Performance Analysis of Blind Constant Modulus Algorithm for Smart Antenna in Wireless Communication

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***Abstract*— Smart Antenna is recognized as an important technique for increasing the user capacity of a Wireless Communication network. Smart antennas usually consist of a number of radiating elements (i.e. array antennas) with smart signal processing algorithms used to identify spatial signal signature such as the direction of arrival. Smart antennas usually include both switched beam forming and adaptive beam forming systems. These algorithms are embedded in smart antenna which calculates optimum weight vector that minimizes the total. In this paper, constant modulus algorithm (CMA) kind of blind algorithm are applied for estimated Beamforming. The performance of the traditional CMA algorithm for different number of element array antenna are analyzed in this paper. The CMA technique algorithm was implemented using Matlab code software.**

***Keywords*—Adaptive array, wideband beam-forming, wideband smart antenna.**

I. Introduction

SMART antennas are also known as adaptive array antennas or the 4th generation antennas. These are known a smart antennas because they follow smart signal processing algorithm which are capable of identifying the signal signatures such as direction of arrival (DOA) and this is further used to calculate the beamforming vectors. This beamforming vectors have the ability to track and locate beam on mobile device. Smart antenna is one of the most promising technologies that will enable a higher capacity in wireless communications effectively reducing multipath and co-channel interference. This is achieved by focusing the radiation only in the desired direction and adjusting itself to changing traffic conditions or signal environments. They are capable of automatically changing the directionality of their radiation patterns in the response to their signal environment so they basically attempt to enhance the desired power and suppress the interferers by beamforming toward the DOA of the desired signal and null steering in the case of the interferences. In a Smart antenna system the arrays by themselves are not smart, it is the digital signal processing that makes them smart [1]. The process of combining the signals and then focusing the radiation in a particular direction is often referred to as digital beam forming. Smart antennas utilize the services of multiple antennas to increase the signal reliability. In order to achieve that, the smart antenna base station has an array of antenna along with a control unit so that to divert the beam pattern of the smart antenna array systems according to the requirement[1]. There are several techniques which are used in conjunction with the antenna processing diversity. This includes spatial diversity which is based on multiple antennas, pattern diversity which utilizes the services of the co-located antennas, polarization diversity which uses dual antenna system and transmit / receive diversity which uses separate antennas for transmission and receiving. Smart antennas have the ability to operated in forward or reverse mode both with single and multiple users.

II. The Model of Beamforming Techniques

A. Switched Beam

The Switched beam approach is simpler compared to the fully adaptive array approach. It provides a considerable increase in network capacity when compared to traditional Omni directional antenna systems or sector-based systems.

The antenna systems detect signal strength, choose from one of several predetermined, fixed beams and switch from one beam to another as the mobile moves throughout the sector as shown in Figure 1.

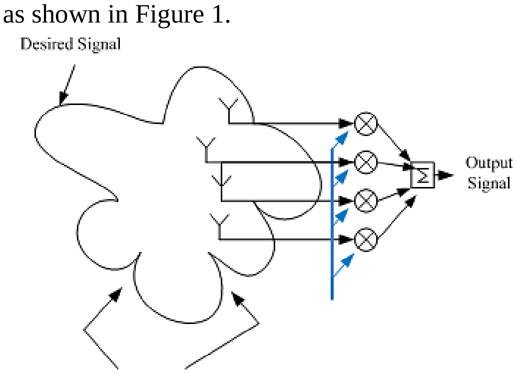

Fig. 1. Switched beam system

B. Adaptive Arrays

The adaptive array system chooses a more accurate placement, thus providing greater signal enhancement as illustrated in Figure 2. Adaptive antenna technology can dynamically alter the signal patterns to optimize the performance of the wireless system. Adaptive array systems provide more degrees of freedom since they have the ability to adapt in real time the radiation pattern to the radio frequency (RF) signal environment [2].

The interfering signals arrive at places of lower intensity outside the main lobe, but again the adaptive system places these signals at the lowest possible gain points. According to signal space information smart antenna can form directional beam in space with the adaptive beam forming algorithm, achieving that the main beam aims at the direction of the expected signal while the side lobe and nulls aims at the interference.

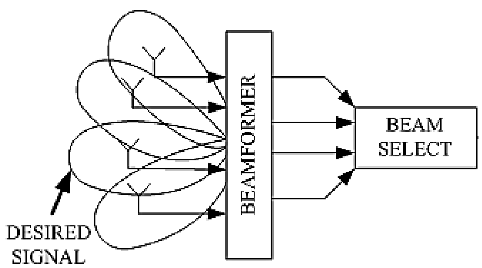

Fig. 2. Adaptive Array

III. THE CONSTANT MODULUS ALGORITHM

Many adaptive beam forming algorithms are based on minimizing the error between reference signal and array output. The reference signal is typically a training sequence used to train the adaptive array or a desired signal based upon a priori knowledge of nature of the arriving signals. In the case where a reference signal is not available one must resort to an assortment of optimization techniques that are blind to exact content of the incoming signals [4][5]. CMA is blind algorithm which uses to estimate of the gradient vector from the available data. This algorithm makes successive corrections to the weight vector in the direction of the negative of the gradient vector which finally concludes to minimum mean square error (MSE). The CMA beamforming network illustrated in Figure 3. with N isotropic elements, which forms the integral part of the adaptive beamforming system. The number and types of parameters within proposed model depend on the computational structure chosen for the smart antenna system [6, 7, 8].

Considering a linear beam former followed by CMA in an arrangement using multiple inputs at its array's elements as shown in figure 3. On the elements of antenna the signal array vector received is written as:

$$X_n = [x1, x2, \dots, x_N]^T \qquad (1)$$

Where T signifies the transpose of the vector within the brackets and linear array having N- element composed of radiating antenna elements. The digital signal processor interprets the incoming data information, determines the complex weights (amplitude and phase information) and multiplies the weights to each element output to optimize the array pattern. Then output of the CMA section at *nth* iteration can be defined as:

$$y_n = W_n X_n \qquad (2)$$

Where n is the iteration number., and W is the complex weights vector and X is the received signal vector, then we can wet the complex weights vector as follows:

$$W_{n+1} = W_n + \mu\, e_n X_n \qquad (3)$$

μ is the step size and e_n is the error signal and is given by

$$e_n = \left(y_n - \frac{y_n}{|y_n|}\right) \qquad (4)$$

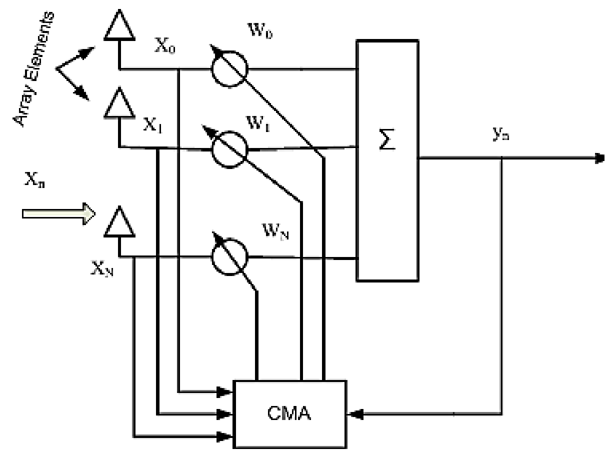

Fig. 3. CMA Beam forming system

IV. SIMULATION METHODOLOGY AND RESULTS

In the algorithm of CMA was implemented by using Matlab code software which the steps of the model are illustrated in Figure 4. The model was executed by 8 steps where linear array is taken with different number of element array antenna for simulation purpose. The spacing between array elements is taken as 0.5 λ to prevent spatial aliasing, the number of samples equal 150, and system noise variance = 0.1. If a large value of step size **μ** is taken then convergence becomes faster but makes the array system unstable/noisy. Conversely if a small value is taken then convergence becomes slow that is also not desirable. Therefore, value of **μ** is taken 0.05 for good convergence. The graph is obtained between phase of desired signal and Phase of Output array CMA signal are indicted in Figure 5. and Figure 6, and we can see two lines a red and a blue. Blue is the phase of desired signal and red is the phase of output array CMA Signal. So in this way we see there is not much difference in the desired and the obtained Output. It is obvious from the above results that by decreasing the value of the step size parameter, a faster convergence is achieved.

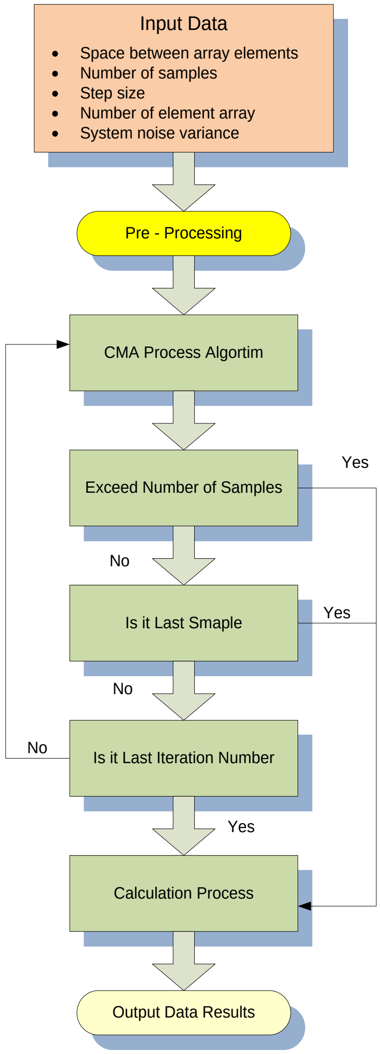

Fig. 4. Flowchart Simulation Algorithm

The Figure 5 show the phase of output array CMA signal increasing and shifted slowly.

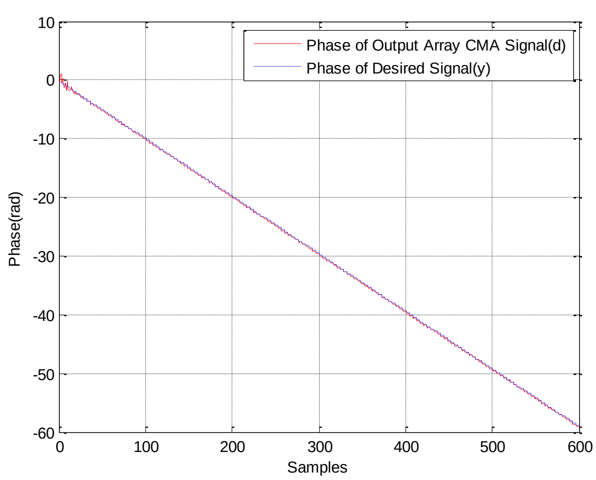

Fig. 5. Comparison of the phase of desired signal and output for CMA signal with number of element array = 4

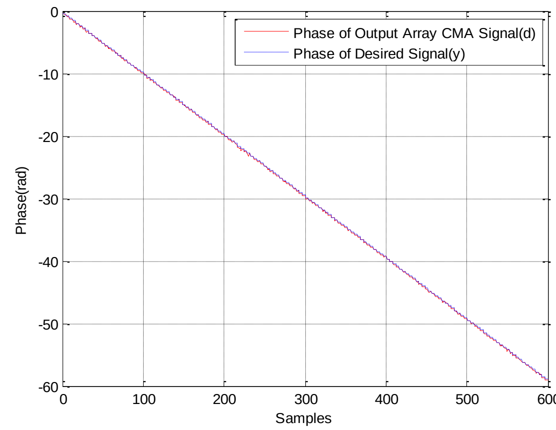

Fig. 6. Comparison of the phase of desired signal and output for CMA signal with number of element array = 8

The consequence of using different number of element array antenna, the magnitude of desired signal and output for CMA signal are changeable and that indicated in Figure 7 and Figure 8. Based on these results, the following can be observed: in Figure. 7, the waveform of the CMA algorithm initially displayed a lot of noise and spikes and after 50th sample displayed almost a smooth waveform. In Figure. 8, the pattern of the waveform became more sharping spikes signifying a more noisy output.

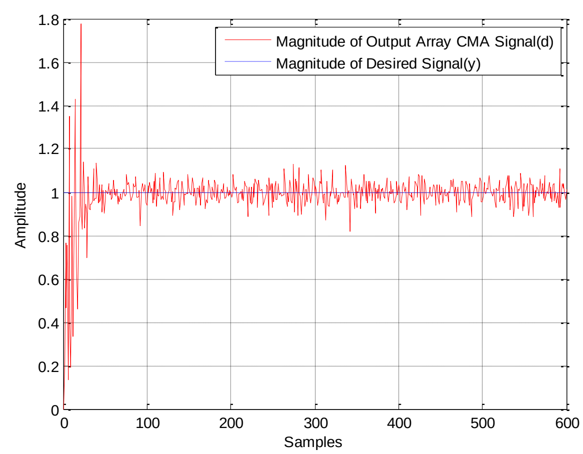

Fig. 7. Comparison of the magnitude of desired signal and output for CMA signal with number of element array = 4

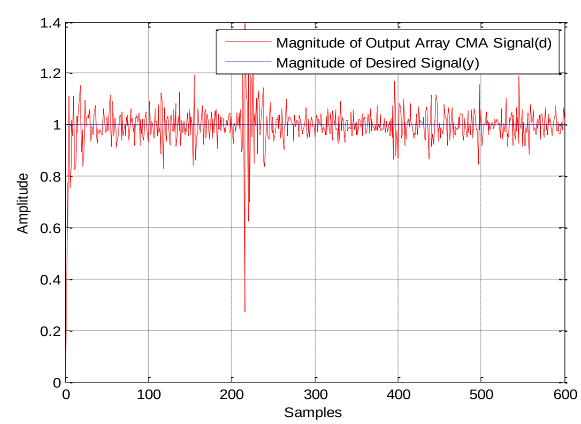

Fig. 8. Comparison of the magnitude of desired signal and output for CMA signal with number of element array = 8

The effect of number of elements on effect error and noise for constant space 0.5 λ between elements is shown in Figure 9 and 10 for 4 and 8 elements respectively. From these figures, it is clear that minimum error and noise is obtained for number of element equal 4 when same μ =0.05 is taken for comparison. It can be observed that the error curve of the CMA algorithm in Figure. 9 assumes the most strong error values before the 25th iteration. When compared to the error values of the CMA algorithm in Figure. 10, we see that the strong error curve values occurred twice, before the 25th and at the 220th samples. we also notice a clearer distinction between that Figure.9 and 10 in terms of the error values. The value of the error curve as can be observed in Figure. 10 does not come as low as that of Figure. 9. These results signify less errors occurring where using 4 element array. Through these results, we can suggest that the smart antenna with number of element array = 4 provides better directivity and a better SNR over the CMA algorithm.

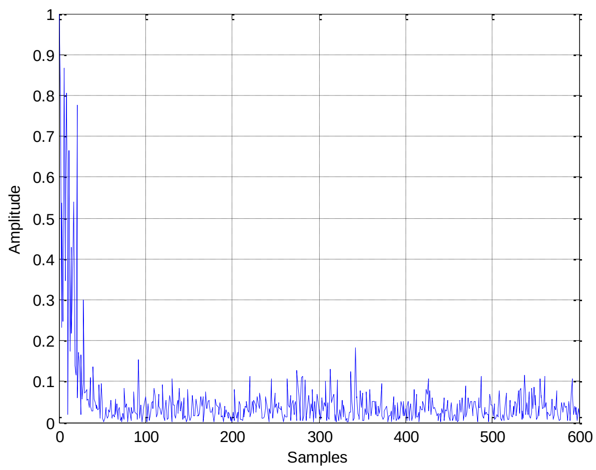

Fig. 9. The curve of error between desired signal and output CMA signal with number of element array = 4

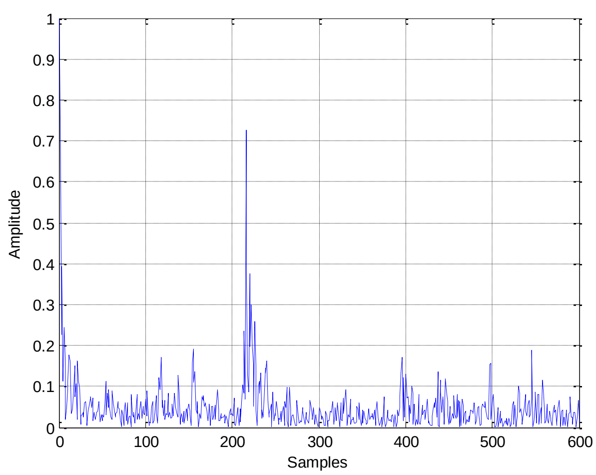

Fig. 10. The curve of error between desired signal and output CMA signal with number of element array = 8

The Figure 11 show the strong of interference at −68◦ was -50 dB ,while maintaining the main lobe in the direction of useful signal (at 37◦). In case of 8 element array, the Figure 12 show that the interference at the same angle are decreased to the -39 dB but with more undesired sidelobes. In this approach, the adaptive array can track the signals, and allocate beams in the direction of the useful signal while simultaneously minimize unwanted sources of interference.

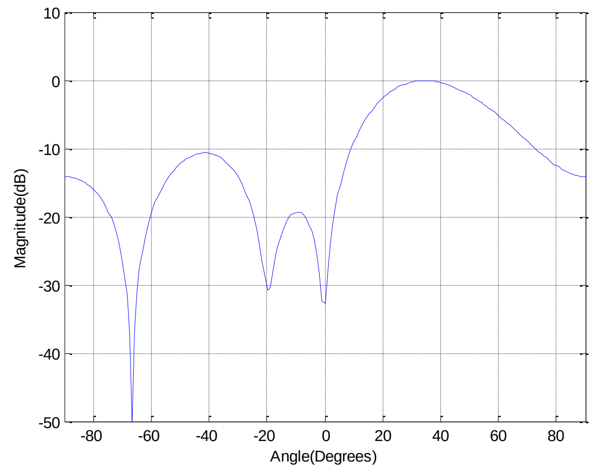

Fig. 11. Amplitude response for given antenna array with number of element array = 4

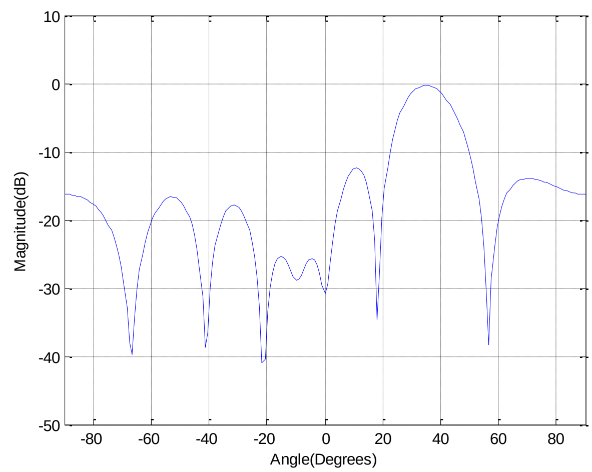

Fig. 12. Amplitude response for given antenna array with number of element array = 8

The magnitude of amplitude response plots in Figure.11, and Figure.12 show that the CMA algorithm is able to iteratively update the weights to force deep nulls at the direction of the interferer and achieve maximum in the direction of the desired signal. By increasing the number of elements it is observed that the magnitude of amplitude response is maximum for the desired signal with more of interferer.

V. Conclusion

In this paper, the beamforming technique algorithms are discussed. We have proposed adaptive beamforming blind CMA algorithm for smart antennas. During the simulation. the different number of array element are considered. This algorithm are used in smart/adaptive antenna array system in coded form to generate beam in the look direction and null towards interferers, thus enhancing mobile communication performance both in quality and capacity.

From the analysis and simulation model it is Important to know just the signal characteristics to get the desired signal.

We can Indicate from the simulation results that the number of element array antenna has significant effect for design the smart antenna systems. Thus the most optimum values obtained for antenna array are $N = 4$ (no. of elements) and $d = 0.5\lambda$ (inter-element spacing). One of the benefits which accrue from the use of CMA for smart antenna is that users residing in different beams but in the same cell are able to reuse intra-cell frequency.

REFERENCES

[1] J. Winters, "Smart antennas for wireless systems," *IEEE Personal Communications, vol.2,* pp. 23-27, Feb 1998.

[2] R. Sahu, R. Mohan, & S. Sharma, " Evaluation of adaptive beam forming algorithm of smart antenna*," International Journal of Scientific Engineering and Technology,* vol. 2, pp. 1031-1037, Oct 2013.

[3] S. Haykin, "Adaptive filter theory", Forth edition, Pearson education asia, Second Indian reprint, 2002.

[4] G. Frank, "Smart Antenna For Wireless Communication" Mcgraw-hill, Sept14, 2005.

[5] C. B. Dietrich Jr., Adaptive arrays and diversity antenna configurations for handheld wireless communication terminals [Ph.D.thesis], Virginia Polytechnic Institute, State University, 2000.

[6] A. Ozen, I. Kaya, and B. Soysal, "A supervised constant modulus algorithm for blind equalization," *Wireless Personal Communications*, vol. 62, no. 1, pp. 151–166, 2012.

[7] S.F. Shaukat, Mukhtar ul Hassan, R. Farooq, H. U. Saeed and Z. Saleem, "Sequetial studies of beamforming algorithms for smart antenna systems," *World Applied Sciences Journal* 6 (6): pp. 754-758, ISSN 1818-4952, 2009.

[8] G.C. Nwalozie, V. Okorogu, K.C. Umeh, and C.D. Oraetue, "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),* vol. 1, pp. 246-254, Nov 2012.