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Development of Modified Digital Beam Forming Algorithm Using Least Minimum Square Algorithm

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Abstract: The demand for increased capacity in wireless communication networks has motivated recent research activities toward wireless systems that exploit the concept of smart antenna and space selectivity. Efficient utilization of limited radio frequency spectrum is only possible to use smart/adaptive antenna system. The smart antenna radiates not only narrow beam towards desired users exploiting signal processing capability but also places null towards interferers, thus optimizing the signal quality and enhancing capacity. The existing algorithm for adaptive beam-forming (LMS (Least Minimum square) and CMA (Constant modulus algorithm)) is having some issues regarding performance. These issues can be resolved and performance can be improved by doing modification in existing LMS algorithm. In this work, a modified digital beamforming algorithm using LMS algorithm is developed. The aim behind developing this algorithm is to improve steady state response, reduce the phase difference between input and output signal and to reduce the error magnitude between input and output signal. The algorithm is modified by computing and combining the antenna response for interferer signal and data signal to the interferer signal and data signal. This response is calculated for both data signal and interferer signal using the distance between the antennas (π/2) and direction angle of signals. We also analyze the performance of Modified (LMS) algorithm for smart antenna systems which very important for smart antenna design. The performance of proposed method is also compared with existing CMA. The performance parameters for comparison are phase response, magnitude response, and error magnitude. MATLAB R2013 has been used as an implementation platform using wireless communication and antenna tool box.

Keywords: Smart Antenna, Beamforming Algorithm, Constant Modulus Algorithm (CMA), Least Mean Square (LMS) Algorithm.

INTRODUCTION

Advancement of wireless access technologies is about to arrive at its advanced generation. The adaptation of smart antenna in the future wireless system is predictable to have a significant impact on the proficient use of the spectrum [9].

The innovative technology Smart Antenna has been used in the mobile communications systems like GSM and CDMA. The introduction of powerful, low cost, digital processing components and the enlargement of software-based techniques has made the smart antenna systems a practical reality for the both base station and the mobile station of a cellular communications system. The essential part of the smart antenna system is the selection of smart algorithms in the adaptive array. By using beam forming algorithms we can adjust the weight of antenna arrays to form a certain amount of adaptive beam to track corresponding users automatically and at the same time to minimize the interference arising from other users by introducing nulls in the respective directions. Thus interferences can be suppressed and the desired signal can be extracted [5].

Conventional base station antennas in existing operational systems are either omnidirectional or sectorized. This is a waste of resources since the vast majority of transmitted signal power radiates in directions other than toward the desired user [4].

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In the past, various different algorithms have been implemented in the smart antennas. Those algorithms track the signal received from the end user. The radiation pattern is adjusted to place nulls in the direction of Interferers and Maxima in the direction of the desired user so, that algorithms have low calculation complexity and poor convergence [1].
A smart antenna is a multibeam adaptive array with its gain pattern adjusted dynamically [3]. Smart antennas may be used to provide significant advantages and improved performance in almost all wireless communications systems. These Smart antennas dynamically adapt to changing traffic requirements. Smart antennas are usually employed at the base stations and they radiate narrow beams to serve different users [2]. Fig.1 shows the block diagram of smart antenna system [6].

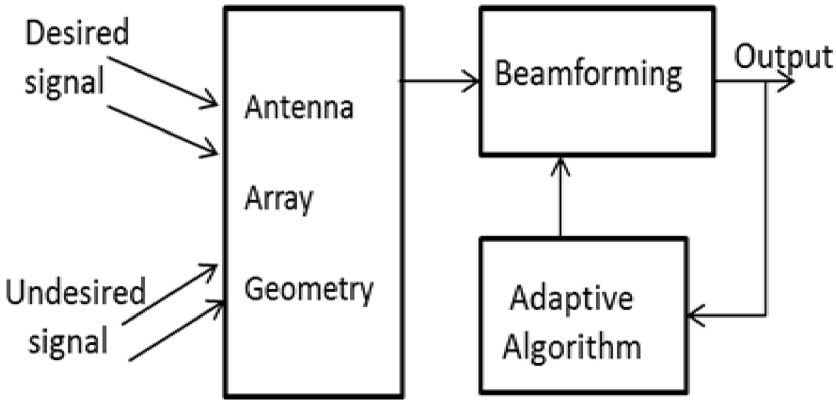

Figure 1: Block diagram of Smart antenna system

Smart Antenna systems continually monitor their coverage areas and adapt to the user's direction providing an antenna pattern that tracks the user and provides maximum gain in the direction of the user. Smart Antenna system was adopted by ITU for 3G wireless networks because of its ability to increase the capacity by reducing interference [7].

ADAPTIVE BEAMFORMING

Adaptive array antennas are nothing but the smart antennas. Adaptive antenna system provides optimal gain by identifying, tracking and minimizing interfering signals. It requires implementation of digital signal processing technology. It has better interference rejection but it is expensive. The high interaction between mobile and base station is required due to continuous steering. It provides better coverage and increased capacity by rejecting multipath components [9].

Constant Modulus Algorithm (CMA)

CMA is a blind algorithm based on the idea to reduce systems overhead and maintain gain on the signal while minimizing the total output energy. As a result, the number of bits for transmitting information is increased which leads to the increased capacity. This algorithm seeks for a signal with a constant magnitude like modulus within the received data vector and is only applicable for modulation scheme, which uses the signal of equal power that includes phase and frequency modulated signals. The received data vector consists of desired signal plus interference and noise [8]. Therefore, it can identify only one signal usually. During transmission, corruption from the channel and noise can distort this envelope. Using the constant modulus algorithm (CMA), the envelope of the adaptive array output can be restored to a constant by measuring the variation in the signal's modulus and minimizing it by using the cost function. μ represents the rate of adaptation, controlled by the processing gain of the antenna array.

Least Mean Square (LMS) Algorithm

The LMS algorithm is the most widely used algorithm invented in 1960 by Stanford University professor Bernard Widrow and his first Ph.D. student, Ted Hoff. The main features that attracted the use of the LMS algorithm are low computational complexity, proof of convergence in a stationary environment, unbiased convergence, and stable behaviour when implemented with finite-precision arithmetic. LMS algorithms are a class of adaptive filter used to mimic the desired filter by finding the filter coefficients

PROPOSED METHODOLOGY

MATLAB R2013 has been used as an implementation platform using wireless communication and antenna tool box. In this work, a modified digital beamforming algorithm using LMS algorithm is developed. The aim behind developing this algorithm is to improve steady state response, reduce the phase difference between input and output signal and to reduce the error magnitude between input and output signal. The algorithm is modified by computing and combining the antenna response for interferer signal and data signal to the interferer signal and data signal. This response is calculated for both data signal and interferer signal using the distance between the antennas ($\pi/2$) and direction angle of signals. The input parameters used in proposed method are as follows:

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S.No.	Parameter Name	Value
1.	Number of antennae	5
2.	Number of samples	50
3.	System Noise Variance	0.1
4	Direction angle for data signal	0.610^0
5	Direction angle for 1st interferer signal	0^0
6	Direction angle for 2nd interferer signal	-0.3491^0
7	Bit rate	100
8	Simulation frequency	400
9	Sample period	0.00250 s

The implementation steps are as follows:

1. Declaration of input parameters
   - Number of antennas in the array
   - Number of bits to be transmitted
   - System Noise Variance
   - Direction of signal x
   - Direction of noise from source 1
   - Direction of noise from source 2
   - Bit rate
2. Computation of time constant
3. Computation of simulation frequency
4. Computation of sample period
5. Generation of complex MSK data for transmission
6. Declaration of loop according to number of samples
7. Re-sampling of data according to new sampling rate (4)
8. Setting and computation of timeline
9. Computation of the complex signal to be received
10. Generation of random noise vectors according to length of signal from both sources (uniform phase (-pi, pi))
11. Generation of system noise for each antenna according to System Noise variance (uniform phase (-pi, pi))
12. Calculation of array responses for desired signal and source noises. Also, it is assumed that antennas are separated by lambda/2
13. Computation of total signal combining responses of desired signal and source noises to the signal and noises.
    - Computation of received signal from signal source x
    - Computation of received signal from noise source n1
    - Computation of received signal from noise source n2
    - Computation of total received signal
14. Initialization of LMS Algorithm
    - Evaluation of weights those satisfy beam-forming at desired direction
    - Creation of dummy vector for output signal
    - Declaration of gradient constant
    - Creation of dummy vector for error between input and output signal
    - Creation of dummy vector for weights
    - Declaration of loop according to number of samples
    - Adding weights to the noisy signal
    - Calculation of error between transmitted and received signal
    - Update of weights according to error and noise signal
15. Calculation and Plotting of phase response of transmitted and received signal
16. Calculation and Plotting of magnitude response of transmitted and received signal
17. Calculation and Plotting of magnitude response of error
18. Calculation and plotting of amplitude Response forgiven Antenna Array.

EXPERIMENTAL RESULTS

In this work, a modified digital beamforming algorithm using LMS algorithm is developed. The aim behind developing this algorithm is to improve steady state response, reduce the phase difference between input and output signal and to reduce the error magnitude between input and output signal. The algorithm is modified by computing and combining the antenna response for interferer signal and data signal to the interferer signal and data signal. This response is

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calculated for both data signal and interferer signal using the distance between the antennas (π/2) and direction angle of signals. These are as follows:

1. For data signal 35 * (pi/180) = 0.610^0
2. For 1st interferer signal 0*(pi/180) = 0^0
3. For 2nd interferer signal -20*(pi/180) = -0.3491^0

The LMS algorithm contains three steps in each recursion:
1. Computation of the processed signal with the current set of weights.
2. Generation of the error between the processed signal and the desired signal.
3. Adjustment of the weights with the new error information by the gradient method.

The input at each element of array antenna consists of sum of input signal which is taken as complex MSK signal in some desired direction, introduced two interrupts in the direction and introduced random noise signal n. By performing the above steps, we got some snapshots of signals. Figure 2 is the snapshot of complex signal at the transmitter. Figure 3 is the snapshot of 1st random interferer vector. Figure 4 is the snapshot of 2nd random interferer vector. Figure 5 is the snapshot of the magnitude of noise. Figure 6 is the snapshot of the phase response of transmitted and received signal. Figure 7 is the snapshot of the magnitude response of transmitted and received signal. Figure 8 is the snapshot of the magnitude response of error between transmitted and received signal. Figure 9 is the snapshot of Amplitude Response forgiven Antenna Array.

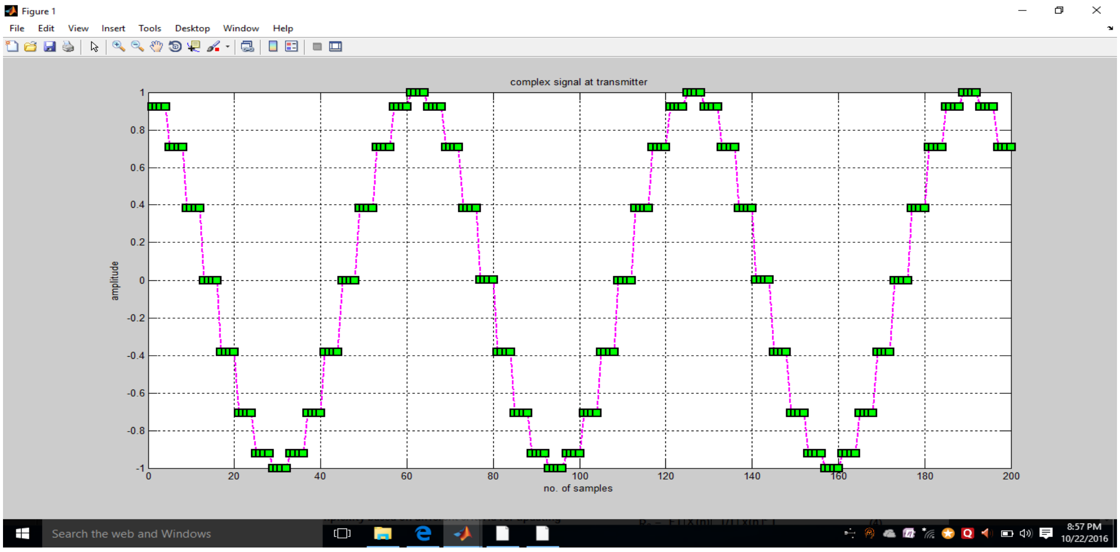

Figure 2 snapshot of complex signal at transmitter

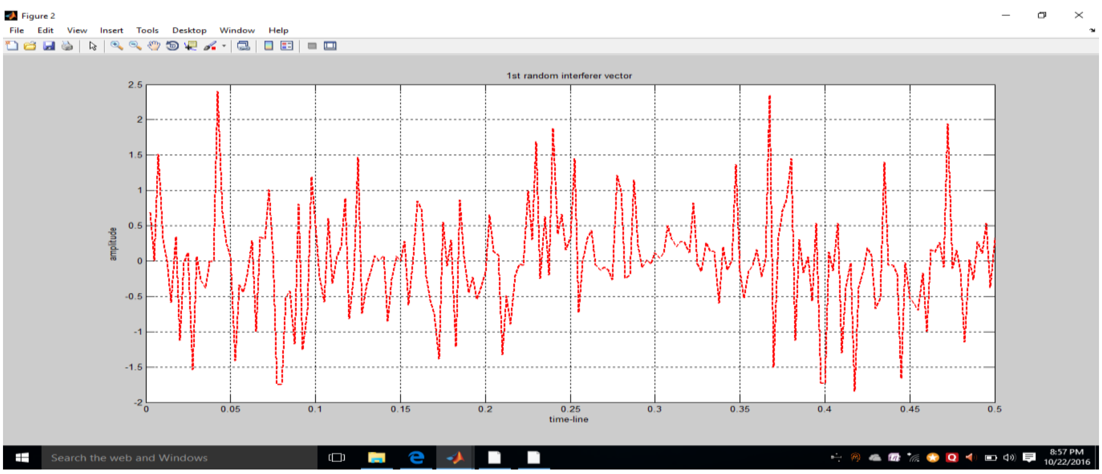

Figure 3 snapshot of 1st random interferer vector

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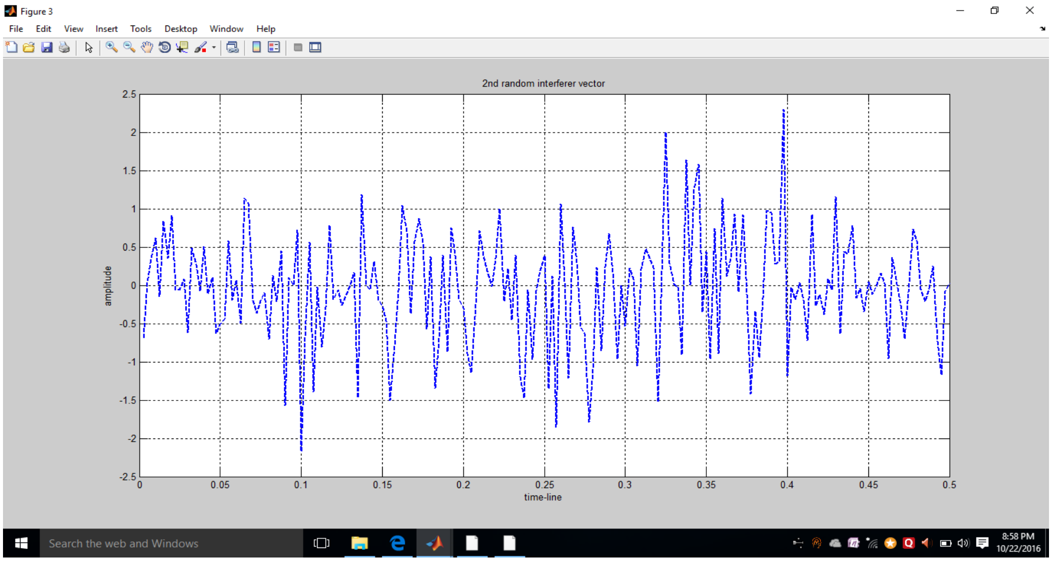

Figure 4 snapshot of 2nd random interferer vector

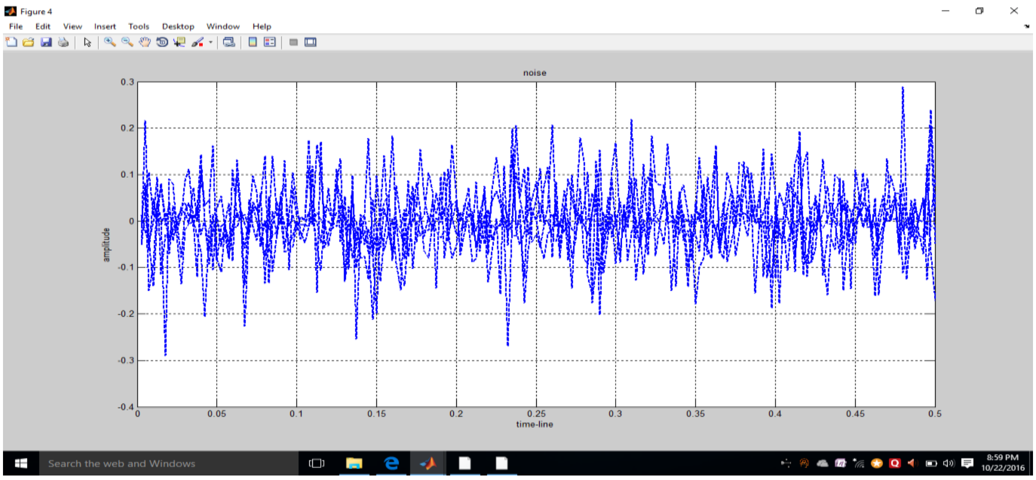

Figure 5 snapshot of magnitude of noise

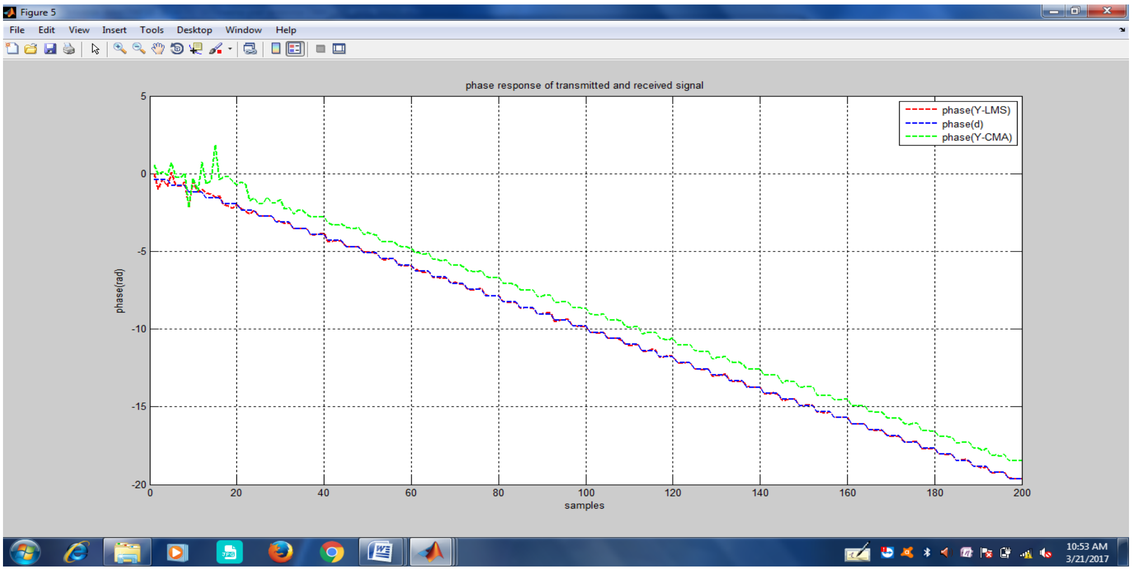

Figure 6 snapshot of phase response of transmitted and received signal

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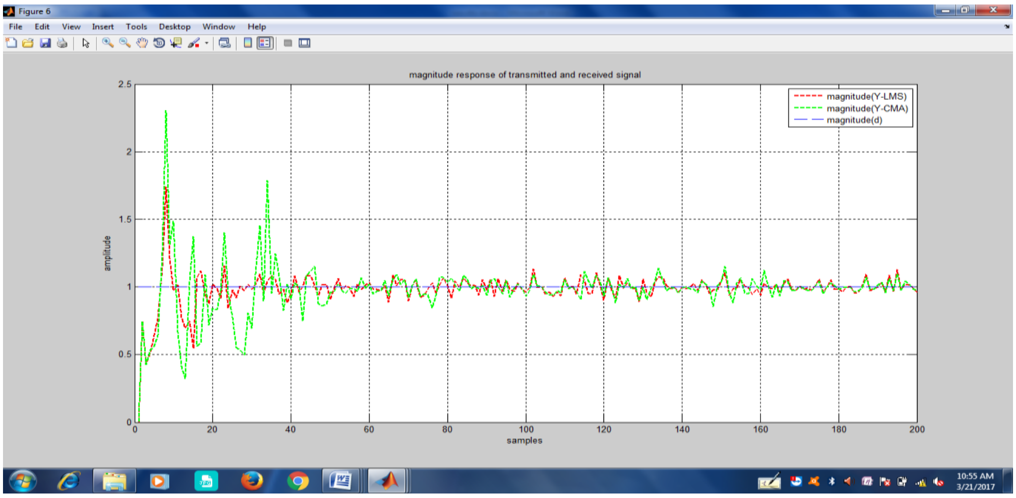

Figure 7 snapshot of magnitude response of transmitted and received signal

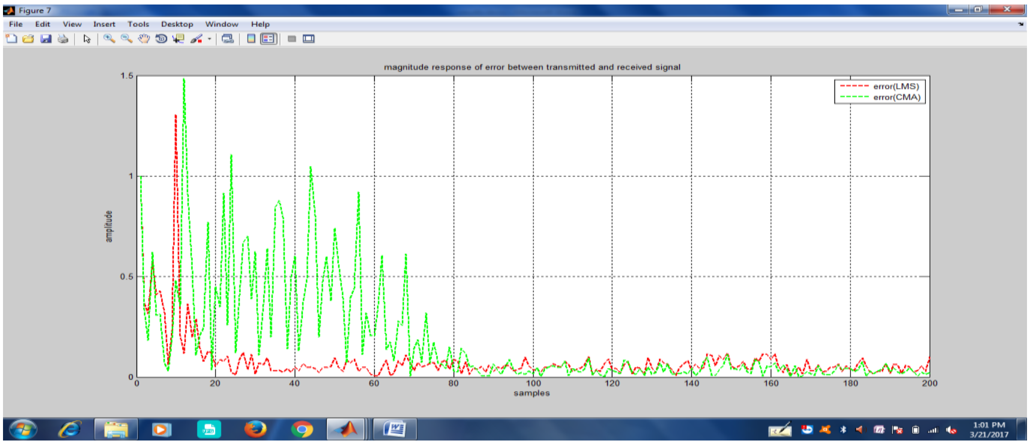

Figure 8 snapshot of magnitude response of error between transmitted and received signal

CONCLUSION

This research work has proposed simple but yet so effective modified digital beamforming algorithm using LMS algorithm. Instead of using basic LMS algorithm, some modifications have been done.

There are some points which could be concluded from experimental results.

1. The direction or phase of the input data signal slightly differs from received signal due to the presence of noise but the maximum signal can be retrieved. Proposed modified LMS method performing much well as compared to that of existing CMA algorithm.
2. The error magnitude between transmitted signal and received signal is very much reduced as compared to that of existing CMA algorithm. Proposed method only shows the considerable errors in the starting samples but in the case of existing showing repeatedly in later samples.
3. The magnitude response for received signal of proposed method is having very lesser transient. The maximum value of transient for proposed method is 1.2 but in the case of existing CMA, the algorithm is more than 1.5. It clearly shows that received signal deviates very lesser from transmitted signal.

From all above statements, it can be concluded that proposed method is performing much better as compared to existing CMA algorithm.

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