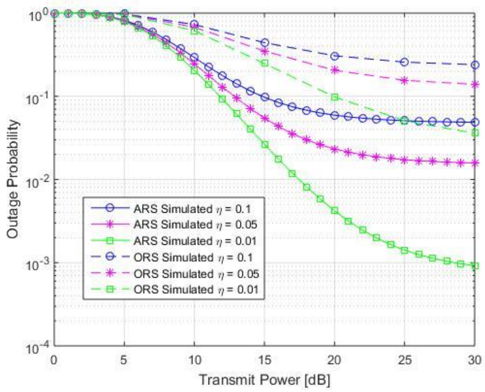

Fig 2. Transmit Power - Outage probability comparison of ARS Scheme and ORS Scheme for M = 1 relays

It shows the effect of different loop interference values a channel possesses on an M = 1 relay system and its comparison with the conventional ORS system. The transmission rate is set at 3 bps/Hz. The outage probability curve matches the result obtained in expression . It can be noted at the probability for attenuation of signals to occur is lowest for η = 0.01 and increases for η =0.1 with an increase in the transmission power in case of ARS system. The performance of M = 0.1 ORS system matches that of M = 0.01 ARS system. Hence, self-interference between the relay nodes must be maintained to a minimum in order to achieve greater throughput and lesser outage probability in an ARS system.

The outage probability for various values of transmit power is obtained by retaining the SI factor η at a constant value of 0.05 and carrying out the analyses for M = 1, 2 and 3 relays in Fig 3. The ARS curves obtained are plotted alongside ORS curves to show the optimized performance of the ARS proposed system.

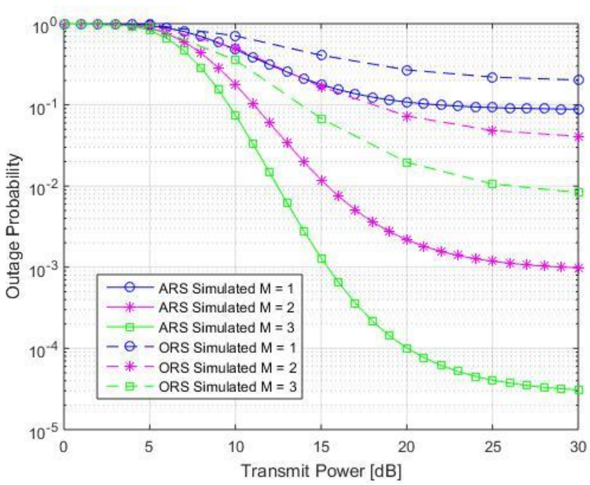

Fig 3. Transmit Power - Outage Probability comparison for ARS Scheme and ORS Scheme for 3η = 0.05

The performance of the proposed system is compared with conventional optimal relay select ORS system. The proposed ARS method achieves the same performance as two relay nodes operating by the ORS method. Thus, the ARS method outperforms the conventional ORS method for full-duplex relay systems

The SER for various values of transmit power is obtained by retaining the SI factor constant, η = 0.05 and carrying out SER analysis for M =1,2 and 3 relays.

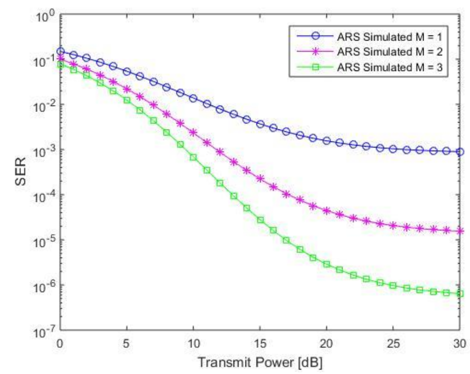

Fig. 4.5 Transmit Power – SER analysis of ARS Scheme for η = 0.05

The graph shows that a single relay system has the highest SER value in comparison to multiple relay systems. The primary reason for this is because additional relay add directional diversity and allow for a better symbol throughput. Multiple relay systems only provide desirable results when the interference value is relatively moderate. For higher values of interference, the system does not perform as required and a large number of packers are lost due to interference and deep fading. This is the shortcoming of the project and an alternative method for reducing SER for high interference must be devised

IV. CONCLUSION

In this paper, a joint relay and antenna selection scheme was proposed and implemented. This scheme consisted of M relays in multiple FD relay networks and a source and destination node. An antenna selection procedure was explained in detail where, the optimal relay with the best transmitter- receiver configuration was chosen to carry out communication between the source and the destination node. Closed form expressions for CDF, Antenna Selection Method, and Outage Probability and SER is derived and the evaluation of their results was achieved. Simulations were obtained for

Outage Probability has been shown in the demonstration. An analysis of the results has been carried out in the same section through a comparison of the proposed system with a conventional system. we have achieved additional space diversity at the destination node which has resulted in better performance in comparison to the ORS system. This additional space diversity was achieved in the ARS method because of a tradeoff with SI. Outage Probability reach high values as the value of SNR increases and analysis of the system could not be achieved at these values. This arises due to self-interference at the relay node. The performance of the system can be better improved by implementing better self-interference cancellation methods at the relay node in future work.

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