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Adaptive Beamforming for Smart Antenna System Using Planar Antenna Array

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ABSTRACT
Smart Antenna System (SAS) is one of emerging technologies for the next generation of wireless communication systems. SAS has made the communication networks of higher capacity and better performance. Performance is also improved by using the appropriate adaptive algorithm to give high data rate.
This paper throw light on the Adaptive Beamforming when the smart antenna system uses a planar antenna array in its input. All results and graphs are simulated using MATLAB software.
***Keywords:* —** adaptive beamforming, Least Mean Square (LMS) algorithm, smart antenna, planar antenna array.

I. INTRODUCTION

A smart antenna is array of antenna elements combined with digital signal processor. Smart Antenna is an innovation to achieve maximum coverage, improved quality, and more capacity. This system is designed to address the previous issues through an advanced technique called Beamforming, through adaptive beamforming the base station can form narrower beam toward user whose signal is desirable and nulls toward interfering users whose signals are not desirable. The antenna array's weights can be adjusted to form an adaptive beam to automatically track users by using beamforming algorithm and to simultaneously minimize interference due to the users by introducing nulls in the directions of unwanted user [1].

This paper is focused on adaptive beamforming approach, Least Mean Square (LMS) algorithm, which is used in smart antenna system when the system uses planar antenna array in its input.

The paper is organized as follows: section (2) describes the smart antenna system and section (3) explains the planar antenna array. The description of LMS algorithm is described in section (4). Section (5) gives implemented simulation results and discussion. Finally in section (6) concludes the work.

II. SMART ANTENNA SYSTEM

The smart antenna technology is gaining more and more attention in increasing the capacity of wireless networks that helps to meet the increasing demand for high speed. Smart antennas are supported as a more technique for higher user capacity by minimizing multipath and co-channel interference and, as a result, improved data rate [2][3].

A smart antenna is an array of elements connected to a digital signal processor, such a structure effectively enhances the capacity of wireless link through a combination of diversity gain, array gain and interference suppression, increased capacity translates to high data rate for a given number of users or more users for a given data rate per user [4]. Fig.1 shows the functional block diagram of smart antenna system.

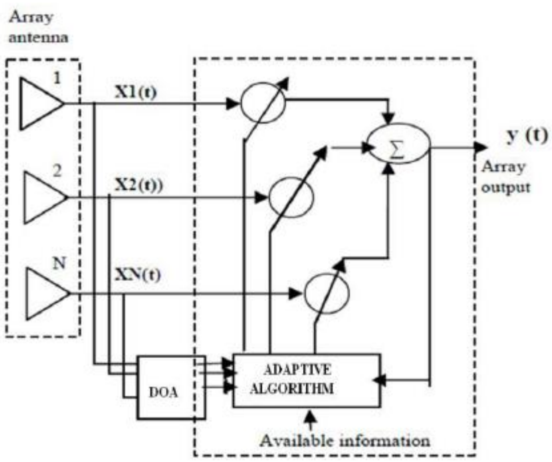

Fig.1 Functional block diagram of smart antenna system

SAS is divided into two main parts; the first one is an estimation of direction of arrival, which estimates the direction of arrival for all signals received by the antenna array, that including interference and multipath signals. This estimation is achieve using direction of arrival estimation algorithms. The second part is adaptive beamforming, which distinguishes the desired user signal and separates it from the rest of unwanted incoming signals, then directs the radiation to the desired user and follows it which moving, which placing the nulls towards interfering signals. This is done by continuously updating the weights of the antenna array elements, according to estimated directions and output error [5][6]. Smart antenna systems are generally categorized into either switched beam or adaptive array systems, In the following, we distinguish between two main categories, according to choices in transmit strategy [7][8][9].

A. Switched Beam Antenna:

Switched Beam Antenna systems form multiple fixed beams with heightened sensitivity in particular directions. These antenna systems detect the signal strength, select one of many predetermined, fixed beams, and switch from one beam to another depending on the mobility of the mobile device across the sector. Switched beam systems combine the outputs of multiple antennas in such a way as to form sectorized (directional) beams with more spatial selectivity than can be achieved using the conventional single element approach, fig.2.

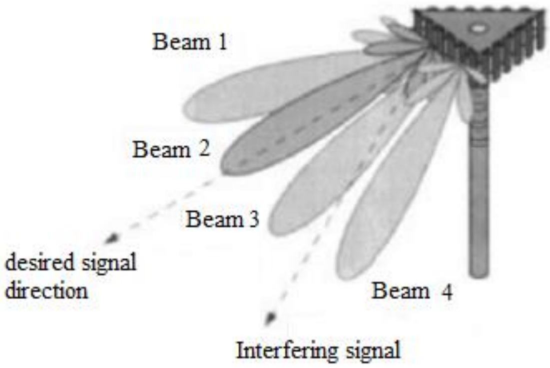

Fig. 2 Switched Beam System

B. Adaptive Array Antenna:

Adaptive Array technology represents the most advanced smart antenna approach to date, using a variety of new signal processing algorithms, the adaptive system takes advantage of its ability to effectively locate and track various types of signals to dynamically minimize interference and maximize intended signal reception. Fig.3.

Although both systems try to increase gain toward the user, only the adaptive array system provides optimal gain, simultaneously detecting, tracking and minimizing interfering signals [10].

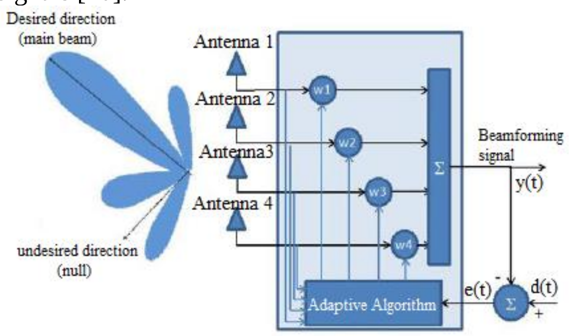

Fig. 3 Adaptive Array Antenna

III. PLANAR ANTENNA ARRAY

In planar array, elements are placed in a planar or rectangular grid. It can be viewed as M linear arrays of N elements or N linear arrays of M elements [11]. Assuming a planar array antenna with elements located in the x-y plane as shown in fig. 4.

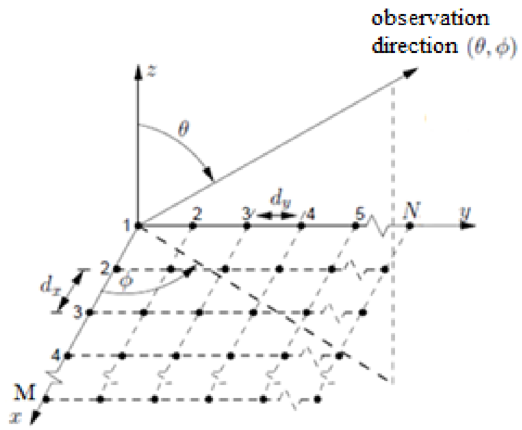

Fig. 4 Planar Antenna Array [12]

The total array factor can be separated into the product of two array factors as following:

$$AF(\theta,\varphi) = AF_x . AF_y = \sum_{m=1}^{M}\sum_{n=1}^{N} w_{mn}\, e^{j[(m-1)(\psi_x+\beta_x)+(n-1)(\psi_y+\beta_y)]} \quad (1)$$

Where

w_{mn} is the complex excitation of element mn.

$\psi_x = kd_x sin\theta cos\varphi$

$\psi_y = kd_y sin\theta sin\varphi$

$\beta_x = -kd_x sin\theta_0 cos\varphi_0$ and

$\beta_y = -kd_y sin\theta_0 sin\varphi_0$ are phase delays, which are used to steer the beam in desired direction.

d_x, d_y are element separations in the x and y directions, respectively.

IV. BASICS OF ADAPTIVE BEAMFORMING

The adaptive word means, automatically adjusts the directionality of radiation pattern in response to the signal's environment, this can be called as adaptive array antennas [13]. Adaptive beamforming is a mechanism that uses the antenna to achieve maximum transmission and reception in a particular direction according to estimated directions, while signals from the other directions are rejected until they operate at the same frequency. This can be achieved by varying the weights for each element of the antenna array. Although signals, which are using the same frequency are sent by different transmitters, they will arrive at different angles. This spatial separation is used to distinguish between the desired and undesired signals [14][15][16].

The simplest algorithm for adaptive processing is least Mean Square (LMS) algorithm. The LMS algorithm belongs to the classification of non-blind algorithms that uses a reference signal to calculate the error value between desired and actual outputs. According to the calculated error value, the LMS algorithm updates the weights of antenna array at each iteration. The output of this algorithm is given by equation [17][18]

$$Y(n) = w^H X(n) \qquad (2)$$

Where w is the complex weight vector and X is the received signal vector.

The LMS algorithm is based on the decent gradient where the error $e(n)$ is formed by next equation

$$e(n) = d(n) - w^H X(n) \qquad (3)$$

Where d(n) denotes to reference signal.

As we mentioned earlier the LMS algorithm uses the error value in order to update the weight vector for the next iteration. The weight vector is updated for the (n+1)th iteration using the following equation:

$$w(n+1) = w(n) + \mu X(n) e(n) \qquad (4)$$

Where μ is the step size.

The convergence of this algorithm is directly proportional to the step size. The stability of this algorithm is ensured by achieving the following condition.

$$0 \leq \mu \leq \frac{1}{\lambda_{max}} \qquad (5)$$

Where λ_{max} is the largest eign value of the correlation matrix Rxx which is given by following equation

$$R_{XX} = X(n) X^H(n) \qquad (6)$$

V. RESULTS AND DISCUSSION

To evaluate the performance of adaptive beamforming that is using the LMS algorithms to form the pattern when the smart antenna system uses a planar antenna array in its input, we consider a planar antenna array with 8×8 elements and half wavelength element spacing in X and Y directions (dx=dy=λ/2). The desired signal is assumed to impinge on the array from the direction $\theta_s = 45^\circ, \varphi_s = 60^\circ$ (elevation and azimuth angles, respectively). Two interferers signals are assumed to impinge the array from the directions $\theta_{i1} = 15^\circ, \varphi_{i1} = 30^\circ$ and $\theta_{i2} = 30^\circ, \varphi_{i2} = 10^\circ$. The noise is white Gaussian noise and it has a zero mean with variance $\sigma_n^2 = 0.1$. The iteration number has been set to 500 iterations and the step size of LMS algorithm is chosen as $\mu = 0.001$.

The simulation showed the possibility of forming the radiation toward the desired angle and suppressing the interference signals. Fig.5 shows the spatial representation of radiation pattern where the peak of the maximum radiation towards the desired signal at the angles $\theta_s = 45^\circ, \varphi_s = 60^\circ$, while the cancellation form towards the interference signals.

Fig.6 also shows the maximum radiation intensity at the intersection of the azimuth and elevation angles of the desired signal, and the radiation intensity is minimal at the interfering signals $\theta_{i1} = 15^\circ, \varphi_{i1} = 30^\circ$ and $\theta_{i2} = 30^\circ, \varphi_{i2} = 10^\circ$.

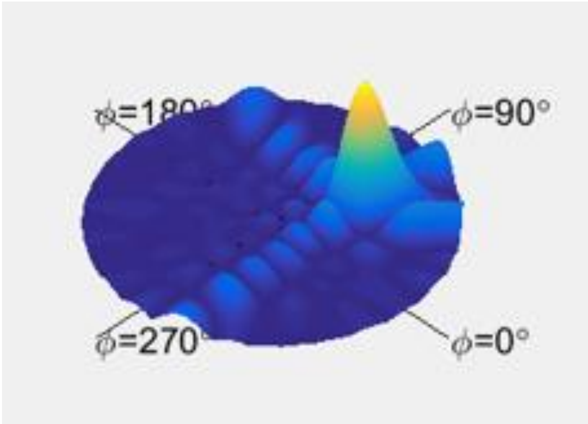

Fig. 5 spatial representation of the beam formed towards the desired signal

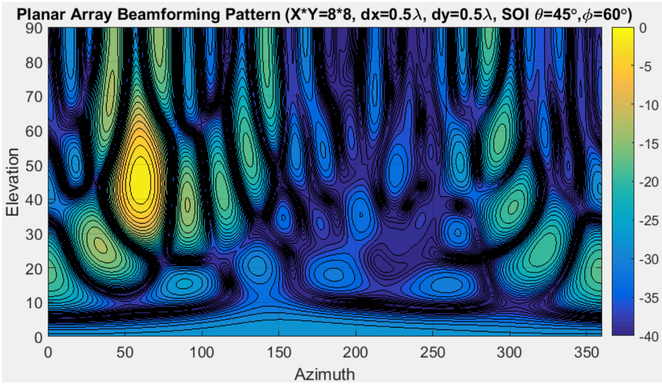

Fig. 6 The formation of the radiation intensity at the desired angle

The fig.7 and fig.8 illustrate the progression of amplitudes and phases of the currents that are used to excitation of the planar array elements, where the excitation amplitudes and phases appear for 64 antenna elements that form the imposed planar antenna array.

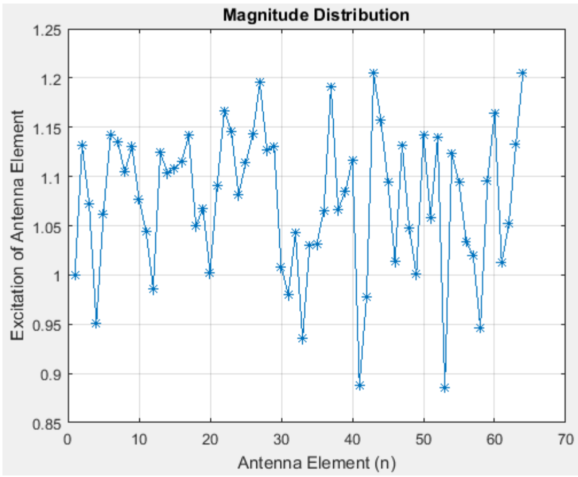

Fig. 7 The distribution of the amplitude of the excitation currents for planar array elements

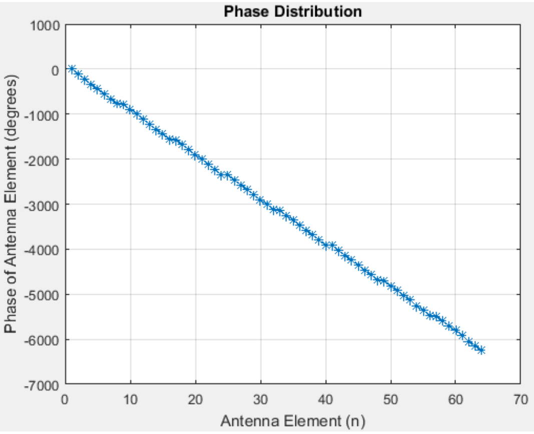

Fig. 8 The distribution of the phase of the excitation currents for planar array elements

Fig.9 depicts a decrease in the mean square error (MSE) value with an increase in the number of iterations. It is noted that LMS algorithm needs 20 iterations to reach a minimum error value between the reference and actual outputs, then the algorithm stabilizes.

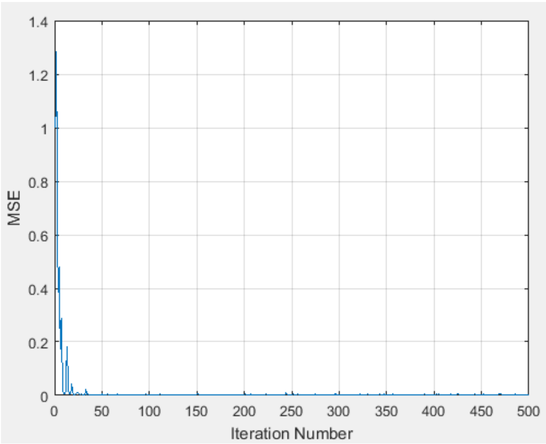

Fig. 9 MSE vs. iteration number

The fig.10 shows the weight error that represents the difference between the current and the previous weights. The value of this error decreases with the increase in the number of iterations until the error stabilizes between 0 and 0.003 after 40 iterations.

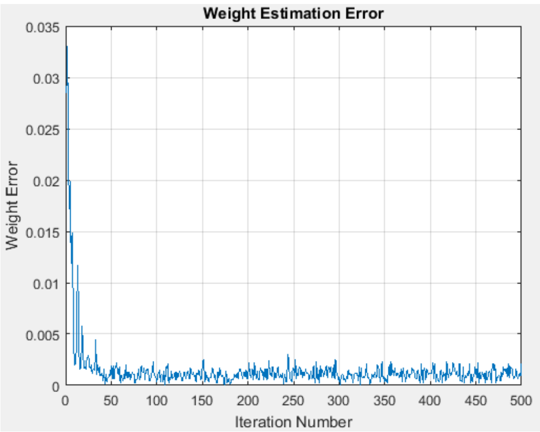

Fig. 10 weight error vs. iteration number

Fig.11 represents the beamforming pattern at the azimuth plane for a constant elevation angle $\theta_s = 45^\circ$. The figure also shows that the main lobe of radiation is formed towards the desired azimuth angle $\varphi_s = 60^\circ$, while the lower side lobes appear in other directions.

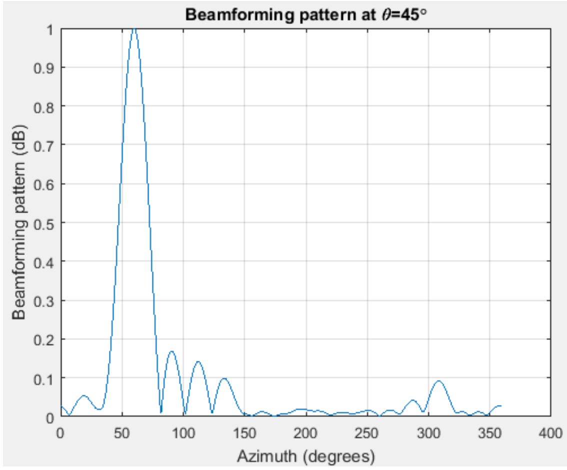

Fig. 11 Radiation pattern in azimuth plane

The fig.12 also shows the radiation pattern at the elevation plane for a constant azimuth angle $\varphi_s = 60^\circ$, where the main lobe of radiation at the desired azimuth angle $\theta_s = 45^\circ$, it also shows corresponding main lobe after 90^o, i.e. at the angle 135^o.

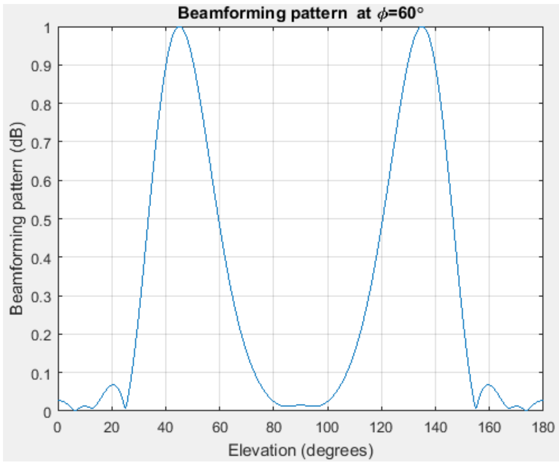

Fig. 12 Radiation pattern in elevation plane

VI. CONCLUSIONS

This paper discussed the possibility of beamforming using an adaptive LMS algorithm for smart antenna system, which uses a uniform planar antenna array in its input. This paper shows how radiation is formed towards the desired signal and nulls towards interference signals.

It also showed that the error decreased until it reached its minimum value and that LMS algorithm needed to 20 iterations until it stabilized. The results showed the formation of radiation in the azimuth plane and the elevation plane separately for a constant elevation and azimuth angle, respectively.

REFERENCES

[1] A. Patwari, G. R. Reddy, H. Gupta, and V. Nigam, "Suitability of Conventional 1D Noise Subspace Algorithms for DOA Estimation using Large Arrays at Millimeter Wave Band," International Journal of Applied Engineering Research, vol. 12, pp. 1591-1597, 2017.

[2] K. A. Kumbar, "Adaptive Beamforming Smart Antenna for Wireless Communication System," International Research Journal of Engineering and Technology, vol.2, pp. 2038-2043, June 2015.

[3] G. Prajapati, and K.C. Mahajan, "Smart Antenna Design for Wireless Communication Using Adaptive Beam-Forming Approach," International Journal of Engineering Sciences & Management, vol.2, pp.36-39, Jan-Mar. 2012.

[4] S. Patidar, K. Kumbhare, and S. Chouhan," Improvement of Spectral Efficiency and Power Control of Smart Antenna," International Journal Of Engineering Sciences & Research Technology, vol.6, pp.736-741, May 2017.

[5] H. M. EL-Kamchouchi, and A. S. EL-Torgoman, "Towards a Precise Direction of Arrival Estimation for Coherent Sources Using EC-MUSIC," Journal of Electrical and Electronic Engineering, vol. 4, pp.40-43, 2016.

[6] A. S. Bhinder, A. Kumar, and E. Belani, "Smart Antenna Investigations for Wireless Cellular Systems," International Journal of Emerging Technologies in Computational and Applied Sciences, vol. 8, pp. 291-294, March-May 2014.

[7] R. Akarte, G. Sorte, T. Tayade, and P. Patil, " Mobile Communication using Smart Antenna System," International Journal of Innovations & Advancement in Computer Science, vol.7, pp. 264-268, March 2018.

[8] L. Bansod, and A. S. Bundela," A survey of Adaptive Beamforming Strategy in Smart Antenna for Mobile Communication," International Research Journal of Engineering and Technology, vol.4, pp. 791-794, Jan. 2017.

[9] S. Hokam, A. Dandekar, A. Tiwari,and G. Sheikh, "An Overview of LMS Adaptive Beamforming Algorithm for Smart Antenna," International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering, vol. 5, pp. 94-97, January 2016.

[10] M. A. Abdala, and A. K. Al-Zuhairy, "Integration of Smart Antenna System in Mobile Ad Hoc Networks," International Journal of Machine Learning and Computing, Vol. 3, pp. 342-346, August 2013.

[11] A. P. Rao, and N. V. S. N. Sarma, "Adaptive Beamforming Algorithms for Smart Antenna Systems," WSEAS TRANSACTIONS on COMMUNICATIONS, vol. 13, pp. 44-50, 2014.

[12] A. Naceur, and B.Merah,"Two-Dimensional Angle of Arrival Estimation with a High Resolution Algorithm," International Conference on Systems and Processing Information,12-14 May, 2013.

[13] Banuprakash. R, H. G. Hebbar, Sowmya.M, and Swetha. M, "Evaluation of MUSIC algorithm for DOA estimation in Smart antenna," International Advanced Research Journal in Science, Engineering and Technology, Vol. 3, pp. 185-188, May 2016.

[14] M. Al-Sadoon, R. A. Abd-Alhameed, I. T. E. Elfergani, J. M Noras, J. Rodriguez, and S. M. R. Jones, "Weight Optimization for Adaptive Antenna Arrays Using LMS and SMI Algorithms," WSEAS TRANSACTIONS on COMMUNICATIONS, vol. 15, pp. 206-214, 2016.

[15] B. Ramineni, G.C. Sagar, K. A. Jain, M. S. G. Prasad, T. V. Ramakrishna, and K. S. Kumar, " Comparison and performance evaluation of different adaptive beam forming algorithms in wireless communications with smart antenna," International Journal of Engineering Research and Applications, vol.2, pp. 630-633, May-Jun 2012.

[16] B.G.Hogarde, S.Wadhe, and S.K.badhe,"Mitigating Effect of CCI and Multipath in Mobile Communication using Smart Antenna," National Conference on Emerging Trends in Engineering & Technology,pp.366-370,30 March, 2012.

[17] D. B. Salunke, and R. S. Kawitkar, "Analysis of LMS, NLMS and MUSIC Algorithms for Adaptive Array Antenna System," International Journal of Engineering and Advanced Technology, vol. 2, pp. 130-133, February 2013.

[18] F. Ali, P. Rawat, and S. Malvia, "Comparative Analysis and Survey of LMS and RLS Adaptive Algorithms," International Journal of Computer Applications, vol.161, pp. 26-29, March 2017.