Blind self-interference cancelation for amplify and forward relaying

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In this paper we introduce a self-interference (SI) cancelation technique for amplify and forward relays. Relays are used to help forward signals between a transmitter and a receiver. This helps increase the signal coverage and reduce the required transmitted signal power. One issue that faces relays communications is the SI problem where an unwanted leaked signal from the relay's output will contaminate the new signal received from the transmitter at the relay's input. A solution is proposed in this paper to cancel this SI which is based upon using the constant modulus adaptive algorithm. This is performed blindly at the relay without the need of any training, a priori knowledge of the SI channel or any other channel weight estimates nor the need of multiple antennas. Simulation results are provided to verify the performance of the proposed method.

1 Introduction

Relays are used in wireless communications to decrease the required transmission power between the transmitter and the receiver or to expand the coverage area or a combination of both [3]. Two types of relays are used, amplify and forward (AF) and decode and forward (DF) [2]. The AF is simpler and its function is to amplify the signal it receives and sends it to the destination. Whereas, the DF decodes the signal first then it re-sends it to the destination. One problem that faces these relays is the fact that the signal sent from its output is leaked to its input due to the imperfect antennas isolation between the relay's output and input. This self-interference (SI) will cause degradation in the relay's system performance.

Many of the discussed relays in the literature assume a priori knowledge of the SI channel such as in [1, 4, 5, 8, 9]. Also, antenna arrays in a multiple-input-multiple-output (MIMO) scheme are required by many methods to perform the SI cancelation [5-9]. The authors in [4] propose an optimised gain control scheme to maximise the overall signal-to-interference-noise-ratio (SINR). The methods in [5] and [9] propose spatial-based solution to this problem. The method in [8] uses precoding techniques to minimise the SI.

A solution is proposed in this paper to cancel this SI which is based upon using the constant modulus adaptive algorithm. The process is performed blindly at the relay without the need of any training nor there is a need for a priori knowledge of the SI channel or any other channel weight estimates. Also, unlike some of the other SI mitigation algorithms, the proposed method does not require multiple antennas to perform the SI cancelation. So, the single-input-single-output (SISO) case is considered in this paper. Still the method can be extended to the MIMO case. This SI cancelation method is named the constant-modulus-based-SI-cancelation (CM-SI) method.

The rest of the paper is organised as follows: Section II presents the system model. Section III explains the CM-SI method. Sections IV presents the simulation results for the CM-SI method. Followed by conclusions in Section V.

2 System Model

Let us consider a SISO relay case. Let be the received signal at the relay at time , This signal can be modeled as

(1)

where is the QPSK signal transmitted by the source, is an amplifying gain for the transmitted signal, is the source-relay channel weight and is a circularly symmetric additive white Gaussian noise (CAWGN) of zero mean and variance

The relay's transmitted signal is denoted by So, the SI signal can be modeled as

(2)

where is the channel weight for the SI and is CAWGN of zero mean and variance .

Also, at the relay, the transmitted signal is a function of its input signal , i.e.,

where is the total signal received at the relay's input (this signal is composed of the signal received from the source added with the SI signal coming the relay's output), i.e.,

(3)

The function depends on the type of relay used (e.g. AF or DF). In this paper the AF relay is

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assumed, and assuming that there is a delay in the relay and no significant delay introduced by the SI channel (recall that the relay size is small and its output and input are close to each other), so

(4)

where is the amplifying gain produced by the relay and is the delay caused by the relay. Without any loss of generality we will assume that is equal to one time index, i.e., so that

(5)

As a result, the signal received at the receiver is given by

(6)

where is the relay-destination channel weight and is CAWGN of zero mean and variance

3 CM-SI

The CM-SI is a method proposed in this paper to cancel the SI channel ( ) blindly at the relay. The CM-SI is based upon using a feedback single tapped filter connecting the relay's output to its input. Let this filter output be modeled as

(7)

where is the filter's weight. This filter output will be subtracted from the received signal at the relay's input given in (3) as follows

(8)

where

which is CAWGN of zero mean and variance . Ideally should equal thus canceling the SI effect.

Since we are not assuming the knowledge of , we propose using the constant modulus adaptive filter to get . If the SI cancelation is successful, the total received signal at the relay will ideally have a magnitude . For the sake of algorithm derivation let us consider the noise free version of (which we denote as), i.e.,

(9)

Thus,

Now use (9) to replace the linear term by . This yields

Now we update using the constant modulus update equation

(12)

where is the update factor and (recall that we are assuming that has a Rayleigh distribution, but it is constant over one detection period). So, (12) becomes

(13)

Notice that the first term in (11) is a constant. Also, when the adaptive filter reaches steady state, it is reasonable to assume that is small enough, then the second term can be neglected. Thus, it follows that

(14)

and the update equation (13) now reads

(15)

Since we are assuming that and are unknowns at the relay then is also unknown. So, we suggest to obtain adaptively using the following constant modulus update equation that runs together with (15)

(16)

where is the estimated value for at time index . Evaluating the gradient part in (16) and replacing with yields

(17)

Thus, the CM-SI method consists of the following update equations

(18)

Note that the CM-SI method runs without the need for any training or a priori knowoledge of the SI channel or any other channel weight estimates and without the requirement of multiple antennas at the relay.

4 Simulation Results

In this section, simulation results are provided to verify the performance of CM-SI. Without any loss of generality, the noise variances for the source-relay and the SI channels are assumed to be equal, i.e., . Thus, the variance . The signal-to-noise-ratio is defined as . The gain and the factor are set to be equal to and , respectively. Also, the initial value of is set to where . Assuming that the channels are fading, then and are changing and their changes are modeled as follows

(19)

and

(20)

where and is taken to be random drawn from a zero mean circular additive white Gaussian distribution and variance 1. The parameters with are CAWGN of zero mean and variances and 1, respectively. Also, and are factors chosen from the period to indicate how close the parameters initialisations are to their true value. Smaller (large) values for or correspond to close (far) initialisation. Note that , and is constant, thus initialisation for will correspond to initialisation for .

Also, assume that and initially equals and , respectively. Now, because of the channels changing nature due to fading, and have to track these changes.

Fig. 1 shows the learning curves averaged over ensembles for using the CM-SI method for different values of with fixed at . Clearly, approaches the value successfully. Also, as expected, the performance is enhanced as increases. Fig. 2 shows the bit-error-rate (BER) (evaluated at the relay after the cancelation stage) for the CM-SI method over different values of SNRs and over different values of with fixed at . Clearly, the results shown in Fig. 2 indicate the CM-SI method succeeds in canceling the SI effect.

5 Conclusion

In this paper we introduced a SI cancelation technique for AF relays. The proposed CM-SI algorithm is based upon the constant modulus adaptive algorithm. The method does not require any training, any a priori knowledge of the SI channel or any other channel weight estimates nor does it require multiple antennas to perform the SI cancelation. Simulation results were presented to illustrate the proposed method performance.

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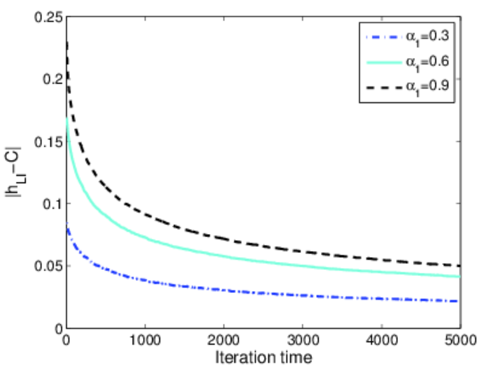
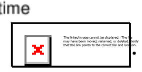


Figure 1: Learning curve for .

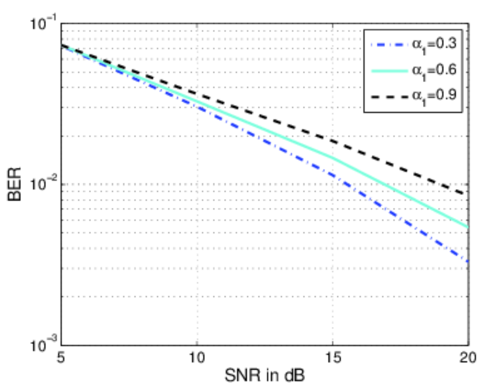


Figure 2: BER vs. SNR.