PERFORMANCE EVALUATION OF ADAPTIVE ARRAY ANTENNAS IN COGNITIVE RELAY NETWORK

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ABSTRACT

Adaptive Array Antennas (AAAs) are expected to play a key role in meeting the demands of the wireless communication systems of the future. AAAs in cognitive relay network is proposed to reduce the symbol error rate and improve the system performance. Many algorithms such as wiener solution and least mean square (LMS) will be explained to show how AAAs in cognitive relay network achieves this object. AAAs at different locations will be investigated under AWGN and Rayleigh fading channel. Moreover, enhancement the system performance by showing the effect of increasing the number of AAAs element at the relay node, increasing the source gain and decreasing the relay gain. In addition, increasing the rate adaptation and number of iterations in LMS algorithm has significant improvement in the system.

KEYWORDS

Adaptive Array Antennas, cognitive relay network and least mean square algorithm

1. INTRODUCTION

Cognitive radio is used to designate intelligent wireless communication system that is able to adapt changes occurring in the surrounding environment [1]. It allows Secondary User (SU) network to coexist with Primary User (PU) network through spectrum sharing, provided that the secondary spectrum access will not affect the PUs performance [2], [3].

To enhance cognitive radio performance, the cooperative communications that it's used in [4], where one or more nodes help the communication between source and destination by acting as relays, achieve spatial diversity even in a network composed of a single antenna device. In [5], three protocols of cooperative communications are presented; Amplify and Forward (AF), Decode and Forward (DF) and Adaptive Relay Protocol (ARP). In the AF protocol, the relay amplifies the received signal and forwards it to the destination. In the DF protocol, the relay tries to decode the source message and then re-encodes and forwards it to the destination. ARP is used to overcome the disadvantage of these two protocols. In our system, AF protocol is used as its low complexity than the other mentioned.

Another critical issue in cognitive radio is to improve the performance of the system by using AAAs [6-8]. AAAs is one of the key technologies that are expected to dramatically improve future wireless communication systems because it has the potential to expand coverage, increase capacity and improve signal quality. AAAs algorithms, which use reference signal (desired signal) will be explained in this paper. Other AAAs algorithms, which doesn't use reference signal are not considered here. Types of AAAs algorithms used with desired signal are wiener solution, method of steepest descent, Least Mean Squares (LMS), Normalized Least Mean

Squares (NLMS) and Recursive Least Square (RLS). Wiener solution and LMS algorithms will be used in this paper. In these algorithms, desired signal is sent during training period. By using the received desired signal at AAAs, optimum weights can be computed. After the training period, data is sent and AAAs use the weights computed previously to process the received signal. AAAs in cognitive relay network will be analysis in this paper to give more improvement in the system performance.

The reminder of this paper is organized as follows: Section II describes the system model for the analysis of AAAs in cognitive relay network including wiener solution and LMS algorithms. Simulation results are illustrated in Section III. Finally, conclusions are made in Section V.

2. SYSTEM MODEL

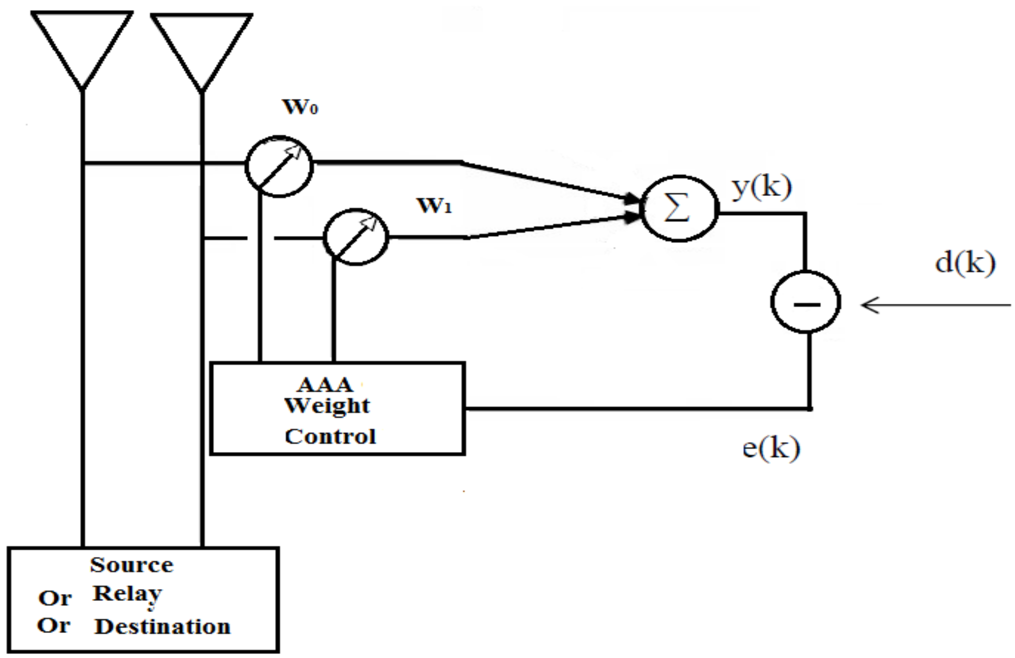

Figure 1. Adaptive array antenna in cognitive relay network.

AAAs in cognitive relay network at the source, relay and destination is illustrated in Figure 1, where S, R and D denotes the source, relay and destination respectively. The relay node is randomly located between the source and the destination to provide most enhancements for the link. The common channels of S and D will be reserved for the usage of direct link. The channels used by R for receiving and transmitting are called indirect channels. They are used for amplifying the received data, and then retransmit it to the destination node.

An antenna array consists of N identical antenna elements arranged in a particular geometry, where the geometry of the array determines the amount of coverage in a spatial region. AAAs algorithms, which use the desired signal, will be used in this paper. In these algorithms, desired signal is sent and by using the received desired signal at AAAs, optimum weights can be computed. Then, data is sent and AAAs uses the previously computed weights to process the received signal.

In the following AAAs algorithms are described which try to minimize the mean square error between the desired signal d (k) and the array output signal y (k).

2.1. Wiener Solution

The error signal e (k) can be expressed as the difference between y (k) and d (k) at sampling instant k as follows [8],

$$e(k) = d(k) - y(k) \quad (1)$$

Where d(k) is the desired signal and the mean squared error is defined by,

$$J(k) = E[|e(k)|^2] = E[|d(k) - y(k)|^2] \quad (2)$$

The optimum weights control can be given as

$$w(k)_{opt.} = R_{xx}(k)^{-1} r_{xd}(k) \quad (3)$$

Where $R_{xx} = E[x(k)^T (x(k)^*)^T]$ is the autocorrelation matrix of the input signal $x(k)$, $r_{xd} = E[d(k)(x(k)^T)^*]$ is the cross correlation matrix between the complex conjugate of the input signal and the desired signal.

The output y(k) of linear combination of data for M elements at time k is denoted as,

$$y(k) = \sum_{i=1}^{M} w_i(k) x_i(k) \quad (4)$$

In vector form the last equation can be written as,

$$Y(k) = X(k)^T W(k) \quad (5)$$

Where $(.)^T$ is the transpose operator.

2.2. LMS Algorithm

The block diagram of Least Mean Square algorithm is represented in Figure 2. The LMS is an iterative beamforming algorithm that uses the estimate of the gradient vector from the available data. The weight vector is updated in accordance with an algorithm that adapts to the incoming data. The simplicity of LMS algorithm comes from the fact that it doesn't require measurements of the correlation functions nor matrix inversion. The updated weight is denoted by [9],

$$w(k+1) = w(k) + 2\mu\, x(k)\, e^*(k) \quad (6)$$

where μ is defined as the rate of adaptation, controlled by the processing gain of the antenna array (step size parameter) and $e^*(k)$ is the complex conjugate of error signal.

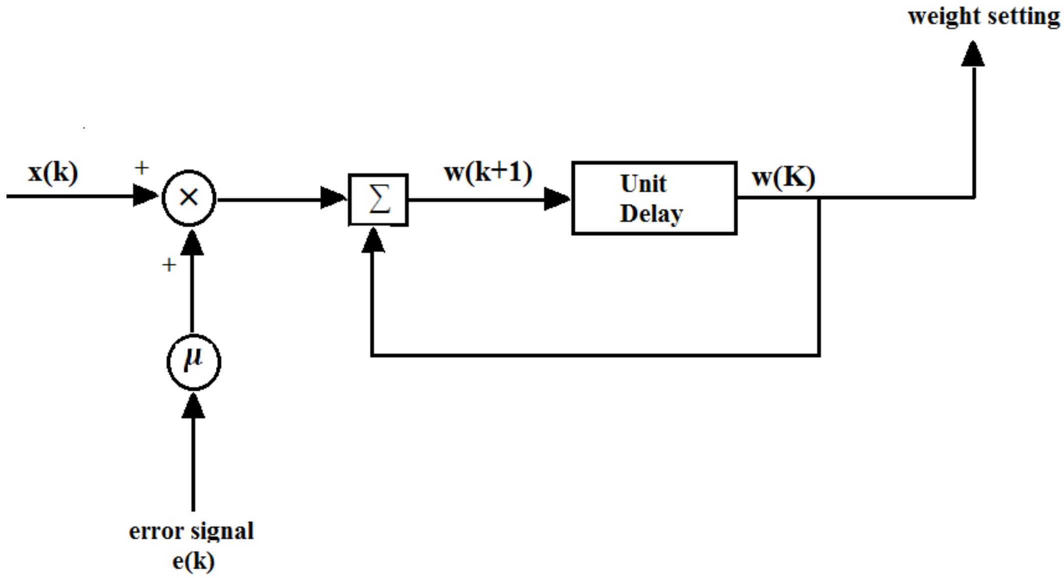

Figure 2. Block diagram representation of LMS algorithm.

3. SIMULATION RESULTS

In this section, the numerical results supporting the analysis of adaptive array antenna in cognitive relay network are presented. Here, the cognitive relay network is demonstrated consisting of a source, a destination and a cognitive relay node between them. The performance of AAAs in cognitive relay network is illustrated using wiener solution and LMS algorithms under AWGN and Rayleigh fading channel. Assume that, the number of transmitted symbols N is equal to10^4. For simplicity, it is assumed that, the same transmitted power of source and relay will be applied.

In the following the effect of many parameters will be studied as follows:

3.1. Effect of AAAs at different locations in cognitive relay network

Figure 3 compares Symbol Error Rate (SER) of AAAs at source, relay and destination node using wiener solution algorithm. Numerical results are obtained by transmitted power of source $p_s = \frac{p_t}{2}$, transmitted power of relay $p_r = \frac{p_t}{2}$. As shown in this figure, locating AAAs at the source has better performance than locating AAAs at the relay and destination.

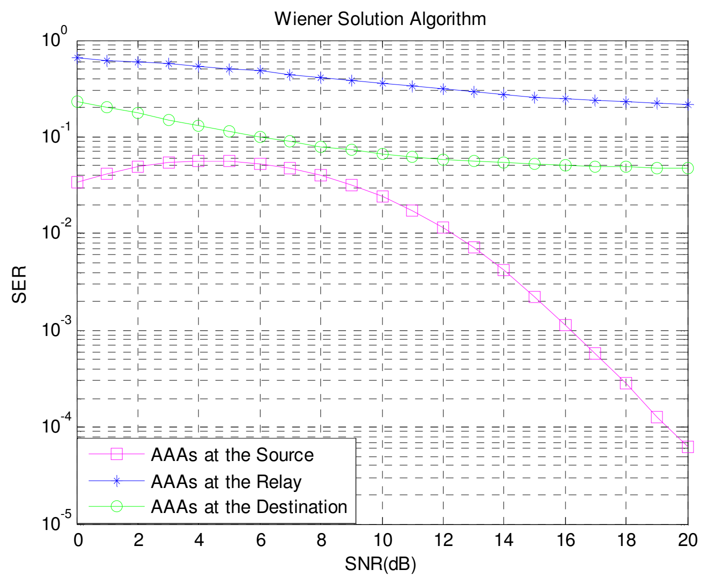

Figure 3. SER of AAAs at different locations in cognitive relay network.

As the AAAs at the relay node using wiener solution algorithm has the worst performance as shown in Figure 3, some parameters are studied to enhance the performance of the system.

3.1.1. Increasing the source node gain

Figure 4 shows the numerical results of increasing the antenna gain at the source (G_s) node when AAAs at the relay node under using wiener solution algorithm. From this figure, it can be concluded that significant improvement in performance is observed by increasing (G_s) .

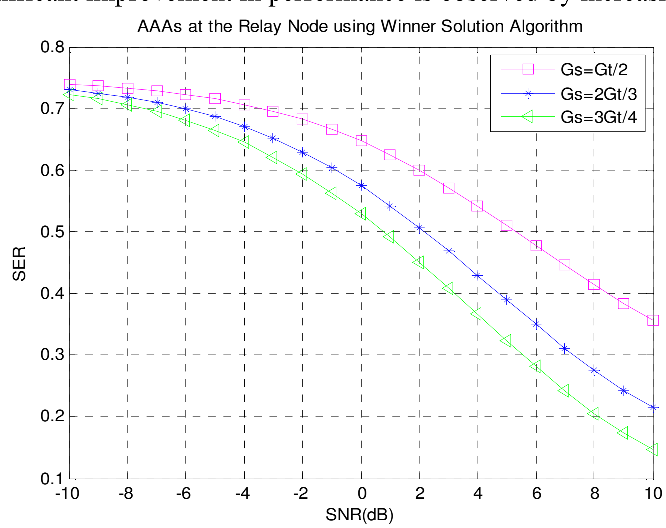

Figure 4. Impact of increasing the source gain when AAAs at the relay node.

3.1.2. Decreasing the relay node gain

The effect of decreasing the antenna gain at the relay (G_r) is illustrated in Figure 5 when AAAs at the relay node using wiener solution algorithm. It is shown in this figure that improving the system performance is obtained by decreasing G_r which explained by occurring interference on the signal.

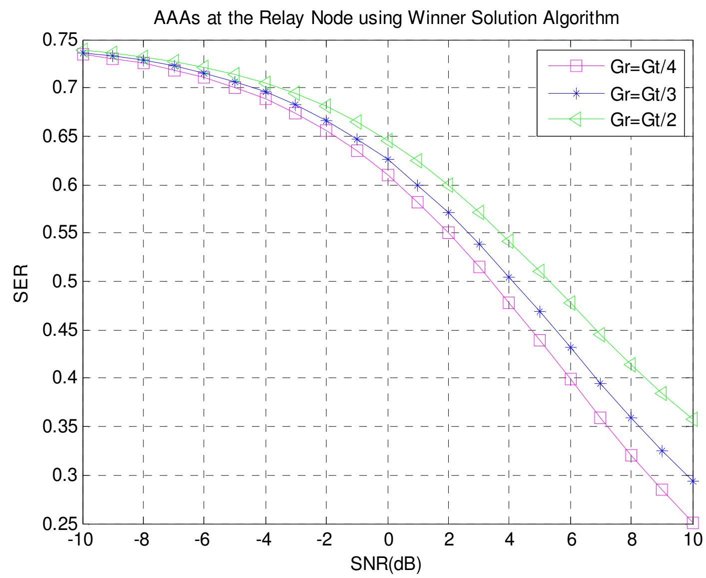

Figure 5. Effect of decreasing the relay gain when AAAs at the relay node.

3.1.3. Increasing AAAs elements

Figure 6 depicts the impact of increasing the number of antennas element of AAAs at the relay node. We can conclude from this figure that, the performance of the system using AAAs with three antennas element outperforms using AAAs with two antennas element.

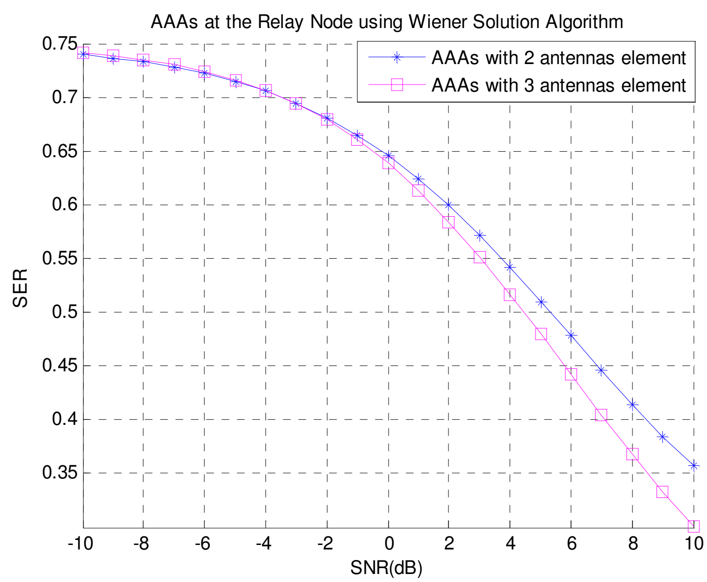

Figure 6. SER at different AAAs elements.

3.1.3.1. Effect of different types of fading channels and noise

The simulative results of AAAs at the source node using wiener solution algorithm under different fading channels are illustrated in Figure 7. For instance, at SNR =8dB, the SER is approximately about 10^{-3} under AWGN, 10^{-2} under Rayleigh fading channel and 10^{-1} under

AWGN plus Rayleigh fading channel. The numerical results indicate that AAAs at the source under AWGN outperforms the other types.

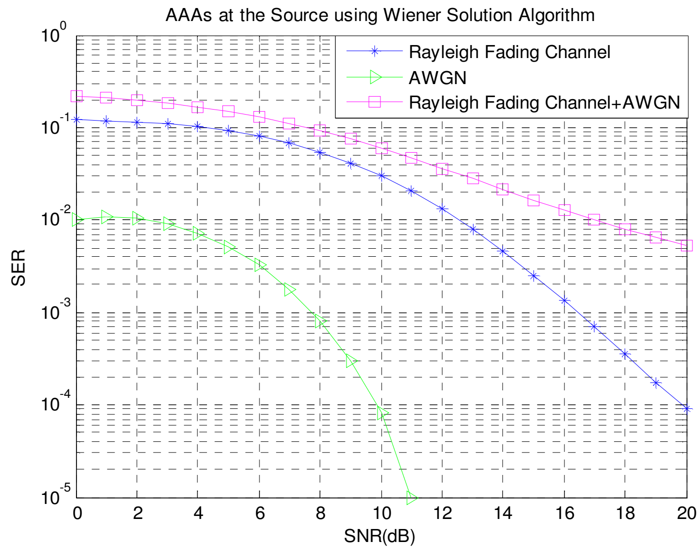

Figure 7. AAAs at the source node under different types of fading channel using wiener solution.

The effect of different fading channels of AAAs at the source using LMS algorithm is depicted in figure 8. For instance, at SNR = 15dB, the SER is approximately 10^{-2}under AWGN and $10^{-0.5}$ under Rayleigh fading channel. The results show that AAAs at the source under AWGN has better performance than under Rayleigh fading channel.

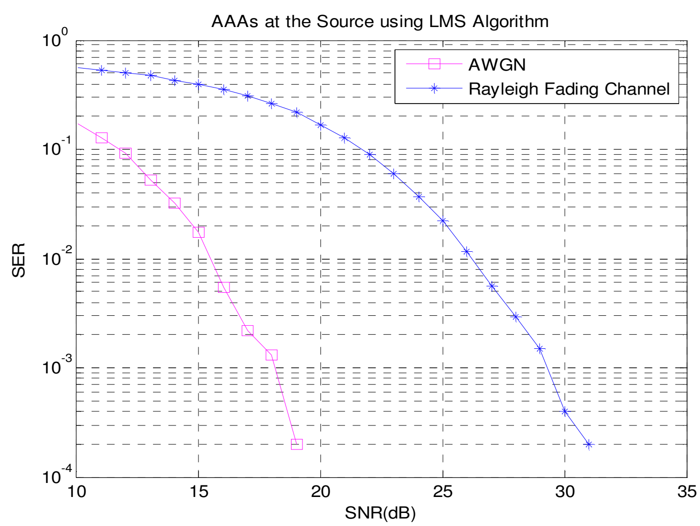

Figure 8. AAAs at the source node under different types of fading channel using LMS algorithm.

3.1.3.2. Effect of different step size parameter in LMS algorithm.

Figure 9 provides AAAs at the source using LMS algorithm with AWGN under different step size parameters. As shown in this figure, by increasing the step size parameter, enhancing the performance of the system.

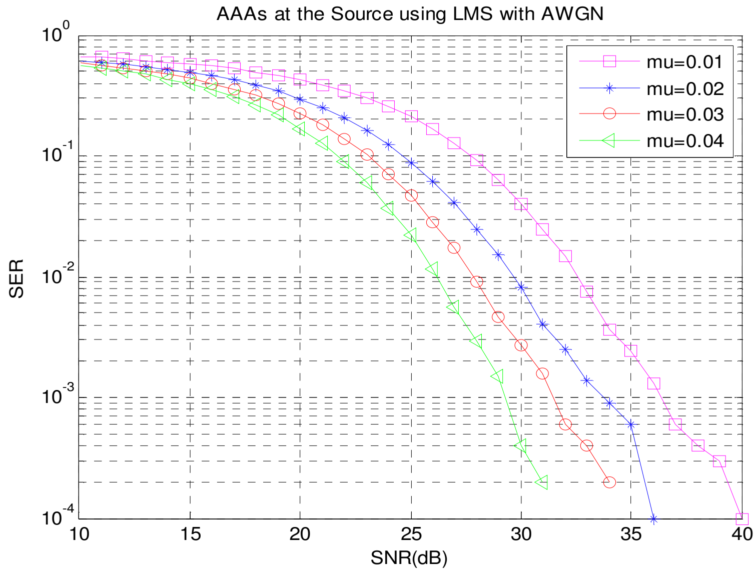

Figure 9. Compares different step size parameter in LMS algorithm.

3.1.3.3. Effect of different number of iterations in LMS algorithm.

AAAs at the source using LMS algorithm with AWGN under various number of iteration is shown in Figure 10. From this figure, it's found that; the performance of the system is improved by increasing the number of iterations.

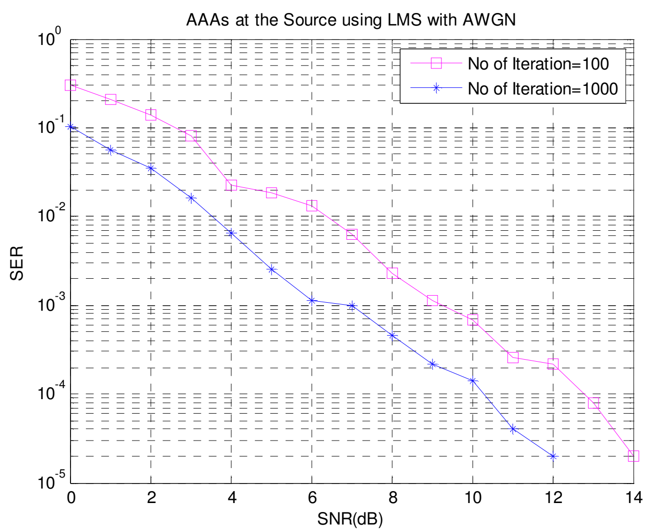

Figure 10. Shows different number of iteration in LMS algorithm.

3. CONCLUSIONS

In this paper, Adaptive array antennas in cognitive relay network are presented to enhance the performance of the network. Wiener solution and least mean square algorithms are analyzed to calculate the optimum weights. Putting AAAs at different locations such as at the source, relay and destination are analytically derived. In addition, the system enhancement is investigated under AWGN and Rayleigh fading channel is proposed. Moreover, increasing the step size parameter and the number of iteration in LMS algorithm, improve the system performance. The simulation results show that combining adaptive array antennas and cognitive relay network present significant improvement in the performance of the system.

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