DEVELOPMENT OF MODIFIED DIGITAL BEAM FORMING ALGORITHM USING LEAST MEAN 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. 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 Mean 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 beam forming algorithm using LMS algorithm is developed. The aim behind developing this algorithm is to improve steady state response, reduce 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 reponse is calculated for both data signal and interferer signal using 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 further generation. The adaptation of smart antenna in the future wireless system is expected to have a significant impact on the proficient use of the spectrum [9].

Basically, an antenna is a device used to transmit or receive the electromagnetic waves. The Directivity or Gain of an isotropic antenna is equal in all directions. Generally such antennas are used for broadcasting (transmitter) applications. But for many applications the maximum gain (lobes) is desired in particular direction and attenuation (nulls) is desired in other direction [10].
Smart antenna technologies have attracted the growing mobile industry and the defense industry in almost every country. Multiple-input multiple-output antenna systems were later in-cooperated to the wireless technology. These systems are implemented by assembling the radiating elements or antennas in an electrical or geometrical configuration. The total field of an antenna array is formed by vector addition of the fields radiated or received by each individual element [11].
Adaptive array antennas are able to adapt in changing traffic requirements. These antennas are used at the base stations which radiates narrow beams to serve different users. Users are well separated spatially same frequency reused even if the users are in the same cell. The process of combining the signals and then focusing the radiation in the particular direction is often referred to as digital beam forming. Beamforming in Smart antenna is recognized as a promising technology for higher user capacity in 3G wireless networks by effectively reducing multipath and co-channel interference [12-14].
The new technology Smart Antenna has been used in the mobile communications systems like GSM and CDMA. 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 adaptive array. By using beam forming algorithms we can adjust the weight of antenna arrays to form 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 omni-directional 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].

In the past, various different algorithms have been implemented in the smart antennas. Those algorithms tracks 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 multi beam 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].

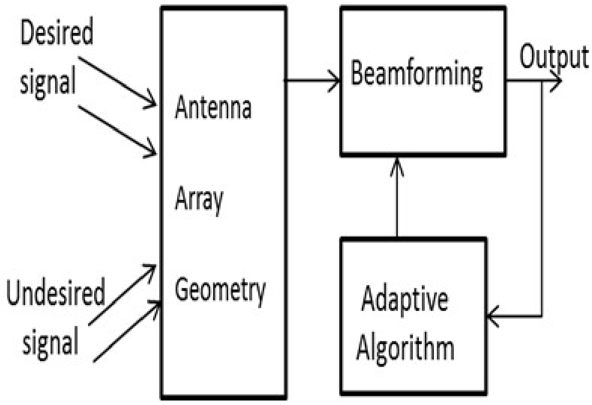

Figure1: Block diagram of Smart antenna system

Smart Antenna systems continually monitor their coverage areas and adapts to the users 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. 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].
SMI avoids the problem of eigen value spread that often limits the convergence rate for close-loop algorithms such as the Least Mean Square (LMS) approach. In practice, the SMI approach makes use of the Sample Average Estimate (SAE) of the data covariance matrix and the numerical inversion of the covariance matrix to find optimum weight values. The Auxiliary Vector (AV) algorithm is another fast beam forming method that uses the SAE of the covariance matrix to approach the MVDR optimum solution and does not need a numerical inversion operation. The results in [17] have shown that the sequence of AV filter estimators provide favorable bias/variance and have better mean square estimation error than LMS, Recursive Least Squares (RLS), SMI and orthogonal multistage decomposition filter estimators. One notes that the LMS algorithm has been widely used because of its simplicity in implementation. However, the trade offs of the LMS method includes its convergence speed and its dependency on the eigen value spread of the input signals. The RLS method uses a recursive matrix inversion algorithm that is more complicated but efficient than LMS. The above mentioned algorithms form a class of algorithms that can be implemented effectively using Digital Beamforming (DBF) technology [18].
A smart antenna system consists of a number of elements which are arranged in different geometries (like Linear, Circular, Time Modulated etc.) and whose weights are adjusted with signal processing techniques and evolutionary algorithms to exploit the spatial parameters of wireless channel characteristics under noisy environment. Smart antennas generally encompass both switched beam and beam formed adaptive systems. Switch beam systems have several available fixed beam patterns. A decision is made as to which beam to access, at any given point in time, based upon the requirements of the systems. Beam formed adaptive systems allow the antenna to steer the beam to any direction of interest while simultaneously nulling the interfering signals. The smart antenna concept is opposed to the fixed beam, dumb antenna, which does not attempt to adapt its radiation pattern to an electromagnetic environment which is ever changing in nature. In the past, smart antennas have alternatively been labeled adaptive arrays or digital beamforming arrays [19-20].

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, 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 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 stationary environment, unbiased convergence, and stable behavior when implemented with finite precision arithmetic. LMS algorithms are a class of adaptive filter used to mimic a desired filter by finding the filter coefficients [15].

PROPOSED METHODOLOGY

MATLAB R2013 has been used as an implementation platform using wireless communication and antenna tool box. In this work, a modified digital beam forming algorithm using LMS algorithm is developed. The aim behind developing this algorithm is to improve steady state response, reduce 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 reponse is calculated for both data signal and interferer signal using distance between the antennas (π/2) and direction angle of signals. Table 1 shows the input parameters used in proposed method.

Table 1: Input Parameters used in Proposed Method

S.No.	Parameter Name	Value
1.	Number of antenna	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 (X_{comp}) to be received

   $X_{comp} = \text{Cos}(\pi * X) + j \sin(\pi * X)$

   Where

   X is random sampled data stream

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 complex input signal and source noises or interferer signal. Also, it is assumed that antennas are separated by lambda/2

    Response (R_X) for complex input signals
    $R_X = e^{\wedge}(j^* K_i *\pi *\sin(\theta_x))$
    Where
    K_i is the antenna number, I=1-5
    Θ_x is direction angle for input signal

    Response (R_{N1}) for first interferer signal
    $R_{N1} = e^{\wedge}(j^* K_i *\pi *\sin(\theta_{N1}))$
    θ_{N1} is direction angle for 1st interferer signal (0^0)

    Response (R_{N2}) for first interferer signal
    $R_{N2} = e^{\wedge}(j^* K_i *\pi *\sin(\theta_{N2}))$
    θ_{N2} is direction angle for 2nd interferer signal

13. Computation of total signal combining responses of desired signal and source noises to the signal and noises.

- Computation of received signal (X) from signal source x
  $X = X_{comp} * R_x$
  Where
  X_{comp} is complex signal to be received
  R_x is Response for complex input signals

- Computation of received signal (n_1) from noise source n1
  $n_1 = X_{N1} *R_{N1}$
  X_{N1} is complex signal to be received
  R_{N1} is Response for 1st interferer signals

- Computation of received signal (n_2) from noise source n2
  $n_2 = X_{N2} *R_{N2}$
  X_{N2} is complex signal to be received
  R_{N2} is Response for complex 2nd interferer signals

- Computation of total received signal (X_{tot})
  $X_{tot} = N_{rand} + X + n_1 + n_2$
  Where,
  N_{rand} = random noise

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 (e) between transmitted and received signal
- $e(i+1) = X_{tot}(i+1) - Y(i+1)$
- Updation of weights (W) according to error and noisy signal
  $W(i+1) = W(i) + \mu^* e(i+1)^* X_{tot}$
  Where
  W(i) is calculated weight factor of last
  μ is gradient constant or gain constant
  e(i+1) is error between input and output
  Where Y is output signal
  $Y_1 (i+1)= W^* X_{tot}$

15. Initialization of CM 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 (e) between transmitted and received signal

  $e(i+1) = Y_1(i+1)/norm(Y_1(i+1)) - Y_1(i+1)$

  where

  Y_1 is the output received signal

  $Y_1(i+1) = W_1 * X_{tot}$
- Updation of weights (W_1) according to error and noisy signal

  $W_1(i+1) = W_1(i) + \mu * e(i+1) * X_{tot}$

  Where

  $W_1(i)$ is calculated weight factor of last

  μ is gradient constant or gain constant

  $e(i+1)$ is error between input and output

16. Calculation and Plotting of phase response of transmitted and received signal
17. Calculation and Plotting of magnitude response of transmitted and received signal
18. Calculation and Plotting of magnitude response of error
19. Calculation and plotting of amplitude Response for given Antenna Array

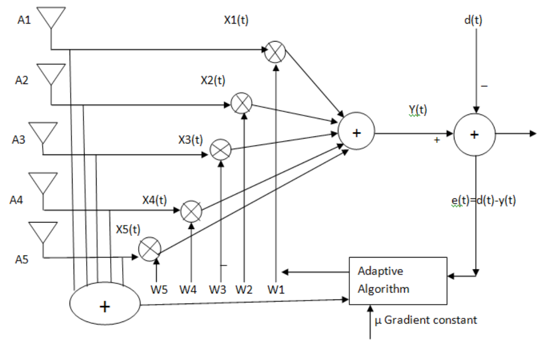

Figure 2: Block diagram of proposed methodology

EXPERIMENTAL RESULTS

In this work, a modified digital beam forming algorithm using LMS algorithm is developed. The aim behind developing this algorithm is to improve steady state response, reduce phase difference between input and output signal and to reduce the errror 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 reponse is calculated for both data signal and interferer signal using distance between the antennas ($\pi/2$) 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 2ndinterferer 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 ofinput 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 3 is the snapshot of complex signal at transmitter. Figure 4 is the snapshot of 1st random interferer vector. Figure 5 is the snapshot of 2nd random interferer vector. Figure 6 is the snapshot of magnitude of noise. Figure 7 is the snapshot of phase response of transmitted and received signal. Figure 8 is the snapshot of magnitude response of transmitted and received signal. Figure 9 is the snapshot of magnitude response of error between transmitted and received signal.

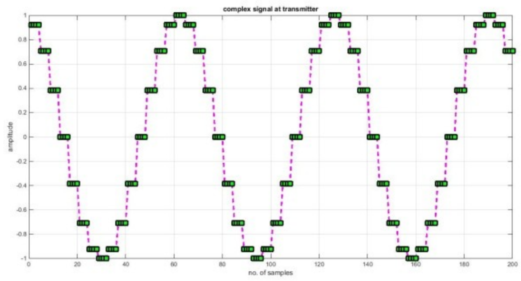

Figure 3: complex signal at transmitter

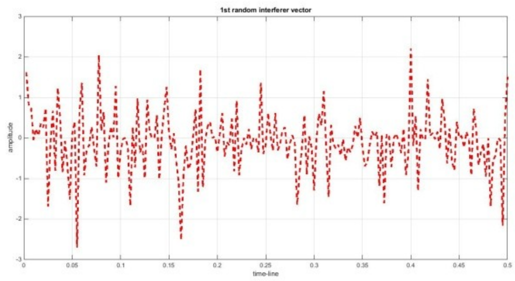

Figure 4:1st random interferer vector

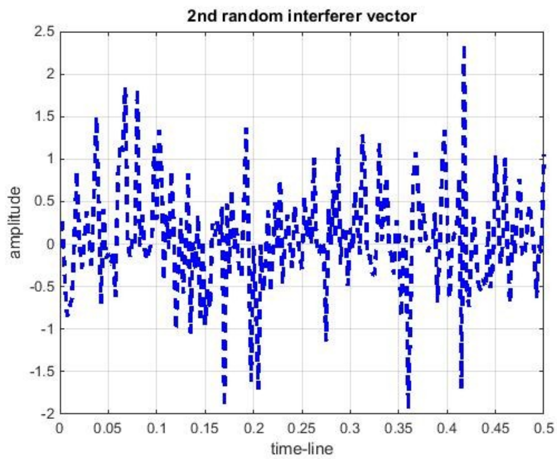

Figure5: 2nd random interferer vector

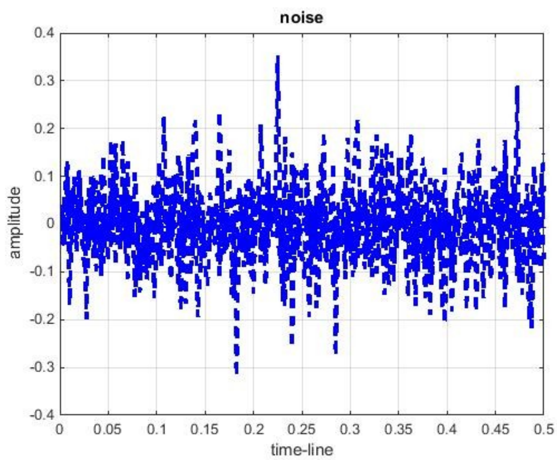

Figure6: magnitude of noise

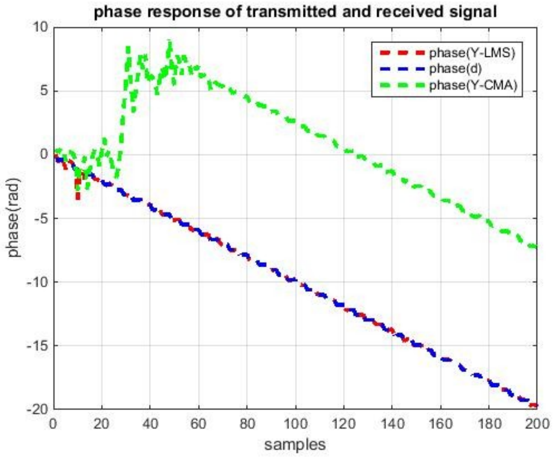

Figure7: phase response of transmitted and received signal

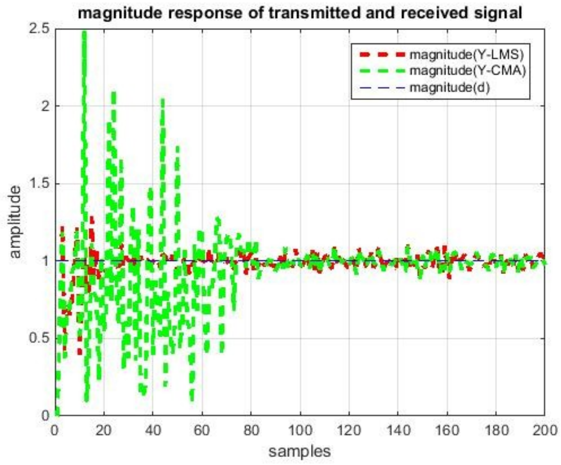

Figure8: magnitude response of transmitted and received signal

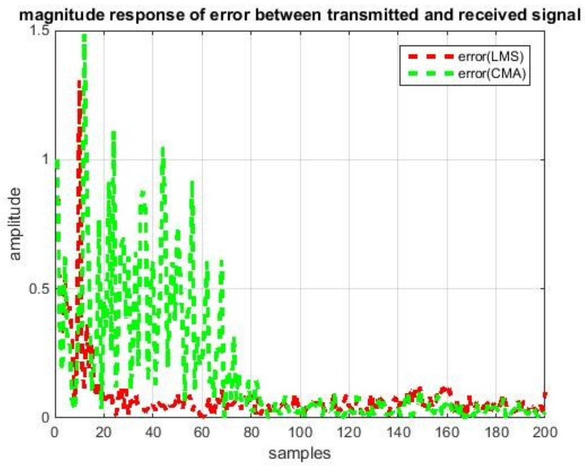

Figure9: magnitude response of error between transmitted and received signal

CONCLUSION

This research work has proposed simple but yet so effective modified digital beam forming 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 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 case of existing showing repeatedly in later samples.
3. The magnitude response for received signal of proposed method is having very lesser transient. Maximum value of transient for proposed method is 1.2 but in case of existing CMA 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.

REFERENCES

[1] A. Jhansi Rani and Ch. Raghavendra (2011), Adaptive Beam Forming Using DMI and CMA Algorithms, International Journal of Electronics Computing and Engineering Education, Volume 2, Number 1, PP. 13-16.

[2] Nwalozie G.C, Okorogu V.N, Umeh K.C, and Oraetue C.D (2012), Performance Analysis of Constant Modulus Algorithm (CMA) Blind Adaptive Algorithm for Smart Antennas in a W-CDMA Network, International Journal of Engineering Science and Innovative Technology (IJESIT), Volume 1, Issue 2, PP. 246-254.

[3] Javad Razavilar, Farrokh Rashid-Farrokhi, and K. J. Ray Liu (1999), Software Radio Architecture with Smart Antennas, Volume 17, Number 4, PP. 662-676.

[4] G.C Nwalozie, V.N Okorogu, S.S Maduadichie, A. Adenola (2013), A Simple Comparative Evaluation of Adaptive Beamforming Algorithms, International Journal of Engineering and Innovative Technology (IJEIT), Volume 2, Issue 7, PP. 417- 424.

[5] V.L. Bhavani Maddirala, C. Subba Rao (2011), Analysis of Smart Antenna Beamformer characteristics using CMA and DMI, International Journal of Scientific & Engineering Research, Volume 3, Issue 7, PP. 1-3.

[6] Amara Prakasa Rao, N.V.S.N Sarma (2014), Adaptive Beamforming Algorithms for Smart Antenna Systems, WSEAS Transactions on Communications, Volume 13, PP. 44-51.

[7] Ch. Santhi Rani, Dr. P.V Subbaiah and Dr. K. Chennakesava Reddy (2008), Smart Antenna Algorithms for WCDMA Mobile Communication Systems, International Journal of Computer Science and Network Security, Volume 8, Number 7, PP. 182-186.

[8] Ms Juslin F (2015), Simulations of Adaptive Algorithm for Spatial Beamforming, International Journal of Innovations in Engineering Research and Technology, Volume 2, Issue 6.

[9] Ms. Snehal N. Shinde Mrs. Ujwala A. Bongale (2015), A Review Paper on Adaptive Beamforming Algorithms for Smart Antenna, International Journal for Research in Technological Studies, Volume 3, Issue 1, PP. 14-18.

[10] B. S. Reddy, Dr. A. S. Bhalchandra, Dr. V. R. Ratnaparkhe (2014), Adaptive Digital Beam Forming using LMS Algorithm, IOSR Journal of Electronics and Communication Engineering, Volume 9, Issue 2, PP. 63-68.

[11] Chirappanath B. Albert, Hao Chen (2016), Performance Comparison in Digital Beamforming Using LMS, RLS and D3LS Algorithms, IJCSMC, Volume 5, Issue 5, PP. 221 – 230.

[12] A. Arunitha, T. Gunasekaran, N. Senthil Kumar, N Senthilvel (2015), Adaptive Beam Forming Algorithm for MIMO Antenna, International Journal of Innovative Technology and Exploring Engineering (IJITEE), ISSN: 2278-3075, Volume 4, Issue 8, PP. 9-12.

[13] Joseph Paulin Nafack Azebaze, Elijah Mwangi, Dominic B.O. Konditi, Performance Analysis of the LMS Adaptive Algorithm for Adaptive Beamforming, International Journal of Applied Engineering Research, Volume 12, Number 22, PP. 12735-12745.

[14] Hagar Sudha, Hema Karthik, Rashmi N. Reddy and C. Sivaprakash (2011), Fast Converging Layer Adaptive Beam Forming Algorithm, International Journal of Electronic and Electrical Engineering, ISSN 0974-2174, Volume 4, Number 2, PP.169-181

[15] Chintan S. Jethva and Dr. R.G. Karandikar (2013), Algorithms of Adaptive Beam Forming for Smart Antenna: A Comparative Study, IOSR Journal of Electronics and Communication Engineering (IOSR-JECE), Volume 8, Issue 1, PP. 27-30.

[16] K.R. Shankar Kumar and T. Gunasekaran (2009), Performance Analysis of Adaptive Beamforming Algorithms for Microstrip Smart Antennas, TECHNIA International Journal of Computing Science and Communication Technologies, Volume 2, Number 1, PP. 287-289.

[17] Lay Teen Ong (2015), Adaptive Beamforming Algorithms for Cancellation of Multiple Interference Signals, Progress in Electromagnetic Research, Volume 43, PP. 109-118 .

[18] Anupama Senapati, Jibendu Sekhar Roy (2016), Adaptive Beamforming In Smart Antenna Using The Byscheff Distribution And Variants Of Least Mean Square Algorithm, Journal of Engineering Science and Technology, Volume 12, Number 3, PP. 716 – 724.

[19] Somnath Patra, Nisha Nandni, Abhishek Kumar Pandey, Sujeet Kumar (2014), Study the Behavioral Change in Adaptive Beamforming of Smart Antenna Array Using LMS and RLS Algorithms, International Journal of Engineering Trends and Technology (IJETT), Volume17, Number 7, PP. 310-314.

[20] Satgur Singh, Er. Mandeep Kaur (2015), A LMS and LMNS Algorithm Analysis for Smart Antenna, International Journal of Advanced Research in Computer Science and Software Engineering, Volume 5, Issue 4, PP. 380-384.