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Adaptive Filtering based Noise Cancellation in Stochastic Wireless Channels

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Abstract

Fading is major impairment of the wireless communication which along with other phenomenon gives rise to noise in the channel. Adaptive filters are useful in noise cancellation applications because of the fact that they can track the variations in the input signal compared to a given reference signal. In this paper, we explore a method of noise cancellation using an adaptive filter trained with Least Mean Square (LMS), Normalised Least Mean Square (NLMS) and Recursive Least Square (RLS) algorithms to extract the transmitted signal through a severely faded stochastic channel. The proposed systems gives satisfactory results in a severely faded Rayleigh channel in SISO, SIMO, MISO and MIMO set-ups. The work shows a depiction of the approach and formulates a framework for developing certain insight into the use of adaptive filtering to fight fading in wireless channel.

***General Terms** Algorithms*

***Keywords:** Adaptive algorithms, rayleigh fading channel, SISO, SIMO, MISO, MIMO systems.*

I. INTRODUCTION

Any real-world communication system is plagued by noise and thus is susceptible to errors in the transmission of information. Noise cancellation is a process to remove noise from a corrupted signal. The usual method of estimating a signal corrupted by additive noise acquired in the channel is to pass it through a filter that tends to suppress the noise while leaving the signal relatively unchanged. Filters used for this purpose may be fixed or adaptive [1]. In adaptive filters, the filter parameters change with time to suit and modify itself accordingly to the changing signal characteristics. Real-time adaptive filtering algorithms are essential components of most present-day and future generation communications in both wired and wireless forms.

In this paper, we explore a method of noise cancellation using an adaptive filter trained with Least Mean Square (LMS), Normalised Least Mean Square(NLMS) and Recursive Least Square (RLS) algorithms to extract the transmitted signal through a severely faded stochastic channel.

The proposed systems gives satisfactory results in a severely faded Rayleigh channel in SISO, SIMO, MISO and MIMO set-ups. The work shows a depiction of the approach and formulates a framework for developing certain insight into the use of adaptive filtering to fight fading in wireless channel.

2. THEORETICAL BACKGROUND

In this section we described very briefly the theoretical notions essential in the work.

2.1 Adaptive Filter

An adaptive filter consists of two basic elements [2]:-

- Digital filter, which produces an output in response to an input signal.
- An adaptive algorithm, which adjusts the coefficients of the digital filter.

Adaptive Filter block diagram is shown in Figure 1. The signal d(n) is called the desired signal. The input and the output of the filter are denoted by x(n) and y(n) respectively. The signal e(n) is called the estimation error and is defined by e(n)=d(n)-y(n). The adaptive algorithm is designed that it minimizes some objective function contributed from this error signal.

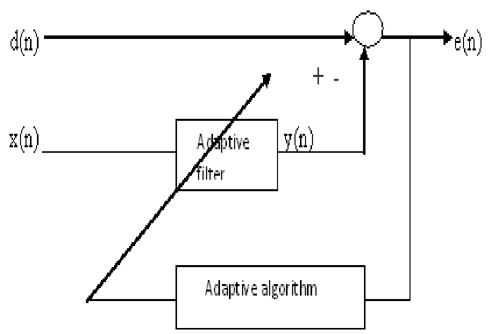

Fig1: Adaptive Filter Block Diagram

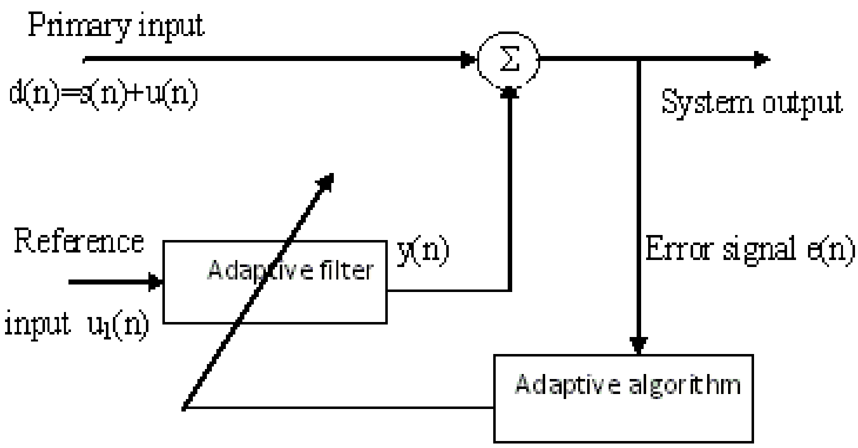

Fig 2: Block Diagram of dual input adaptive canceller

Adaptive Noise Cancellation:

The adaptive noise canceller operates on the outputs of two sensors:

- A primary sensor that supplies a desired signal of interest buried in noise
- A reference sensor that supplies noise alone.

Adaptive filters have the ability to adjust their own parameters automatically and their design requires little or no a priori knowledge of signal or noise characteristics. It is assumed that the signal and noise at the output of the primary sensor are uncorrelated and the noise at the output of the reference sensor is correlated with the noise component of the primary-sensor output.

The adaptive noise canceller consists of an adaptive filter that operates on the reference sensor output to produce an estimate of the noise, which is then subtracted from the primary sensor output. The overall output of the canceller is used to control the adjustments applied to the tap weights in the adaptive filter. The adaptive canceller tends to minimize the mean-square error (MSE) value of the overall output, thereby causing the output to be the best estimate of the desired signal in the minimum-mean-square error sense. The block diagram of dual input adaptive noise canceller is shown Figure 2. An adaptive filter designs itself based on the characteristics of the input signal to the filter and a signal that represents the desired behavior of the filter on its input [2].

Adaptive Algorithms:

Adaptive algorithms can be broadly classified as under:

- Stochastic Gradient Algorithms
- Recursive Least-Square Algorithms

The LMS algorithm is a stochastic gradient algorithm [2] in that it iterates each tap weight of a transversal filter in the direction of the gradient of the squared magnitude of an error signal with respect to the tap weight. The main drawback of the LMS is that it is sensitive to the scaling of its input. This makes it very hard to choose a learning rate μ that guarantees stability of the algorithm.

The Normalised Least Mean Square filter (NLMS) is a variant of the LMS algorithm that solves this problem by normalizing with the power of the input. The problems associated with the LMS algorithm are namely slow convergence and high sensitivity to the eigen value spread To overcome this problems the RLS algorithm is often used.

The RLS algorithm represents increase complexity, computational cost and fidelity. In performance, RLS approaches the Kalman filter in adaptive filtering applications, at somewhat reduced required throughput in the signal processor [2].

2.4 Stochastic Wireless Channels:

Fading is a physical phenomenon associated with transmitted signals in wireless communication. The time-varying random behaviour observed in wireless channel can be modeled by Rayleigh and Rician fading representations [6].

Certain diversity considerations are used to fight such fluctuations and imperfections observed in the wireless channel [3]. As a result, arrangements like single input multiple output (SIMO), multiple input single output (MISO) and multiple input multiple output (MIMO) arrangements are obtained form the basic single input single output (SISO) set-up. A narrowband flat fading MIMO system is modeled as

$$y=Hx+n$$

where y and x are receive and transmit vector, H and n are channel matrix and noise vector (Figure 3).

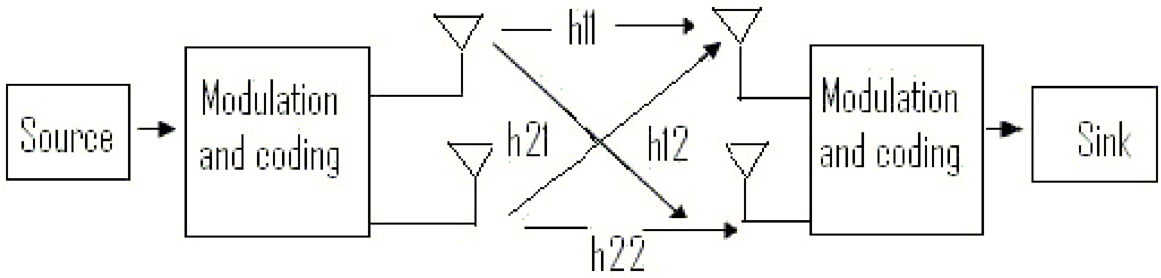

Fig 3. MIMO System Model

3. ADAPTIVE FILTERING BASED NOISE CANCELLATION IN STOCHASTIC WIRELESS CHANNELS:

Experimental Considerations

Here, we generate a set of stochastic wireless channels and certain noise cancellation experiments are performed using the LMS, NLMS and RLS algorithm based adaptive filters. The channels used are Rayleigh fading [7] filled SISO, SIMO, MISO channel and MIMO channels. The corresponding BER curves are plotted for all the cases with and without using alamouti space time coding.

The process diagram without using alamoiti STC is depicted by Figure 4. Adaptive filters trained with LMS, NLMS and RLS algorithms [8] initially track variations in slow-faded channel and perform noise cancellation. A complex uncorrelated white Gaussian noise with zero mean and unit variance is generated and added to the channels. The overall output is used to control the adjustments applied to the tap weights in the adaptive filter. Starting with a SISO channel, the above is extended to SIMO, MISO and MIMO system. Alamouti Space Time Block Code (STBC) is employed with two antennas [4].

STBC allows the transmitter to transmit information by two antennas in two different time. The flowchart shown in Figure 5 depicts the work done on these systems. For a SISO channel, the BER obtained using the formulated framework is shown in Figure 6 using LMS, NLMS and RLS algorithms.

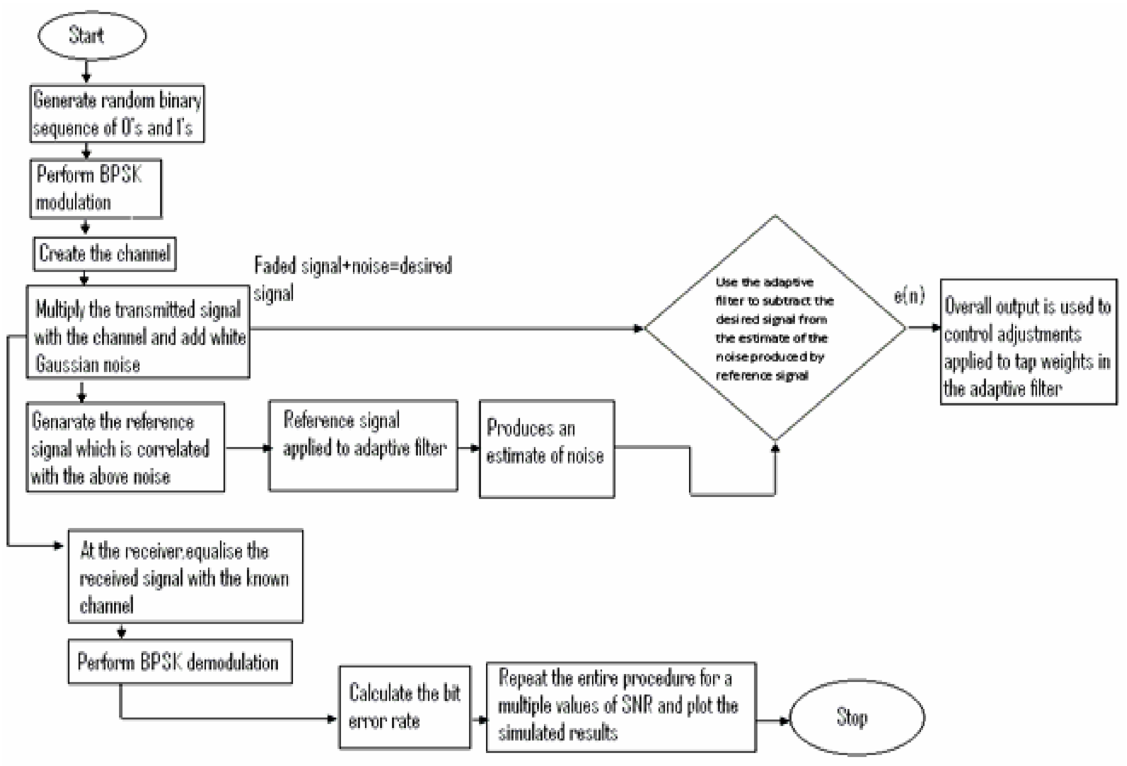

Fig 4: Flowchart depicting the process logic

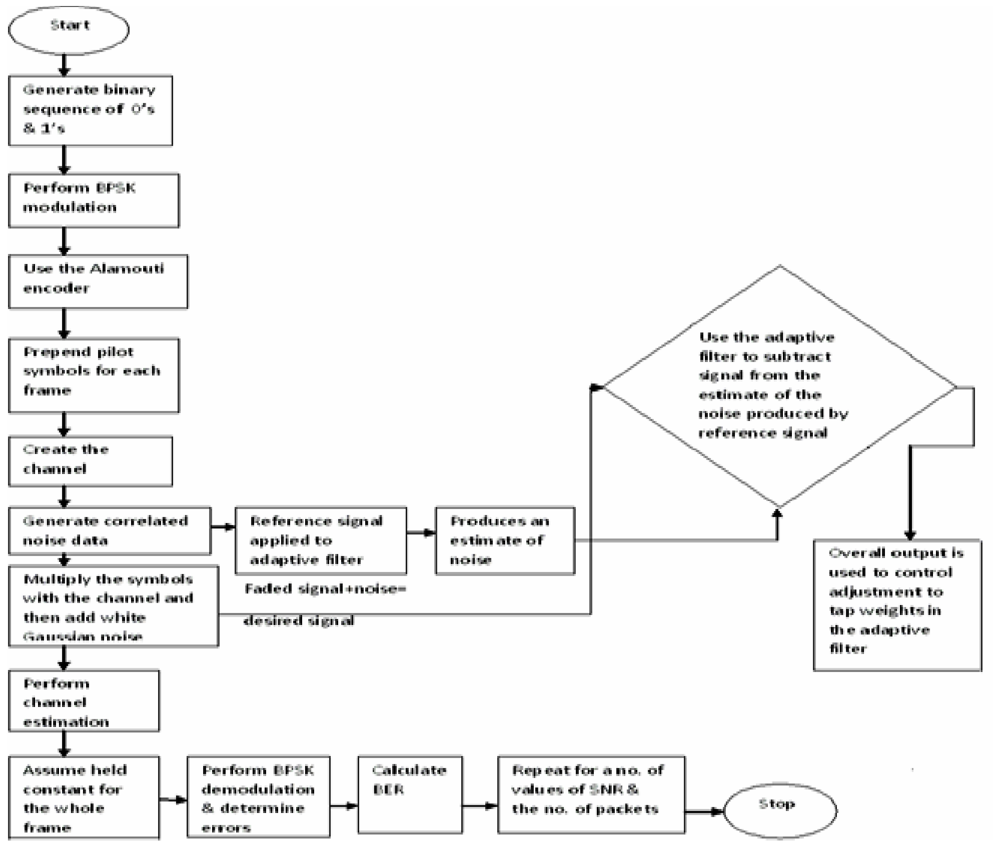

FIG 5: Flowchart on the work done on multiple antenna systems

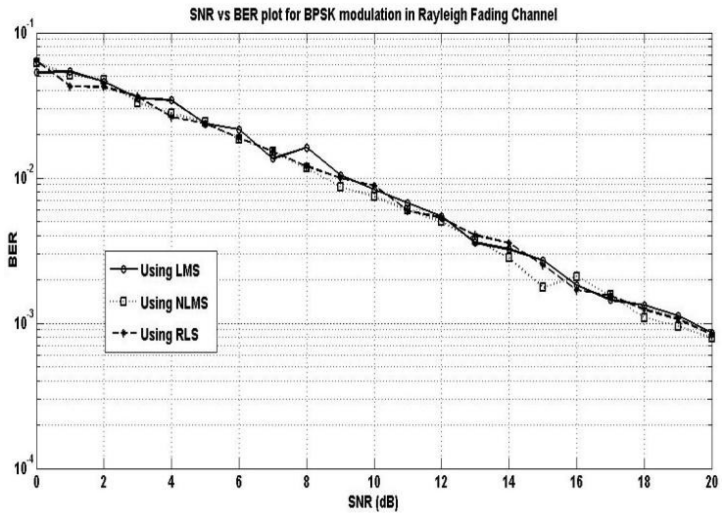

Fig 6: SNR vs BER plot for BPSK modulation in Rayleigh Channel

The plot in Figure 6 is generated using a BPSK modulation. The Rayleigh channel has a background noise which is additive Gaussian. The associated corrupted signals and the estimated waveforms are shown in Figure 7. These figures are plotted without using Alamouti Space time block code.

The considerations shown in the flowchart of figure 5 provide a set of results shown in Fig 8-13.These figures show the use of adaptive filter trained with LMS, NLMS and RLS algorithm in Rayleigh fading filled SISO,SIMO,MISO and MIMO set ups.

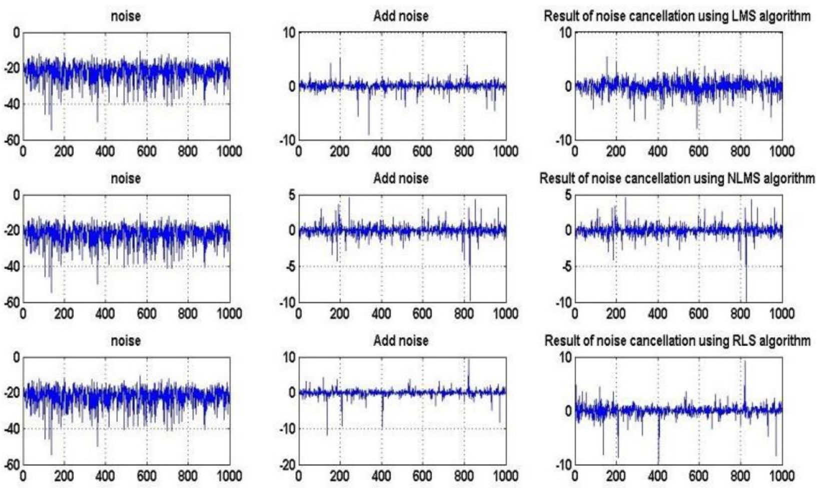

Fig 7: Adaptive nosie chancellation LMS algorithm in a BPSK modualted signal in SISO channel with rayleigh fading.

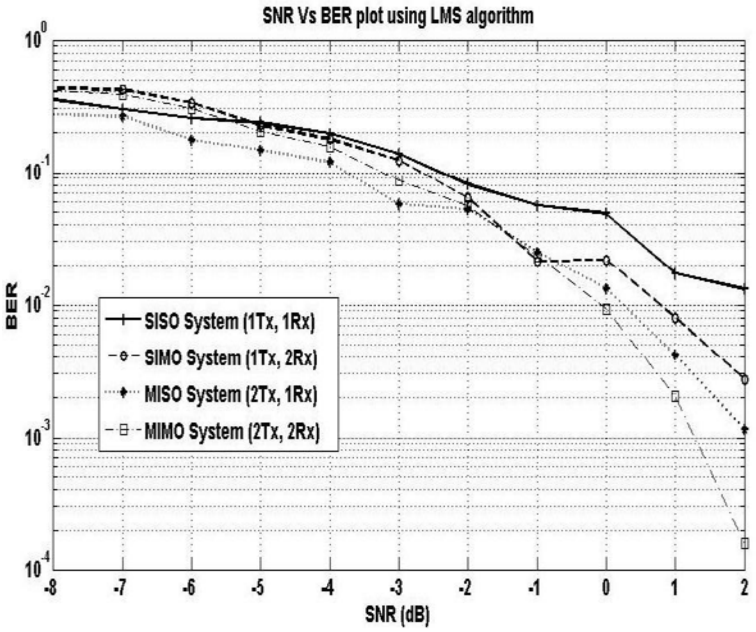

Fig 8: SNR vs BER plot for in Rayleigh Channel using LMS algorithm

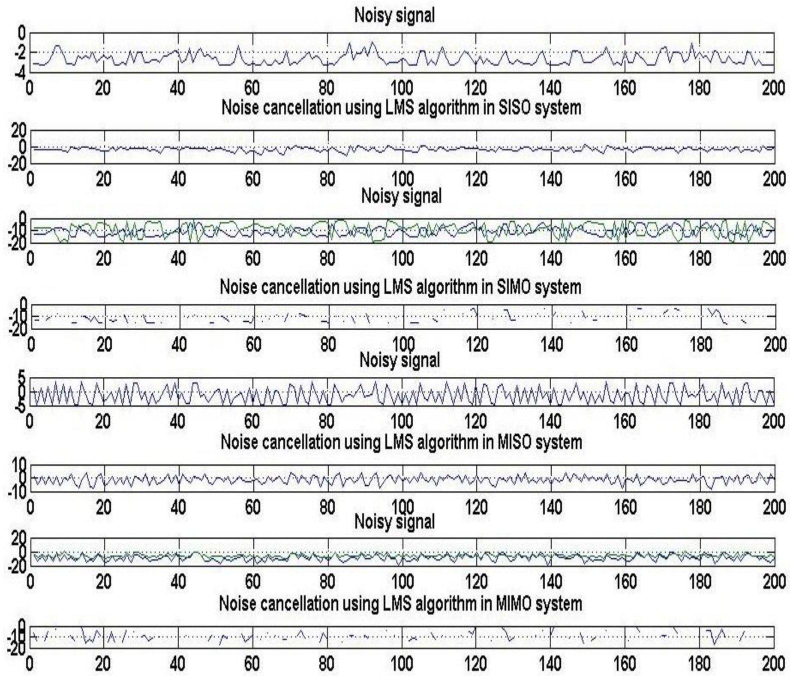

Fig 9: Adaptive nosie chancellation using RLS algorithm in SISO, SIMO, MISO and MIMO channel with rayleigh fading

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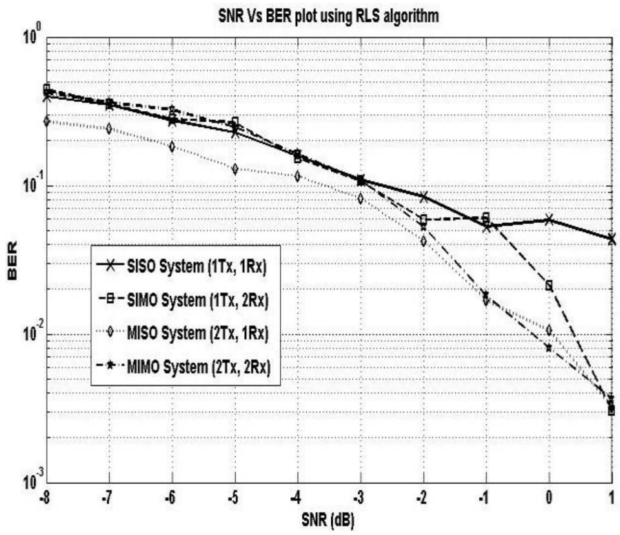

Fig 10: SNR vs BER plot for in Rayleigh Channel using RLS algorithm

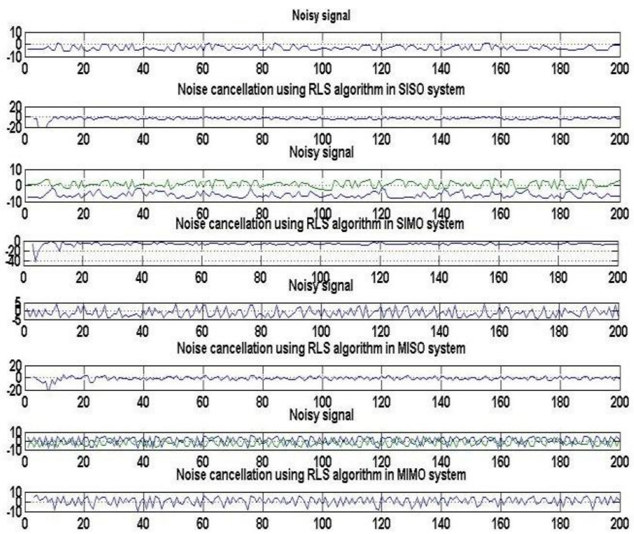

Fig 11: Adaptive nosie chancellation using RLS algorithm in SISO, SIMO, MISO and MIMO channel with rayleigh fading

The result of noise cancellation and the SNR vs BER plot are plotted for BPSK modulation using adaptive filter trained LMS, NLMS and RLS algorithm in SISO,SIMO,MISO and MIMO set ups are plotted. The SNR values vary ftrom -8 to +2 dB. Some of previous results were reported in [9] [10].

The framework thus formualted provides satisfactory performance while carrying out nosie cancellation in Rayleigh faded channels in SISO, SIMO, MISO and MIMO arrangements. The above eperiemtns are also repeated with Rician channel, but as the results are comparitve, these are not included.

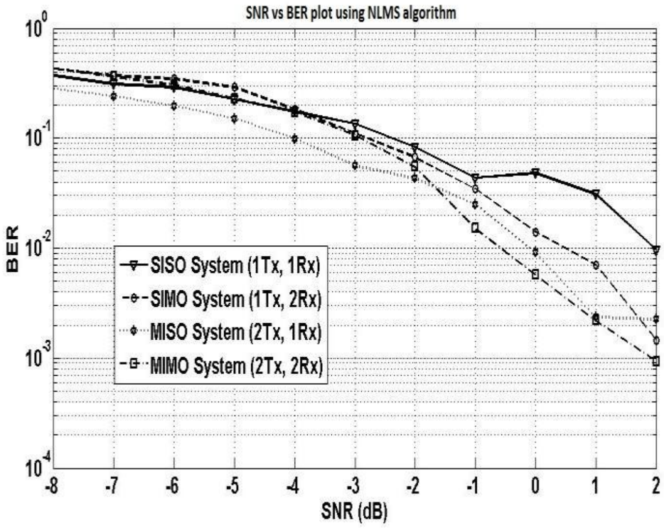

Fig 12: SNR vs BER plot for in Rayleigh Channel using NLMS algorithm

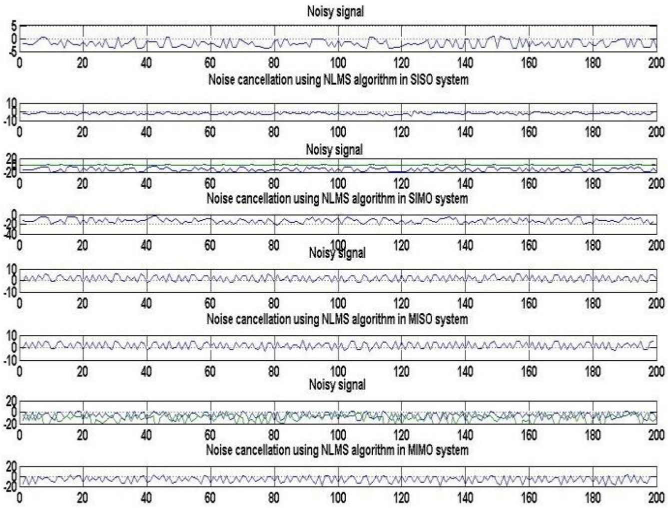

Fig 13: Adaptive nosie cancellation using NLMS algorithm in SISO, SIMO, MISO and MIMO channel with rayleigh fading

CONCLUSION

Here, we formulated a framework for noise cancellation using LMS, NLMS and RLS adaptive filter in severely faded Rayleigh channel in SISO, SIMO, MISO and MIMO set-ups. The experimental results show satisfactory performances and a simplistic arrangement to tackle noise related variations in the channel. With LMS. NLMS and RLS algorithms, Rayleigh fading MIMO system gives better performance with sharp decrease in bit error rate. The work can be further implemented using kalman filter using multiple antenna systems.

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