MATLAB Simulation for Fixed Gain Amplify and Forward MIMO Relaying System using OSTBC under Flat Fading Rayleigh Channel

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Abstract— **Performance Analysis of Fixed Gain Amplify and Forward Based Cooperative Diversity in multiple-input multiple-output (MIMO) relay channels is discussed in this paper. The paper simulates the bit error rate (BER) and channel capacity performance of fixed gain amplify-and-forward (AF) N×L×M MIMO relaying system using optimal power allocation under flat fading Rayleigh channel. The system consists of source (S), relay (R) and destination (D). Where N, L and M are the number of source, relay and destination antennas, respectively. Each node equipped with equal number of antennas such that N=L=M. The simulations cover the cases when N equal 2, 4 and 8. The channel status information (CSI) is perfectly known at both the relay and destination but not known at the source. Diversity was achieved through using orthogonal space-time block coding technique (OSTBC) at the source. OSTBC is used to encode the BPSK modulated signal before being transmitted through flat fading Rayleigh channel. At the destination, the received signals from both the relay and the source in two phases (time slots) were combined by Maximal Ratio Combiner (MRC) and detected by Maximum-Likelihood (ML) detector. MATLAB is used to simulate the BER and capacity performance of AF N×L×M MIMO relaying system. Also make a comparison between the BER and capacity performance of conventional N×M MIMO system and AF N×L×M MIMO relaying system under the same conditions. The fixed gain AF N×L×M MIMO relaying system simulations achieved low BER without need a high E_b/N_o values compared with conventional N×M MIMO system.**

Index Terms—MIMO relaying channels, orthogonal space-time block coding, amplify-and-forward, Fixed Gain.

I. Introduction

Cooperative communications is a new communication paradigm which generates independent paths between the user and the base station by introducing a relay channel. Hence, cooperative communications is a new paradigm shift for the 4th generation wireless system that will guarantee high data rates to all users in the network, and it is anticipated that will be the key technology aspect in 5th generation wireless networks. In terms of research, cooperative communications can be seen as related to research in relay channel and MIMO systems [1][2].

The authors propose amplify-and-forward cooperative spatial multiplexing scheme in which the transmitter (source),

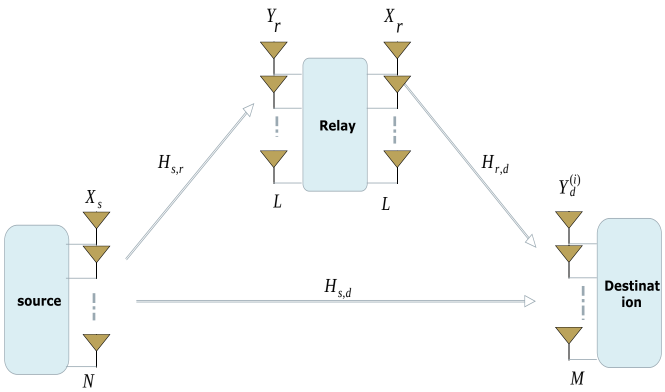

Figure 1. The Model of a cooperative system with muliple antennas at the source, relay and destination.

equipped with single antenna, forms virtual antenna array from collection of distributed single-antenna wireless terminals, and broadcast identical signal to those terminals (relays). Each relay amplifies-and-forwards different portion of the received signal at a reduced data rate to the receiver (destination). The combination of transmitter relays and receiver forms a virtual MIMO system in single antenna wireless terminals environment [3].

The application of MRC on the source-relay (S-R) link and space time coding (STC) on the relay-destination (R-D) link for a MIMO relay channel individually as well as jointly in the MRC-STC scheme. The system model as follows: the source (S), relay (R) and the destination (D) may now support multiple antennas. There are N relays in the system. The source has M_S transmit antennas, the r-th relay has M_r antennas that are used for reception on the S-R link and transmission on the R-D link, and the destination has M_d receive antennas. All transmissions are on orthogonal channels use binary phase shift keying (BPSK) [4]. The basic idea of cooperative diversity is that several nodes, each with single antenna, form a kind of coalition to cooperatively act as a large transmit or receive array. When terminals cooperate as a transmit array,

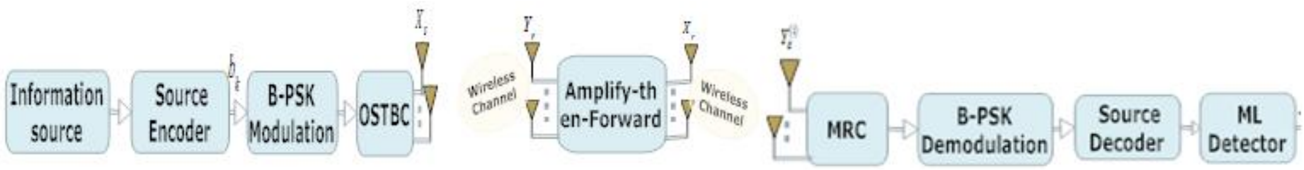

Figure 2. The system detailed block diagram

they first exchange messages and then cooperatively transmit those messages as a multi antenna broadcast transmitter; similarly for receive cooperation. The channel therefore shares characteristics with the MIMO channel, such as diversity. Cooperative diversity for wireless networks was first investigated by Sedonaris et al. for cellular networks and by Laneman et al. for ad-hoc networks [5]. The MIMO scheme is based on Alamouti space-time block coding (STBC) over flat fading Rayleigh channel. The source node, equipped with two transmit antennas, simply broadcasts each STBC code to the relay and the destination nodes. Then, the relay node, equipped with multiple antennas, amplifies-and-forwards (AF) the received STBC codes. Finally, the destination node uses maximum ratio combining (MRC) and exploits the diversity gain obtained through the direct and the indirect links simultaneously. Lower bounds of the symbol error probability (SEP) and the outage probability are derived by using the moment generating function (MGF) of the total signal-to-noise ratio (SNR) for a particular signal of M-ary-quadrature-amplitude modulation (M-QAM) [6]. The diversity performance of scalar fixed gain amplify-and-forward (AF) cooperation in multiple-input multiple-output (MIMO) relay channels with multiple source antennas, multiple relay antennas, and multiple destination antennas. The exact symbol error probability (SEP) for maximum likelihood (ML) decoding of orthogonal space-time block codes with M-ary phase-shift keying modulation over such channels is derive. Also characterized the effect of MIMO cooperative diversity on SEP behavior in a high signal-to-noise ratio [7]. The team work study the performance of a multiple-relay system with fixed-gain amplify-and-forward (AF) relaying in Nakagami-m fading channels. To reduce the complexity at the relays, the fixed-gain relaying scheme has been proposed, which maintains the long-term average transmit power at each relay. With *K* relays and when the maximal ratio combining (MRC) is used at the destination, they obtained the average symbol error probability (SEP) [8].

The paper is organized as follows. In section II, we introduce the system model. Section III presents the constructing of MIMO system and AF MIMO relaying system for diversity. In section IV, we introduce the simulation setup. The main steps for the MATLAB codes are presented in section V. The Simulation results for BER and capacity performance are presented in section VI. Finally, conclusions are drawn in section VII.

II. SYSTEM MODEL

In this section, we describe the system model. Fig. 1 describes the AF MIMO relaying system that contains source, relay and destination. Each node equipped with N, L and M antennas, respectively. We restrict ourselves to the case of N=L=M for simplicity. Such that N equal 2, 4 and 8 antennas. Each antennas has the same power. Where all nodes obey the half-duplex constraint, e.g., a node can't transmit and receive simultaneously. OSTBC is presented. System typically entails in two phases, In Phase 1, the source node broadcasts encoded M modulated BPSK signals simultaneously to both the relay and the destination nodes. These symbols affected by two uncorrelated flat fading Rayleigh channels, $H_{s,d}$ and $H_{s,r}$, source-destination channel and source-relay channel, respectively. Also affected by two additive white Gaussian noise (AWGN) channels. In Phase 2, while the source node remains silent. The relay node, amplify the received symbols by fixed gain and forwards it to the destination node, the forwarded symbols affected by uncorrelated flat fading Rayleigh channel, $H_{r,d}$, relay-destination channel with AWGN channel. These two phases signals from two diversity branches are combined by using maximal ratio combining technique (MRC) and form the final received signal. The destination performs decoding based on the symbols were received in both phases. Then demodulator is applied to recover the original transmitted symbols. Maximum likelihood (ML) detector used for calculates the probability of error and determine the accuracy of the system. Fig. 2 illustrates the system detailed block diagram. In Phase 1, the source transmits a symbol vector $X_s = [X_s\,[1] \;.\;.\;.\; X_s\,[M]]^{T}$ to both the relay and destination, where $X_s[m]$ is the symbol transmitted on the m-th antenna. The signals received at the relay and destination are given by

$$Y_r = \sqrt{P_s} H_{s,r} X_s + w_r \,, \tag{1}$$

$$Y_d^{(1)} = \sqrt{P_s} H_{s,d} X_s + w_d^{(1)}. \tag{2}$$

respectively, where P_s is the transmission power of the source, $H_{s,r}$, $H_{s,d}$ are $L \chi N$ and $M \chi N$ channel matrices of the S-R and the S-D links, and $w_r \sim CN(0_L\,,\, \sigma_r^2 I_{L \chi L})$, $w_d^{(1)} \sim CN(0_M\,,\, \sigma_d^2 I_{M \chi M})$ are the AWGN at the relay and destination, respectively. In Phase 2, the relay generates an $L \times 1$ symbol vector X_r according to the specific cooperation scheme and forwards the signal to the destination with power P_r. Where the signal vector X_r is a linear transformation of Y_r. Consider the AF-based MIMO relay system where the relay employs a linear pre-coder F on the received signal vector. Therefore, the signal transmitted by the relay is given by

$$X_r = F\,Y_r, \tag{3}$$

where F is an $L\chi L$ pre-coding matrix and can be calculated as

$$F = 1/\sqrt{\mathrm{tr}\left(\sigma_r^2 I_{M_r} + (P_s/M_s) H_{s,r} H_{s,r}^H\right)}. \quad (4)$$

The signal received at the destination in Phase 2 is given by

$$Y_d^{(2)} = \sqrt{P_r} H_{r,d} X_r + w_d^{(2)}, \quad (5)$$

where $H_{r,d}$ is an $M \chi L$ channel matrix, and $w_d^{(2)} \sim CN\ (0_M, \sigma_d^2 I_{M\chi M})$, is the AWGN at the destination in phase 2 [1].

The capacity of MIMO channel is given by

$$C = \log_2\left(\det\left(I_{M_r} + \frac{E_s}{M_t N_0} HH^H\right)\right). \quad (6)$$

The capacity of the AF MIMO relay channel without direct link (S-D) is given by

$$C = \frac{1}{2}\log_2\left(\frac{\det\left(I_L + \left(I_L + \frac{P_s}{N\,\sigma_r^2} H_{s,r} H_{s,r}^H\right)\frac{P_r \sigma_r^2}{\sigma_d^2} F^H H_{r,d}^H H_{r,d} F\right)}{\det\left(I_L + \frac{P_r \sigma_r^2}{\sigma_d^2} F^H H_{r,d}^H H_{r,d} F\right)}\right). \quad (7)$$

The capacity of the AF MIMO relay channel with direct link (S-D) is given by

$$C = \frac{1}{2}\log_2 \det\left(I_M + \frac{P_s}{N\,\sigma_d^2} H_{s,d} H_{s,d}^H\right) + \frac{1}{2}\log_2\left(I_M + \frac{P_s P_r}{N} H_{r,d} F H_{s,r}\left(I_N + \frac{P_s}{N\,\sigma_d^2} H_{s,d}^H H_{s,d}\right)^{-1} \times H_{s,r}^H F^H H_{r,d}^H \left(P_r \sigma_r^2 H_{r,d} F F^H H_{r,d}^H + \sigma_d^2 I_M\right)^{-1}\right). \quad (8)$$

For a fixed total transmitted power, the total transmitted power $P_s + P_r = P$. For sufficiently high SNR, the optimum power allocation for AF cooperation systems with M-PSK modulation is

$$P_s = \frac{\sqrt{\delta_{s,r}^2} + \sqrt{\delta_{s,r}^2 + 8\,\delta_{r,d}^2}}{3\,\sqrt{\delta_{s,r}^2} + \sqrt{\delta_{s,r}^2 + 8\,\delta_{r,d}^2}}\,P, \quad (9)$$

$$P_r = \frac{2\sqrt{\delta_{s,r}^2}}{3\,\sqrt{\delta_{s,r}^2} + \sqrt{\delta_{s,r}^2 + 8\,\delta_{r,d}^2}}\,P. \quad (10)$$

Where $\delta_{s,r}^2$ and $\delta_{r,d}^2$ are variance of source-relay and relay-destination channels, respectively. We observe that the optimum power allocation for AF cooperation system is not modulation dependent. This is due to the fact that, in AF cooperation systems, the relay amplifies the received signal and forwards it to the destination regardless of what kind of received signal it is. We note that the asymptotic optimum power allocation scheme does not depend on the channel linked between source and destination, but instead depends only on the channel that links between source and relay and between relay and destination.

Depend on the equation 9 and 10, the optimum ratio of transmitted power P_s at the source over the total power P is less than 1 and larger than 1/2, while the optimum ratio of power P_r used at the relay over the total power P is larger than 0 and less than 1/2 [1][2].

III. CONSTRUCTING MIMO SYSTEM AND AF MIMO RELAYING SYSTEM FOR DIVERSITY

This paper simulates the fixed gain AF MIMO relaying system using flat fading Rayleigh channel through means of space-time block coding (STBC), which constructed from known orthogonal designs, achieving full diversity, and are easily decodable by maximum likelihood decoding via linear processing at the receiver. Assuming that the channel is unknown for the source and perfectly known at both the relay and destination for all systems. In all MIMO systems and AF MIMO relaying systems we use orthogonal space time block coding (OSTBC) which is employable when multiple transmitter antennas are used e.g. in 2×2 MIMO system and AF 2×2×2 MIMO relaying system, we use full rate Alamouti STBC, while we use half rate OSTBC in 4×4 MIMO system, AF 4×4×4 MIMO relaying system, 8×8 MIMO system, and AF 8×8×8 MIMO relaying system. The following matrices in which the columns represent the symbol period (time slot) and the rows represent the antennas (space) are used to generate the STBC. These matrices are considered as the important part in building MIMO system and AF MIMO relaying system codes which are used to simulate the performance of different cases [9].

a. Two-transmit two-receive antenna diversity (full rate S)

$$S = G_{2-\text{Alamouti}} = \begin{bmatrix} S_1 & -S_2^* \\ S_2 & S_1^* \end{bmatrix}. \quad (11)$$

b. Four-transmit four-receive antenna diversity (half rate S)

$$G_{4-\text{transmitters}} = \begin{bmatrix} S_1 & -S_2 & -S_3 & -S_4 \\ S_2 & S_1 & S_4 & -S_3 \\ S_3 & -S_4 & S_1 & S_2 \\ S_4 & S_3 & -S_2 & S_1 \end{bmatrix}, \quad (12)$$

$$S = [G_4 \ \ G_4^*]. \quad (13)$$

c. Eight-transmit eight-receive antenna diversity (Half rate S)

$$G_8 = \begin{bmatrix} S_1 & -S_2 & -S_3 & -S_4 & -S_5 & -S_6 & -S_7 & -S_8 \\ S_2 & S_1 & S_4 & -S_3 & S_6 & -S_5 & -S_8 & S_7 \\ S_3 & -S_4 & S_1 & S_2 & -S_7 & -S_8 & S_5 & S_6 \\ S_4 & S_3 & -S_2 & S_1 & -S_8 & S_7 & -S_6 & S_5 \\ S_5 & -S_6 & S_7 & S_8 & S_1 & S_2 & -S_3 & -S_4 \\ S_6 & S_5 & S_8 & -S_7 & -S_2 & S_1 & S_4 & -S_3 \\ S_7 & S_8 & -S_5 & S_6 & S_3 & -S_4 & S_1 & -S_2 \\ S_8 & -S_7 & -S_6 & -S_5 & S_4 & S_3 & S_2 & S_1 \end{bmatrix}, \quad (14)$$

$$S = [G_8 \quad G_8^*]. \quad (15)$$

IV. SIMULATION SETUP

The simulation covers an end-to-end conventional SISO system, N×M MIMO system, fixed gain AF SISO relaying system and fixed gain AF N×L×M MIMO relaying system where N, L and M are equal. Such that N equal 2,4 and 8. Giving that the channel state information (CSI) is unknown at the source and perfectly known at both the relay and destination.

In 2×2 MIMO system and AF 2×2×2 MIMO relaying system, the modulated symbols transmitted in 2 time slots using full rate Alamouti STBC. In 4×4 MIMO system and AF 4×4×4 MIMO relaying system, the modulated symbols transmitted in 8 time slots using half rate OSTBC. In 8×8 MIMO system and AF 8×8×8 MIMO relaying system, the modulated symbols transmitted in 16 time slots using half rate OSTBC. By considered that STBC is used to encode the transmitted symbols; transmitting different symbols through different antennas and different time slots as follows: The first column of S will be transmitted through the N antenna array elements at the source during the first symbol period, then the symbol of column two of S will be transmitted from the N antenna array elements during the following symbol period, and this process continues until all columns are transmitted. Monte-Carlo simulation method is used to make realization for the channel when the channel capacity is simulated.

V. MAIN STEPS FOR THE MATLAB CODES

A. Amplify-and-Forward N×L×M MIMO Relaying System BER Performance Codes

1. The MATLAB code begins by defining simulation parameters such as packet length, number of packets, number of each node antennas, and the power range.
2. Create BPSK modulation and de-modulation objectives.
3. Pre-allocate variables for speed up the simulation process, and set up the figure variables for visualizing the BER results.
4. Allocate power for both the source and relay at each value of the power range.
5. Generate random binary data vector per channel. Then modulate the generated data by using BPSK modulation scheme. Then encoding the modulated signals using orthogonal space-time block coding (OSTBC).
6. Generate three random Rayleigh channels with AWGN.
7. In phase 1, the source transmit the modulated signals vector to the destination and relay, simultaneously.
8. The received signal vector at the relay is amplified by pre-coding matrix. Then forwarded to the destination in phase 2 at each power range value.
9. Combined the received signal vector from the source in phase 1 using MRC then combined the received signal vector from relay in phase 2 using MRC. Finally demodulate the total combined signals from two phases using BPSK demodulator.
10. Calculate the simulation BER for each value of the power range.
11. Plot the BER results versus E_b/N_o.

B. Amplify-and-Forward N×L×M MIMO Relaying System Capacity Performance Codes

1. The MATLAB code begins by defining simulation parameters such as channel bandwidth, power range, channel variances, Monte–Carlo iterations and number of each node antennas.
2. Pre-allocate variables to avoid growing matrix inside loop.
3. Generate three random Rayleigh channels and take the Hermitian of each channel at every Monte-Carlo iteration.
4. Calculate pre-coding matrix at every Monte-Carlo iteration.
5. Calculate the instantaneous capacity at every Monte–Carlo iteration.
6. Calculate the mean capacity for each E_b/N_o range and plot the results.

VI. SIMULATION RESULTS

A. Amplify-and-Forward N×L×M MIMO Relaying System BER Performance

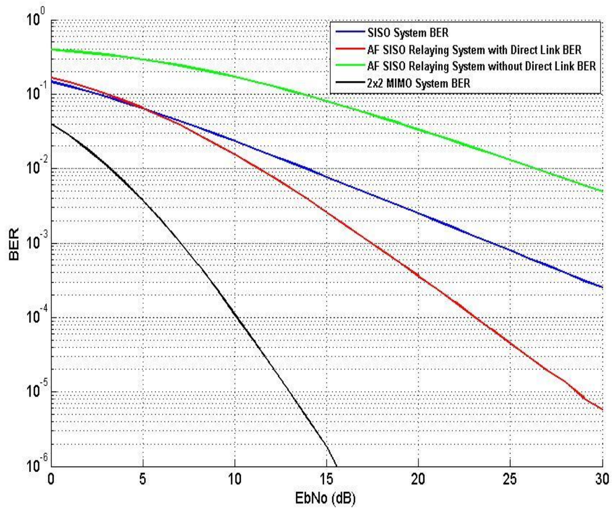

Figure 3. Comparison between SISO system, 2×2 MIMO system and fixed gain AF SISO relaying system with and without direct link using optimal power allocation under flat fading Rayleigh channel in terms of BER performance

From Fig. 3, We notice that the BER performance of 2×2 MIMO system is better than the BER performance of both conventional SISO system and fixed gain AF SISO relaying system with and without direct link using optimal power allocation, e.g. at E_b/N_o equals 15 dB, the BER of 2×2 MIMO system equals 1.8×10^{-6}, while the BER of SISO system, fixed gain AF SISO relaying system with and without direct link using optimal power allocation equal 7.708×10^{-3}, 2.593×10^{-3}, and 8.046×10^{-2} , respectively. The BER performance of fixed gain AF SISO relaying system with direct link using optimal power allocation is better than the BER performance of conventional SISO system. This due to the diversity of two links at the destination. The BER performance of conventional SISO system is better than the BER of fixed gain AF SISO relaying system without direct link due to the signal that affected by two cascaded channel (S-R channel and R-D channel).

Fig. 4 shows that the BER performance of fixed gain AF 2×2×2 MIMO relaying system with direct link is better than the BER performance of both 2×2 MIMO system and fixed gain AF 2×2×2 MIMO relaying system without direct link. We notice that, before E_b/N_o equals 4.603dB, the BER performance of 2×2 MIMO system is better than the BER performance of fixed gain AF 2×2×2 MIMO relaying system without direct link, but after this E_b/N_o value, the BER performance of fixed gain AF 2×2×2 MIMO relaying system without direct link becomes better than the BER performance of 2×2 MIMO system, because using optimal power allocation in AF 2×2×2 MIMO relaying system without direct link and the allocated power increases by increasing the E_b/N_o value. We notice that after E_b/N_o equal 5 dB, the dB difference between fixed gain AF 2×2×2 MIMO relaying system with and without direct link BER is approximately constant and equals 3 dB.

Fig. 5 shows that, before E_b/N_o equal 2 dB, the BER performance of 4×4 MIMO system is better than the BER performance of fixed gain AF 4×4×4 MIMO relaying system with direct link, while after this E_b/N_o value, the BER performance of fixed gain AF 4×4×4 MIMO relaying system with direct link becomes better than the BER performance of 4×4 MIMO system, due to the using of optimal power allocation in AF 4×4×4 MIMO relaying system with direct link and the value of the allocated power increases by increasing the E_b/N_ovalue, e.g. at E_b/N_o equals 0 dB, the BER of 4×4 MIMO system equals 2.695×10^{-2}, while the BER of fixed gain AF 4×4×4 MIMO relaying system with direct link equals 6.609×10^{-2}. But at E_b/N_o equal 5 dB, the BER of 4×4 MIMO system is equal 5.969×10^{-4}, while the BER of fixed gain AF 4×4×4 MIMO relaying system with direct link equals 3.4×10^{-6} . After E_b/N_o equals 3 dB, the dB difference between fixed gain AF 4×4×4 MIMO relaying system with and without direct link BER is approximately constant and equals 4 dB.

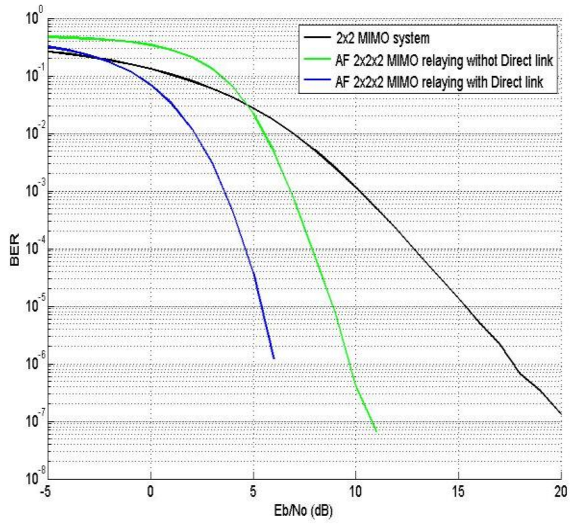

Figure 4. Comparison between 2×2 MIMO system and fixed gain AF 2×2×2 MIMO relaying system with and without direct link using optimal power allocation under flat fading Rayleigh channel in terms of BER performance

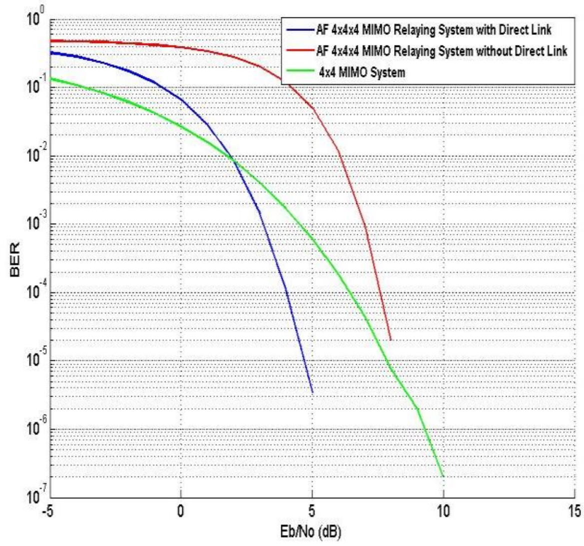

Figure 5. Comparison between 4×4 MIMO system and fixed gain AF 4×4×4 MIMO relaying system with and without direct link using optimal power allocation under flat fading Rayleigh channel in terms of BER performance

Fig. 6 shows that, the BER performance of fixed gain AF 8×8×8 MIMO relaying system with direct link is better than the BER performance of both fixed gain AF 8×8×8 MIMO relaying system without direct link and 8×8 MIMO system. Before E_b/N_o equals 2.288 dB, the BER performance of 8×8 MIMO system is better than the BER performance of fixed gain AF 8×8×8 MIMO relaying system with direct link. But after this E_b/N_o value, the BER performance of fixed gain AF 8×8×8 MIMO relaying system with direct link is better than the BER performance of both conventional 8×8 MIMO system and fixed gain AF 8×8×8 MIMO relaying system without direct link, e.g. at E_b/N_o equals 3 dB, the BER of fixed gain AF 8×8×8 MIMO relaying system with direct link equals

1.3×10^{-5}, while the BER of conventional 8×8 MIMO system, fixed gain AF 8×8×8 MIMO relaying system without direct link equal 4.9×10^{-5} and 1.9×10^{-1}, respectively.

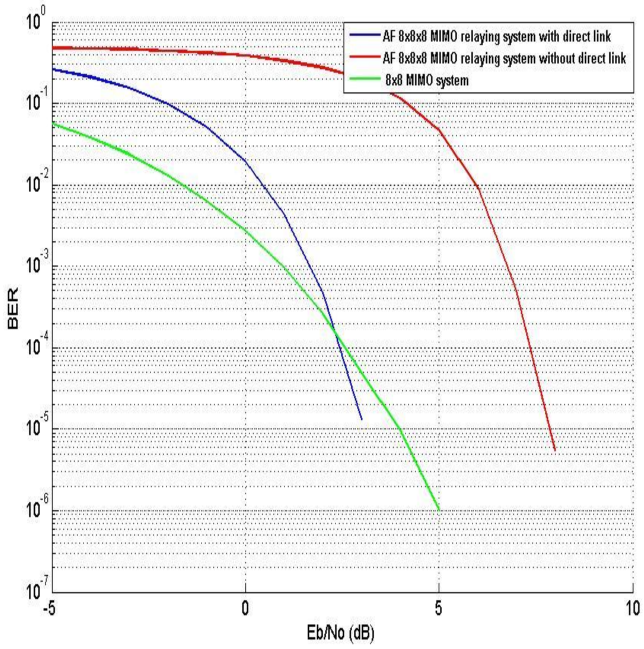

Figure 6. Comparison between 8×8 MIMO system and fixed gain AF 8×8×8 MIMO relaying system with and without direct link using optimal power allocation under flat fading Rayleigh channel in terms of BER performance

Fig. 7 shows all simulated cases for fixed gain AF MIMO relaying system BER performance. The BER performance of fixed gain AF 8×8×8 MIMO relaying system is better one followed by AF 4×4×4 MIMO relaying system, AF 2×2×2 MIMO relaying system, and AF SISO relaying system, respectively, e.g. at E_b/N_o equals 1 dB and 3 dB, the BER performance of fixed gain AF 8×8×8 MIMO relaying system equals 4.273×10^{-3} and 1.65×10^{-5}, respectively, the BER performance of fixed gain AF 4×4×4 MIMO relaying system equals 2.87×10^{-2} and 1.393×10^{-3}, respectively, the BER performance of fixed gain AF 2×2×2 MIMO relaying system equals 4.156×10^{-2} and 3.344×10^{-3}, respectively, and the BER performance of fixed gain AF SISO relaying system equals 1.269×10^{-1} and 8.933×10^{-2}, respectively.

To achieve BER equals 1.065×10^{-4} for AF 8×8×8 MIMO relaying system, AF 4×4×4 MIMO relaying system and AF 2×2×2 MIMO relaying we need 2.439 dB, 4.021 dB and 4.349 dB, respectively.

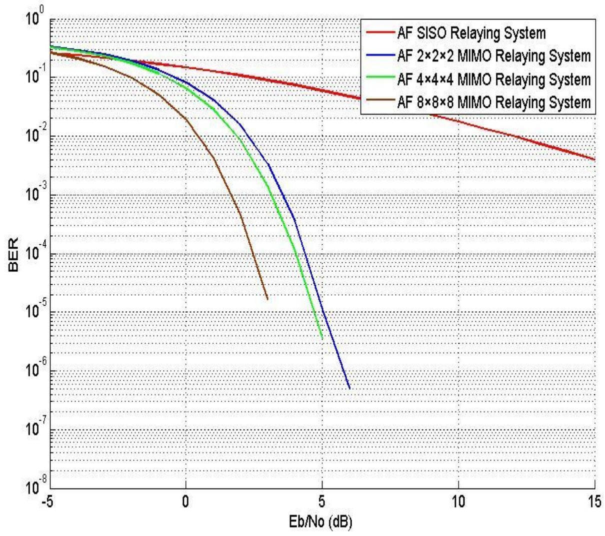

Figure 7. Comparison between fixed gain AF SISO, AF 2×2×2 MIMO, AF 4×4×4 MIMO and AF 8×8×8 MIMO relaying system with direct link using optimal power allocation under flat fading Rayleigh channel in terms of BER performance

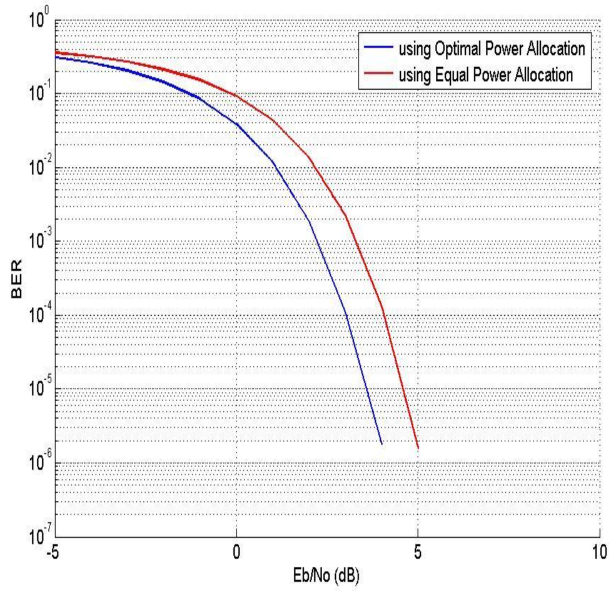

Figure 8. Comparison between fixed gain AF 4×4×4 MIMO relaying system with direct link using optimal and equal power allocation under flat fading Rayleigh channel in terms of BER performance

Fig. 8 shows a comparison between fixed gain AF 4×4×4 MIMO relaying system with direct link using optimal and equal power allocation under flat fading Rayleigh channel in terms of BER performance. Assuming that, the channel variance equals 1 in both S-R link and R-D link, in order to achieve optimal power allocation ($P_s = \frac{2}{3} P$, $P_r = \frac{1}{3} P$). The channel variance equals 1 in S-R channel and equal 0 in R-D channel to achieve equal power allocation

($P_s = \frac{1}{2}$ P, $P_r = \frac{1}{2}$ P). The BER performance of fixed gain AF 4×4×4 MIMO relaying system using optimal power allocation is better than using equal power allocation. This is due to that the allocated power in S-D link is more than the allocated power in R-D link, this decreases the probability of error in decoding. This results matches all other AF MIMO relaying BER performance cases.

B. *Amplify-and-Forward N×L×M MIMO Relaying System Capacity Performance*

Fig. 9, Fig. 10 and Fig. 11 show the capacity performance for conventional MIMO system and AF MIMO relaying system. In three figures the capacity performance of conventional MIMO system is better than the capacity performance of AF MIMO relaying system. This is due the assumption that the source is remain silent during relay transmit symbols, half of the channel resources are allocated to the relay for transmission. The capacity performance of AF MIMO relaying system with direct link is better than capacity performance of AF MIMO relaying system without direct link due to the direct link (S-D link) that decreases the amount of losing bits in decoding. After a certain value of E_b/N_o, there is constant dB difference between the conventional MIMO system and AF MIMO relaying system with direct link capacities.

Fig. 12 shows all simulated cases for fixed gain AF MIMO relaying system capacity performance. The mean capacity of AF 8×8×8 MIMO relaying system is greater one followed by AF 4×4×4 MIMO relaying system, AF 2×2×2 MIMO relaying system, and AF SISO relaying system, respectively, e.g. at E_b/N_o equals 20 dB and 40 dB, the mean capacity of AF 8×8×8 MIMO relaying system equals 14.07 bits/s/Hz and 60.45 bits/s/Hz, respectively. The mean capacity of AF 4×4×4 AF MIMO relaying system equals 10.45 bits/s/Hz, 34.07 bits/s/Hz, respectively. The mean capacity of AF 2×2×2 MIMO relaying system equals 7.485 bits/s/Hz and 19.74 bits/s/Hz, respectively, and the mean capacity of AF SISO relaying system equals 2.968 bits/s/Hz and 6.251 bits/s/Hz, respectively. The capacity performance of AF relaying system becomes more better and more efficient at high E_b/N_o.

Fig. 13 shows a comparison between fixed gain AF 4×4×4 MIMO relaying system with direct link using optimal and equal power allocation under flat fading Rayleigh channel in terms of capacity performance. The capacity performance of fixed gain AF 4×4×4 MIMO relaying system using optimal power allocation is better than the capacity performance of fixed gain AF 4×4×4 MIMO relaying system using equal power allocation. This is due that the allocated power in S-D link is more than the allocated power in R-D link, this increases the probability of correct decoding, so decreases the amount of losing bits. This result matches all other AF MIMO relaying capacity performance cases.

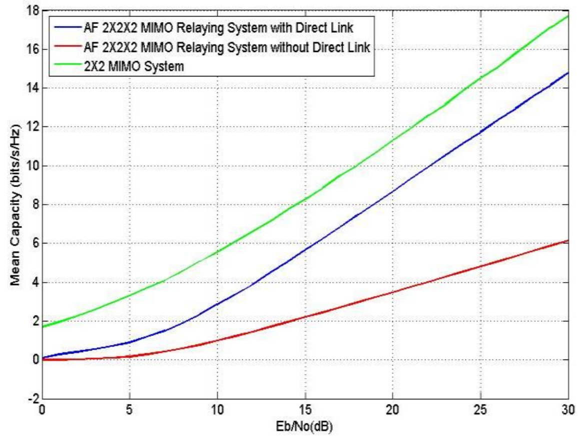

Figure 9. Comparison between 2×2 MIMO system and fixed gain AF 2×2×2 MIMO relaying system using optimal power allocation under flat fading Rayleigh channel in terms of capacity performance

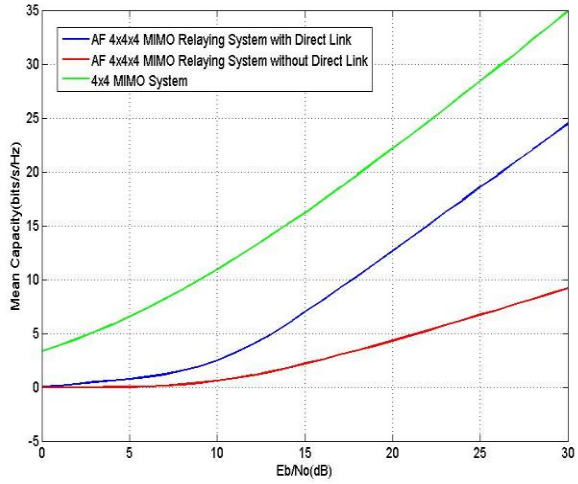

Figure 10. Comparison between 4×4 MIMO system and fixed gain AF 4×4×4 MIMO relaying system using optimal power allocation under flat fading Rayleigh channel in terms of capacity performance

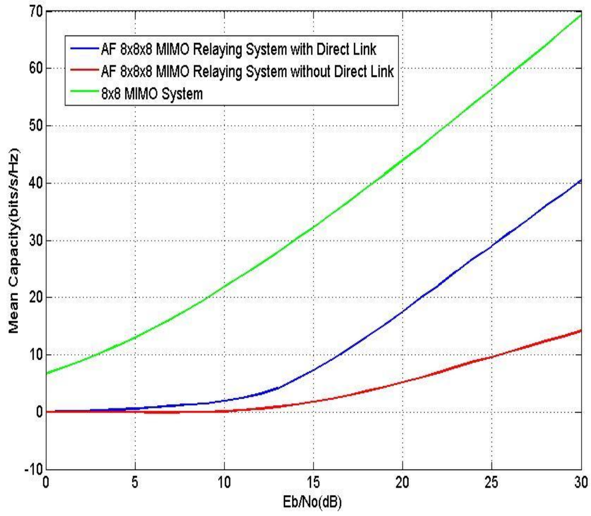

Figure 11. Comparison between 8×8 MIMO system fixed gain AF 8×8×8 MIMO relaying system using optimal power allocation under flat fading Rayleigh channel in terms of capacity performance

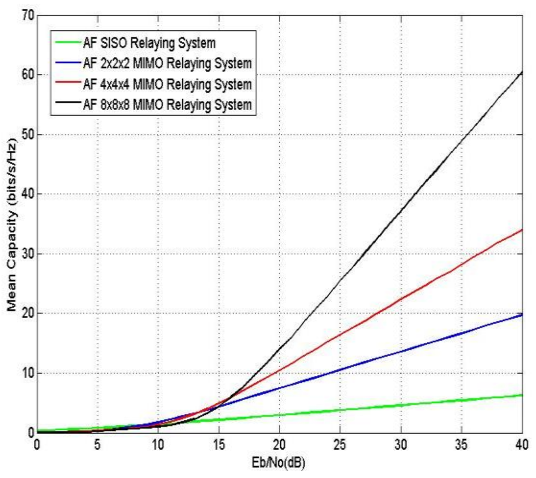

Figure 12. Comparison between fixed gain AF SISO, AF 2×2×2 MIMO, AF 4×4×4 MIMO and AF 8×8×8 MIMO relaying system with direct link using optimal power allocation under flat fading Rayleigh channel in terms of capacity performance

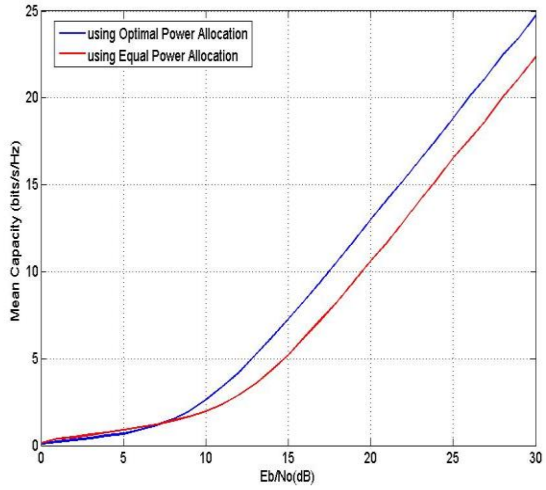

Figure 13. Comparison between fixed gain AF 4×4×4 MIMO relaying system with direct link using optimal and equal power allocation under flat fading Rayleigh channel in terms of capacity performance

VII. CONCLUSION

The capacity performance of all studied conventional N×M MIMO system is better than the capacity performance of all studied fixed gain AF N×L×M MIMO relaying system with and without direct link using optimal power allocation. *This is due to assumption that the source is remain silent during relay transmitting symbols, which mean half of the channel resources are allocated to the relay for transmission.* The BER and capacity performance of all studied fixed gain AF N×L×M MIMO relaying systems using optimal power allocation is better than using equal power allocation. *This is due to allocate more power in direct link that assist the destination to decode correctly. So decrease the amount of losing bits in decoding.*

The BER and capacity performance of all studied fixed gain AF N×L×M relaying systems with direct link using optimal power allocation is better than fixed gain AF N×L×M relaying systems without direct link using optimal power allocation. *This is due to the direct link that decreases the amount of losing bits in decoding so decreases the BER.* The BER performance of all studied fixed gain AF N×L×M MIMO relaying systems with direct link using optimal power allocation is better than the BER performance of conventional N×M MIMO system. This is due to two branches diversity that are resulted from direct link and the assistance link from relay. *This decreases the amount of losing bits in decoding and thereby decreases the BER.*

The BER performance of all studied conventional N×M MIMO system is better than the BER performance of all studied fixed gain AF N×L×M MIMO relaying system without direct link using optimal power allocation, this is due to the signal that is affected by two cascaded channel and the relay amplify the signal with its noise using fixed gain AF N×L×M MIMO relaying system without direct link. But after a certain value of E_b/N_o, there is inversion in the generated simulation curves and this is *due to using optimal power allocation and the allocated power increasing as E_b/N_o increases.*

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