

Performance Enhancement for Co-Channel Interference Cancellation with Smart Antenna and Power Adaptive in Cooperative Communication

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Abstract— Co-channel interference cancellation method are investigated for cooperative communication employing a decode-and-forward protocol when the base station is disturbed by the co-channel interference (CCI). In order to solve such interference problem, the beamforming method with the appropriate weight estimation for a smart antenna at the base station will be employed. We can also control the transmitted power at the interfering source, and maintain nearly a full diversity gain compared with the existing decode-and-forward cooperative communication. The network performance can be enhanced by the proposed power adaptive at the interference source by the quality of channel criterion and signal combining method. The maximum ratio combining (MRC) and the cooperative maximum ratio combining (C-MRC) are used to combine the received signals arrived at the base station to achieve the minimum probability of error based on the experimental results from simulations. The results show proposed method in C-MRC systems had the lower probability of error than MRC because the effect of three gain factors: the antenna array gain obtained from the beamforming algorithm, the power gain of the proposed power adaptive strategy, and the diversity gain obtained from a signal combining of received signals from the relay.

Keywords— Interference Cancellation, Beamforming, Power adaptive, Diversity Gain, Cooperative Maximum Ratio Combining (C-MRC)

I. INTRODUCTION

Recently, the demand of the high data rate and quality of service is continuously increased for the next generation of wireless communications. In fact, a radio wave propagation is a complicated phenomenon characterized in wireless channels by various effects, such as multipath fading and shadowing. An accurate mathematical description of this phenomenon is either unknown or too complex for communication system analysis. To reduce such effects, the diversity can be used by transferring the different samples of the same signal over essentially independent channels [1, 2]. There are different approaches to implement the diversity in a wireless transmission. One of the most important diversity is a spatial diversity. Spatial diversity has been studied

intensively in the context of peer-to-peer communications especially in a multiple-input multiple-output (MIMO) system. One of the tremendous interests is a cooperative wireless network for improving the performance of data transmission over the time-varying wireless channel. The cooperative communication has been introduced as the recent paradigm of diversity gain to imitate the strategies designed for multiple antenna systems. By operation the radiate phenomenon of the wireless medium the cooperative communication permits the single-antenna wireless systems radios to divide their antennas to form a virtual antenna array resulting in achieving the diversity gain for improving the wireless system performance and improve advantage efficiency elevations.

In [3,4], the authors proposed different cooperative diversity protocols and analysed their performance in terms of an outage behaviour. The terms called, decode-and-forward (DF) and amplify-and-forward (AF) have been explained. In DF, each relay receives and decodes the signal transmitted by the source and then it forwards the decoded signal to the destination which combines these entire duplicates in a usual way. AF is a simpler method in which the relay amplifies the received signal and then forwards it to the destination. Although the noise is amplified along with the signal in this technique it still gains the spatial diversity by transmitting the signal over two spatially independent channels.

The performance analysis for general AF has been shown in [5] where it is that shown that a full diversity is achievable with AF. In [6] for the source to the relay links a weighted superposition of the source and relay signals arriving at the destination can be combined using maximum-ratio-combining (MRC) which also collects the maximum available diversity order. With DF protocol, MRC does not offer a full diversity [7]. The best of our knowledge, no efficient demodulation method is available, which is at an affordable complexity that can provably collect full diversity, regardless of the constellation, when using the most practical relay strategy as DF. The combining technique, namely a cooperative maximum ratio combining (C-MRC), is proposed to improve from the diversity gain limitation of the classical DF [8], C-MRC results in serious propagation error under asymmetrical networks when SNR of R-D link is larger than that of S-D link (or S-R link) [22]. In [23], Yi et al. have demonstrated that cooperative-MRC (C-MRC) technique

achieves the full diversity order for the DF based cooperative system, while it has less computational complexity than ML based procedure of detection.

Traditional cooperative communications, interested to improve and enhancement the capacity performance of single source destination pair through single or multiple relays. However, in practice, because of the limited of radio bandwidth, it must implement frequency reuse by the same channel resulting in the co-channel interference (CCI) from the interfering source. Interference is an important problem in wireless communications, and it can be disturbed the system in several ways. By a development of parallel cooperative transmissions between multiple source-destination pairs, the interference cancellation (IC) [9,10] has been proposed to further improve the capacity performance. Despite of the traditional approaches that separate concurrent transmissions, multiple source-destination pairs can now transmit simultaneously by cancelling the cross-user interference among them [11]. The authors in [12] proposed a co-channel interference cancellation strategy based on successive interference cancellation (SIC) employing a minimum mean square error (MMSE) algorithm and a zero-forcing (ZF) algorithm. In [13], authors presented the interference cancellation is one of the critical tasks for beamforming antenna employing a digital beamforming (DBF) antenna array with Constant Modulus Algorithm (CMA) based on the method of Gaussian Radial Basis Functions (RBF). In [14], authors considered in the uplink power adaptive problem because the transmitted power is regulated to provide each user an acceptable connection by limiting the interference caused by other users. In [15], authors presented the equal bit error rate (BER) power control (PC) algorithm for this optimal SIC receiver in quasi synchronous uplink multi-carrier code division multiple access (MC-CDMA).

Given the advantages of interference cancellation, it can be applied to cooperative communications for performance enhancement with the beamforming array antenna together with the power adaptive strategy and signal combining techniques. It is of interest to evaluate the performance enchantment by the proposed hybrid system in the cooperative wireless networks, in which a thorough investigation of such problem is not fully studied. In addition, some performance comparison should be done properly in verify the merit of the proposed hybrid system.

The rest of this paper is organized as follows. Section 2 describes the arithmetical design of the system. In Section 3, the proposed method of beamforming, method of signal combining and power adaptive technique were investigated. In Section 4, the simulation results are shown, and the conclusion is given in Section 5.

II. SYSTEM MODEL

In this section, let us introduce the system model and the received signal model for uplink cooperative wireless communications. The cooperative communication system is shown in Figure 1, in which the source is a User1 (S) and the base station is a destination node (D) communicate over flat Rayleigh fading wireless channels where a channel coefficient $h_{s,d}$ and a channel variance is $\sigma_{s,d}^2$. The User2 is a relaying

node (R), that is also able to receive the signal from source node, and it is willing to cooperate and relay the signal to the destination. The channel coefficients between S and R is $h_{s,r}$, and between R and D is $h_{r,d}$, in which they are modeled as flat Rayleigh fading wireless channels with variances $\sigma_{s,r}^2$ and $\sigma_{r,d}^2$ respectively. In addition, the noise signal at the receiver is modeled as an additive white Gaussian noise (AWGN) having a variance of N_0 . We also employ a time division multiple access (TDMA) as a channel multiple access method for sharing the medium in such wireless networks, and a M-ary phase shift keying (MPSK) is used as a digital modulation scheme for signal transmission. We also assume that the destination is disturbed by the co-channel interference from the interfering source, which is interfering source in Figure 1.

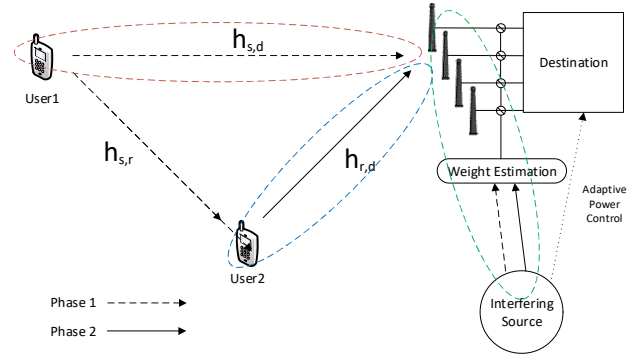


Figure 1: The system model of the decode-and-forward (DF) cooperative communication system with a co-channel interference at the destination

A. Received Signal Model

Let us present a received signal model in this section. In phase 1, S broadcasts the modulated symbol to R and D. The received signal model at R and D can be written as, respectively [16, 21]:

$$y_{s,d} = \underbrace{\sqrt{P_1} h_{s,d} u_{s,d} s}_{\text{Desired Signal}} + \underbrace{\sqrt{P_i} h_i u_{s,d} s_i}_{\text{Interfering Signal}} + \underbrace{n_{s,d}}_{\text{Noise}} \quad (1)$$

where P_1 denotes the transmit power of S, $h_{s,d}$ are the channel state information (CSI) of the Source to Destination link, s is the transmitted symbol, u denotes a M-row vector of the array antenna system with M being a number of antenna in the Destination. For the interfering signal at D, P_i denotes the transmit power of interfering source, h_i denotes the CSI of the interfering source-S link, s_i denotes the transmitted symbol of interference source and $n_{s,d}$ is the M-row AWGN vector with zero-mean and variance N_0 .

In addition, $u_{s,d} = [u_{11}, u_{12}, \dots, u_{1M}]^T$, where $u_{1m} = e^{-j\beta m \Delta x \cos \phi}$ is an m^{th} array response, in which

$\beta = 2\pi / \lambda$ is phase propagation factor, λ is the wavelength of the carrier frequency, $\Delta x = \lambda/2$ is an antenna's element spacing, and ϕ_1 is the direction-of-arrival (DOA) of the transmitted signal in the S-D link in the azimuth plane given that the elevation plane is perpendicular to the direction of the impinging signal. The array of antennas is usually implemented as a linearly equally spaced (LES), uniform circular, or uniformly spaced planar array of similar, co-polarized, low gain elements, which are oriented in the same direction [18].

The received signal vector at R can be described by:

$$y_{s,r} = \underbrace{\sqrt{P_1} h_{s,r} s}_{\text{Desired Signal}} + \underbrace{n_{s,r}}_{\text{Noise}} \quad (2)$$

where P_1 is the power of transmitting of s , $h_{s,r}$ denotes the CSI of the Source to Destination link, s is the transmitted symbol and $n_{s,r}$ is the AWGN with zero-mean and variance N_0

In phase 2, at the relay node, R decodes, encodes and retransmits the received signal in (2) with a proper transmit power P_2 to the destination node. The received signal vector at D is given by:

$$y_{r,d} = \underbrace{\sqrt{P_2} h_{r,d} u_{r,d} \hat{y}_{s,r}}_{\text{Desired Signal}} + \underbrace{\sqrt{P_1} h_{i,r,d} s_i}_{\text{Interfering Signal}} + \underbrace{n_{r,d}}_{\text{Noise}} \quad (3)$$

where P_2 is the power of transmitting from R, and $h_{r,d}$ denotes the CSI of Relay to Destination link $u_{r,d}$ is the array vector of antenna, $\hat{y}_{s,r}$ denotes the decoded symbols using a Maximum-Likelihood (ML) receiver at the relay and $n_{r,d}$ denotes the M-row AWGN vector with zero-mean and variance N_0 . In addition, $u_{r,d} = [u_{11}, u_{12}, \dots, u_{1M}]^T$, where $u_{1m} = e^{-j\beta m \Delta x \cos \phi_2}$ denotes an m^{th} array response, in which $\beta = 2\pi / \lambda$ is phase propagation factor, λ is the wavelength of the carrier frequency, $\Delta x = \lambda/2$ is an antenna's element spacing, and ϕ_2 is the direction-of-arrival (DOA) of the transmitted signal in the R-D link.

III. THE PROPOSED BEAMFORMING AND POWER ADAPTIVE TECHNIQUES

In this section, we proposed a beamforming algorithm with the weighted estimation for array antenna at the destination and the power adaptive at the interfering source by using a channel quality as a criterion. The signal combining techniques are also presented.

A. Beamforming Algorithm

At the destination node, the received signal vectors in (1) and (3) were weighted by the M-row weight vectors $w_{s,d}$ and $w_{r,d}$ respectively, as follows:

$$r_{s,d} = w_{s,d}^H y_{s,d} \quad (4)$$

$$r_{r,d} = w_{r,d}^H y_{r,d} \quad (5)$$

where $r_{s,d}$ and $r_{r,d}$ denotes the weighted received signals in phase 1 and 2, respectively. In order to obtain an optimal weight vectors for $w_{s,d}$ and $w_{r,d}$

We determine the weight vector. $w_{s,d}$ and $w_{r,d}$ for the array antennas with beamforming based on the with a least mean squares (LMS) algorithm [18]. The LMS algorithm requires the desired signal to be supplied using a training sequence. In order to obtain the optimal weight vectors for $w_{s,d}$ and $w_{r,d}$ we send a pilot signal from S to D prior to the signal transmission in phase 1 for training the array antenna system obtaining $w_{s,d}$. Next, prior to the signal transmission is phase 2, we also send a pilot signal from R to D for training the array antenna system for obtaining $w_{r,d}$. The pilot signal is simply a unit energy signal, i.e. $s_p = 1$, in our experiment. Hence, the received signal at D during this training period is prior to the signal transmission in phase 1 as follows:

$$y_p^I = \sqrt{P_1} h_{s,d}^I s_p + n_{s,d}^I \quad (6)$$

where $h_{s,d}^I$ denotes the CSI of the S-D link, and $n_{s,d}^I$ denotes the M-row additive Gaussian noise vector. Similarly, the received signal at D during this training period is prior to the signal transmission in phase 2 as follows:

$$y_p^II = \sqrt{P_2} h_{r,d}^II u_{r,d} s_p + n_{r,d}^II \quad (7)$$

where $h_{r,d}^II$ denote the CSI of the R-D link, and $n_{r,d}^II$ denotes the M-row additive Gaussian noise vector. In addition, $h_{s,d}^I$ and $h_{r,d}^II$ are modeled as zero-mean, complex Gaussian random variables, $n_{s,d}^I$ and $n_{r,d}^II$ are modeled the AWGN with zero-mean and a variance of N_0 .

We employ the LMS adaptive algorithm [18] for updating the weight vector. $w_{s,r}$ and $w_{r,d}$ described as follows:

$$w(0) = 0, \quad (8)$$

$$e(i) = d(i) - w^H(i) y_p, \quad (9)$$

$$w(i+1) = w(i) + \mu y_p e^*(i) \quad (10)$$

where i denotes the iteration index, $d(i) = 1$ denotes the desired response that is a unit energy, μ denotes the step size parameter is the convergence factor which controls the rate of adaptation, e denotes the error function, y_p denotes the pilot

signal, $(\cdot)^*$ denotes the complex-conjugate, and $(\cdot)^H$ denotes the complex-conjugate transpose. Specifically, y_p^I is used for obtaining $w_{s,r}$, and y_p^H is used for obtaining $w_{r,d}$.

B. Power Adaptive at the Interfering Source

In this paper the power adaptive that is reducing of the transmission power of source in order to reduce interference from the interfering source to interfere less with the primary system. The proposed power adaptive algorithm at the interfering source can be expressed as:

$$\text{Power adaptive factor} = \min(|h_{s_i,r_i}|, \text{mean}(|h_{s_i,r_i}|)) / |h_{s_i,r_i}| \quad (11)$$

where $\text{mean}(|h_{s_i,r_i}|)$ is the average channel quality threshold, $|h_{s_i,r_i}|$ is the n^{th} of channel quality of symbol.

C. Signal Combining Techniques

In this section, we combine the received signals in all phases by using a maximum ratio combining (MRC) technique [19] and a cooperative maximum ratio combining (C-MRC) technique [8].

1) Maximum Ratio Combining Technique: We employ a maximum-ratio combining (MRC) to combine the weighted received signals, in (4) and (5) expressed as follows [17]:

$$z_{MRC} = a_1 r_{s,d} + a_2 r_{r,d} \quad (12)$$

where

$$a_1 = \sqrt{P_1} h_{s,d}^* \cdot \frac{(w_{s,d}^H \cdot u_{s,d})^*}{\sqrt{P_1} h_{s,d} u_{s,d} S_i + N_0 \|w_{s,d}\|^2 N_0} \quad (13)$$

and

$$a_2 = \sqrt{P_2} h_{r,d}^* \cdot \frac{(w_{r,d}^H \cdot u_{r,d})^*}{\sqrt{P_2} h_{r,d} u_{r,d} S_i + N_0 \|w_{r,d}\|^2 N_0} \quad (14)$$

2) Cooperative Maximum Ratio Combining Technique: We apply a cooperative maximum ratio combining (C-MRC) to combine the weighted received signals, in (4) and (5) express as follows [8]:

$$z_{C-MRC} = a_1 r_{s,d} + \left(\frac{\gamma_{\min}}{\gamma_{r,d}} \right) a_2 r_{r,d} \quad (15)$$

where $\gamma_{\min} = \min(\gamma_{s,d}, \gamma_{r,d})$ with $\gamma_{s,r} := \frac{|h_{s,r}|^2 P_1}{N_0}$ and

$\gamma_{r,d} := \frac{|h_{r,d}|^2 P_2}{N_0}$ are instantaneous signal-to-noise-ratio (SNR) of the S-R and R-D links, respectively.

D. Signal to Interference Plus Noise Ratio Analysis

Now, let us analyze the signal to interference plus noise ratio (SINR). In the S-D link, we can calculate the average SINR for (4) as follows:

$$\text{SINR}_{s,d} = \frac{P_1 |h_{s,d}|^2 \|u_{s,d}^H w_{s,d}\|^2}{\sqrt{P_1} h_{s,d} u_{s,d} S_i + N_0 \|w_{s,d}\|^2} \quad (16)$$

In the R-D link, we can calculate the average SINR for (5) as follows:

$$\text{SINR}_{r,d} = \frac{P_2 |h_{r,d}|^2 \|u_{r,d}^H w_{r,d}\|^2}{\sqrt{P_2} h_{r,d} u_{r,d} S_i + N_0 \|w_{r,d}\|^2} \quad (17)$$

We also derive a closed-form expression of the total SINR resulted from MRC and C-MRC in the next section combining techniques

1) Maximum Ratio Combining Technique: It could be shown that the output of the MRC detector at the destination can be expressed as follows [16]:

$$\gamma_{\text{total}}^{\text{MRC}} = \gamma_{s,d} + \gamma_{r,d} \quad (18)$$

where γ_{total} is the total SINR, $\gamma_{s,d}$ is the SINR_{s,d} in the S-D link, and $\gamma_{r,d}$ is the SINR_{r,d} in the R-D link, which can be expressed as:

$$\gamma_{\text{total}}^{\text{MRC}} = \frac{P_1 |h_{s,d}|^2 \|u_{s,d}^H w_{s,d}\|^2}{\sqrt{P_1} h_{s,d} u_{s,d} S_i + N_0 \|w_{s,d}\|^2} + \frac{P_2 |h_{r,d}|^2 \|u_{r,d}^H w_{r,d}\|^2}{\sqrt{P_2} h_{r,d} u_{r,d} S_i + N_0 \|w_{r,d}\|^2} \quad (19)$$

2) Cooperative Maximum Ratio Combining Technique: From (15) and (19), it could be shown that the output of the C-MRC detector at the destination can be expressed as follows:

$$\gamma_{\text{total}}^{\text{C-MRC}} = \frac{P_1 |h_{s,d}|^2 \|u_{s,d}^H w_{s,d}\|^2}{\sqrt{P_1} h_{s,d} u_{s,d} S_i + N_0 \|w_{s,d}\|^2} + g \frac{P_2 |h_{r,d}|^2 \|u_{r,d}^H w_{r,d}\|^2}{\sqrt{P_2} h_{r,d} u_{r,d} S_i + N_0 \|w_{r,d}\|^2} \quad (20)$$

it is worth nothing that the expression of $g = \gamma_{\text{eq}} / \gamma_{r,d}$, where $\gamma_{\text{eq}} = \min(\gamma_{s,d}, \gamma_{r,d})$ and $\gamma_{s,r}$, $\gamma_{r,d}$ are the instantaneous SINR between S-R and R-D links.

IV. SIMULATION RESULTS

A. Simulation Parameters

This section, the simulation is conducted under slowly varying channels of Rayleigh flat fading. In addition, Jake's model [20] is employed with a normalization Doppler shift of 5 kHz. We deploy QPSK digital modulation and will show the performance of the proposed methods through a computer simulation. We adjust an equal power transmitted for the source and relay nodes, i.e. $P_1 = P_2 = 1$ W. The summary of transmit

power is $P_{total} = 2$ W. And the bandwidth efficiency is 1 bit/s/Hz. The variances of channel links will be varied to different values in order to examine the proposed system in various scenarios.

In the simulation, we have been defined $(\sigma_{s,d}, \sigma_{s,r}, \sigma_{r,d} = 1, 1, 1)$ as channel variances of the source (S) to destination (D), the source (S)-to-relay(R), and the relay (R)-to-destination (D) links, respectively. We apply the array antenna with 4 elements ($M=4$). Furthermore, a number of pilot during a training period prior to the signal transmission in phase 1 and phase 2 consists of 500 packets, the step size for the weight adaptation is $\mu = 0.1$, and the iterative loop = 100 rounds.

B. Simulation Results

For a fair in comparison, we display graphs of the symbol error rate (SER) and curves as a function of SINR (dB).

1) Maximum Ratio Combining Technique: Figure 2 presents the curves of simulated SER versus SINR(dB) for proposed interference cancellation by MRC. From the simulations, results show that if the cooperative network was interrupted by the interfering signal (CCI) with power = 1 watt and channel variance of interference signal = 1, the system cannot communicate between S, R and D. The PC method yields a better SER than the case of no PC about 2.5 dB at $SER=10^{-3}$. When employing the BF and the power adaptive together in the system compared with the conventional system, the result show that the probability of error is lower than conventional system because of the effect of the weighting factor of the proposed power adaptive strategy and the BF algorithm with the weighted estimation for the array antenna.

2) Cooperative Maximum Ratio Combining Technique: Figure 3 presents the simulated curves SER versus SINR (dB) for the proposed interference cancellation with C-MRC. From the simulation results, the power adaptive strategy yields a better SER better than the case of no power adaptive the in high SINR regimes at SINR=10 dB because of the weighted received signal from the relay. When we employed the BF and the power adaptive together in the system compared with the conventional system, the results show that the probability of error is lower than the conventional system of about 3 dB at $SER=10^{-3}$ in the high SINR regimes at SINR=20 dB, because of the effect of the weighting vector of the proposed power adaptive strategy, the BF algorithm with the weight estimation of the array antenna, and the weighted of received signal from the relay.

3) Comparison of MRC and C-MRC: Figure 4 presents the curves of simulated SER versus SINR(dB) for the proposed interference cancellation with MRC and C-MRC compared with the conventional system without the interference signal and the interference cancellation algorithm in [12]. The results show that the proposed interference cancellation with C-MRC yields lower probability of error than other methods because of the effect of the BF algorithm with the weight estimation of the array antenna, the weighting vector of the proposed power adaptive strategy, and the weighted of received signal from the relay.

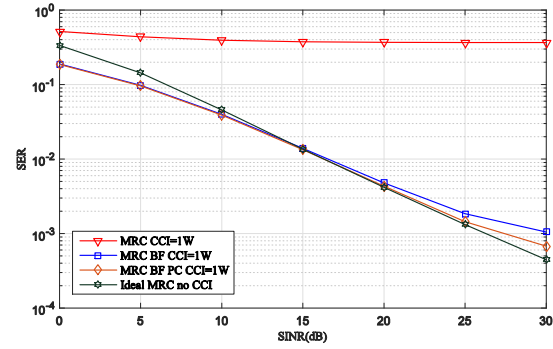


Figure 2: The curves of simulated SER performance comparison for the proposed interference cancellation with MRC

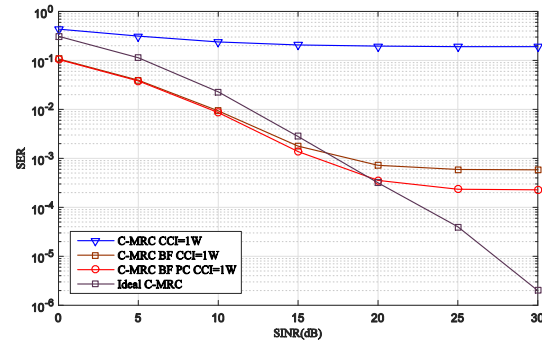


Figure 3: The curves of simulated SER performance comparison for the proposed interference cancellation with C-MRC

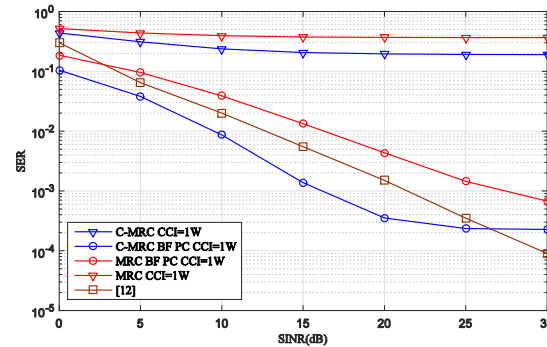


Figure 4: The curves of simulated SER performance comparison for the proposed interference cancellation with MRC and C-MRC

V. CONCLUSION

In this paper, we have proposed the beamforming algorithm with the weighted estimation for array antenna and the power adaptive strategy for the interfering source with two signal combining techniques at the destination, namely MRC and C-MRC. The results show proposed method in C-MRC systems had the lower probability of error than MRC because the effect of three gain factors the antenna array gain obtained from the

beamforming algorithm, the power gain of the proposed power adaptive strategy, and the diversity gain obtained from a signal combining of received signals from the relay.

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