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Research Paper

PERFORMANCE OF BEAMFORMING FOR SMART ANTENNA USING MODIFIED LMS ALGORITHM

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Smart antenna systems attract lot attentions now and believably more in the future, as it can increase the capacity of mobile communication systems dramatically. Adaptive signal processing sensor arrays, known also as smart antennas .The smart antenna adaptive algorithms achieve the best weight vector for beam forming by iterative means. The Least Mean Square (LMS) algorithm, is an adaptive algorithm. LMS incorporates an iterative procedure that makes successive corrections to the weight vector in the direction of the negative of the gradient vector which eventually leads to the minimum mean square error, Compared to other algorithms LMS algorithm is relatively simple; it does not require correlation function calculation nor does it require matrix inversions. The traditional LMS algorithm is explained in this paper then performance of Modified LMS algorithm is analyzed. This algorithm can be applied to Smart antenna system to observed beam forming with the software Matlab. Both the algorithms are compare, the result obtain is achieving faster convergence and lower steady state error. The algorithms can be simulated in MATLAB 7.10 version.

Keywords: Smart antenna, LMS algorithm, Direction of arrival (DOA)

INTRODUCTION

Traditional base station antennas are Omni-directional; this is actually a waste of power because most of it will be transmitted in other directions than toward the desired user. In addition, other users will experience the power radiated in other directions as interference. A promising technique to increase the spectrum efficiency is using smart antennas. This technique adds a new way of separating users on one base station by space, so called Spatial Division Multiple Access (SDMA). This is because smart antennas have tremendous potential to enhance the performance of future generation wireless systems as evidenced by the antennas' recent deployment in many systems. Smart antenna systems attract lot attentions now and believably more in the future, as it can increase the capacity of mobile communication systems dramatically (Wang and Giesner, 2006). This is because smart

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antennas have tremendous potential to enhance the performance of future generation wireless systems as evidenced by the antennas' recent deployment in many systems. There are two basic types of smart antennas. The first type is the phased array or multibeam antenna, which consists of either a number of fixed beams with one beam turned on towards the desired signal or a single beam (formed by phase adjustment only) that is steered toward the desired signal. The other type is the adaptive antenna array is an array of multiple antenna elements, with the received signals weighted and combined to maximize the desired signal to interference plus noise power ratio (Shiann-Jeng and Ju-Hong, 1996). This essentially puts a main beam in the direction of the desired signal and nulls in the direction of the interference. A smart antenna is therefore a phased or adaptive array that adjusts to the environment. That is, for the adaptive array, the beam pattern changes as the desired user and the interference move; and for the phased array the beam is steered or different beams are selected as the desired user moves. Nearly every company the WTEC panel visited is doing significant work in smart antennas. Indeed, some companies placed strong emphasis on this research. In particular, researchers at NEC and NTT stated that they felt that smart antenna technology was the most important technology for fourth generation cellular systems. Researchers at Filtronics and other companies agreed that smart antenna technology was one of the key technologies for fourth generation systems (Shiann-Jeng and Ju-Hong, 1996).

SMART ANTENNA

Smart antennas are composed of a collection of two/ N number of equally/unequally spaced antennas (Sidi Bahri and Fethi, 2009) jointly works to achieve a unique radiation pattern. The antenna elements work in group/array, which is accomplished either hardware/software basis. Smart antenna system is basically an array antenna with a signal processing ability to transmit /receive information in an adaptive manner (Reed and Mallett, 1974). Smart Antenna system has ability to change its radiation patterns in reaction to change in environment. This can dramatically increase the capacity of a wireless system, SNR is also improved. Another benefit of smart antennas is that the effects of multipath mitigated by suppressing undesired users and maximize gain in desired angle/direction. Smart antenna system can differentiate the desired signal and co-channel interferences may normally requires either reference signal knowledge or direction of the desired signal source or required some sort of training. There are many methods/ algorithms used for updating array weights, each have different speed of convergence and processing time (Wang and Giesner, 2006; Leandro).

The smart antenna system is divided into two parts

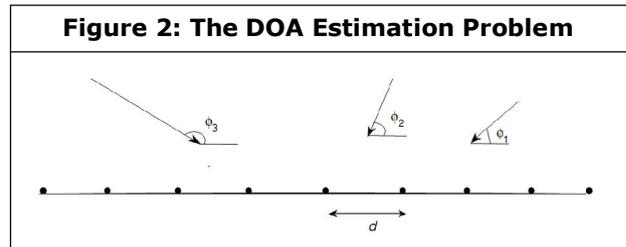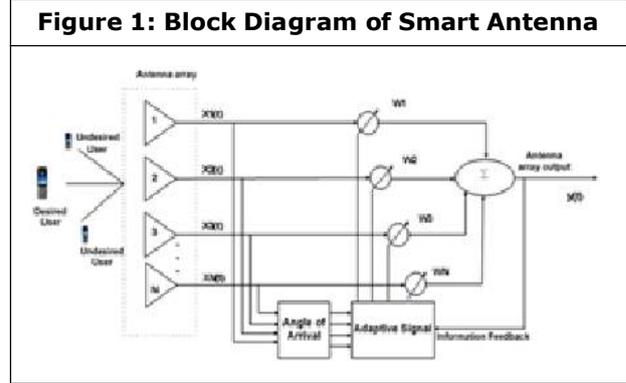1. Direction of Arrival (DOA)

2. Adaptive beamforming algorithm

DIRECTION-OF-ARRIVAL

We have seen that there is a one-to-one relationship between the direction of a signal and the associated received steering vector. It should therefore be possible to invert the relationship and estimate the direction of a signal from the received signals. An antenna array therefore should be able to provide for direction of arrival

estimation. We have also seen that there is a Fourier relationship between the beam pattern and the excitation at the array. This allows the DOA estimation problem to be treated as equivalent to spectral estimation.

The goal of DOA estimation is to use the data received on the downlink at the base-station sensor array to estimate the directions of the signals from the desired mobile users as well as the directions of interference signals (Raed *et al.,* 2007). The results of DOA estimation are then used to adjust the weights of the adaptive beamformer so that the radiated power is maximized towards the desired users, and radiation nulls are placed in the directions of interference signals. Hence, a successful design of an adaptive array depends highly on the choice of the DOA estimation algorithm which should be highly accurate and robust.

The problem set up is shown in Figure 1. Several (M) signals impinge on a linear, equispaced, array with N elements, each with direction φi. The goal of DOA estimation is to use the data received at the array to estimate φi, i = 1, ... M. It is generally assumed that M < N, though there exist approaches (such as maximum likelihood estimation) that do not place this constraint. In practice, the estimation is made difficult by the fact that there are usually an unknown number of signals impinging on the array simultaneously, each from unknown directions and with unknown amplitudes. Also, the received signals are always corrupted by noise. Never the less, there are several methods to estimate the number of signals and their directions. Figure 2 shows some of these several spectral estimation (Shiann-Jeng and Ju-Hong, 1996) techniques 1. Note that this is not an

Figure 1: Block Diagram of Smart Antenna


Figure 2: The DOA Estimation Problem

exhaustive list. This chapter is organized as follows. We begin by determining the Cramer-Rao bound the theoretical limit on how well the directions of arrival can be estimated. We then look at methods to estimates the directions assuming we know the number of incoming signals. We will only describe five techniques: correlation, Maximum Likelihood, MUSIC, ESPRIT and Matrix Pencil. Finally we look at two methods to estimate the number of signals.

TRADITION LMS ALGORITHM

Consider a Uniform Linear Array (ULA) with N isotropic elements, which forms the integral part of the adaptive beamforming system as shown in the Figure 3 below. The output of the antenna array x (t) is given by

$$x(t) = s(t)a(\theta_0) + \sum_{i=1}^{N_u} u_i(t)a(\theta_i) + n(t) \quad ...(1)$$

As shown below the outputs of the individual sensors are linearly combined after being scaled using corresponding weights such that the antenna

Figure 3: LMS Adaptive Beamforming Network
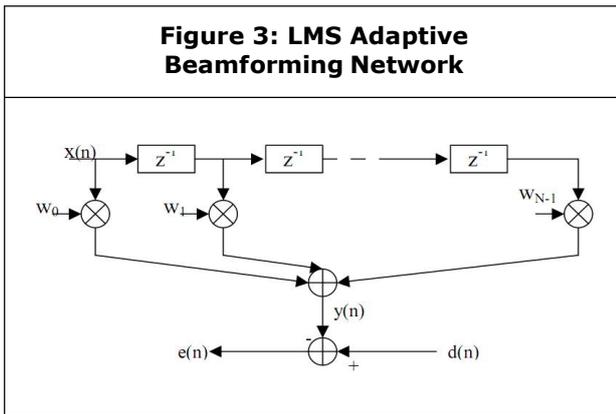
array pattern is optimized to have maximum possible gain in the direction of the desired signal and nulls in the direction of the interferers.

The weights here will be computed using LMS algorithm based on Minimum Squared Error (MSE) criterion. Therefore the spatial filtering problem involves estimation of signal s (t) from the received signal x(t) (i.e., the array output) by minimizing the error between the reference signal d(t) which closely matches or has some extent of correlation with the desired signal estimate and the beamformer output y(t). This is a classical Weiner filtering problem for which the solution can be iteratively found using the LMS algorithm.

LMS algorithm formulation: (All signals are represented by their sample values) from the method of steepest descent, the weight vector equation is given by

$$w(n+1) = w(n) + \frac{1}{2}\mu\left[-\nabla\left(E\{e^2(n)\}\right)\right] \quad ...(2)$$

Where μ is the step-size parameter and controls the convergence chachteristics of the LMS algorithm $e^2(n)$ is the mean square error between the beamformer output y(n) and the reference signal which is given by,

$$e^2(n) = \left[d^*(n) - w^h x(n)\right]^2 \quad ...(3)$$

The gradient vector in the above weight update equation can be computed as

$$\nabla_w\left(E\{e^2(n)\}\right) = -2r + 2Rw(n) \quad ...(4)$$

In the method of steepest descent the biggest problem is the computation involved in finding the values r and R matrices in real time (Komal and Kulkarni, 2010). The LMS algorithm on the other hand simplifies this by using the instantaneous values of covariance matrices r and R instead of their actual values i.e.

S(t) denotes the desired signal arriving at angle θ_o and $u_i(t)$ denotes interfering signals arriving at angle of incidences θ_i respectively. $a(\theta_o)$ and $a(\theta_i)$ represents the steering vectors for the desired signal and interfering signals respectively. Therefore it is required to construct the desired signal from the received signal amid the interfering signal and additional noise n(t).

$$R(n) = x(n)x^h(n)$$

$$r(n) = d*(n)x(n)$$

Therefore the weight update can be given by the following equation,

$$w(n+1) = w(n) + \mu x(n)\left[d^*(n) - x^h(n)w(n)\right]$$

$$= w(n) + \mu x(n)e^*(n)$$

The LMS algorithm is initiated with an arbitrary value w(0) for the weight vector at n=0 (Komal and Kulkarni, 2010). The successive corrections of the weight vector eventually leads to the minimum value of the mean squared error.

Therefore the LMS algorithm can be summarized in following equations;

$$output, \quad y(n) = w^h x(n)$$

Error, $\quad e(n) = d^*(n) - y(n)$

Weight, $\quad w(n+1) = w(n) - \mu x(n) e^*(n)$

CONVERGENCE AND STABILITY OF THE LMS ALGORITHM

The LMS algorithm initiated with some arbitrary value for the weight vector is seen to converge and stay stable for

$$0 < \mu < \frac{1}{\lambda_{max}} \qquad \qquad ...(4.1)$$

where λ_{max} is the largest eigenvalue of the correlation matrix R (Reed and Mallett, 1974). The convergence of the algorithm is inversely proportional to the eigenvalue spread of the correlation matrix R. When the eigenvalues of R are widespread, convergence may be slow. The eigenvalue spread of the correlation matrix is estimated by computing the ratio of the largest eigenvalue to the smallest Eigenvalue of the matrix. If μ is chosen to be very small then the algorithm converges very slowly. A large value of μ may lead to a faster convergence but may be less stable around the minimum value. One of the literatures [will provide reference number here] also provides an upper bound for μ based on several approximations as μ= 1/(3trace(R)).

MODIFIED LMS ALGORITHM

The variable step LMS has been proposed based on the relationship between the performance and step μ. The basic principle of variable step-size LMS is that at the stage of beginning to converge or change of system parameter for the weight of adaptive algorithm is far away from the optimal weight; choose a bigger value for μ to ensure it

has faster convergence rate and tracing rate. When the weight of algorithm is near to the optimal one, in order to reduce the steady state error choose a smaller value for μ.

During the adaptive process in smart antenna, the error between the output of antenna array and expected signal will be affected by the noise and interference. When there is serious noise and interference if μ is adjusted by only making use of the error signal LMS performance will be greatly affected. The result is that the instantaneous weight cannot be near to the optimal one, instead, it can only wave around the optimal weight (Wang and Glesner, 2006). So in this paper we update the weight through the self-correlation estimate of the current error and the previous to eliminate influence of irrelevance noise (Sidi Bahri and Fehti, 2009). At the same time the unitary LMS is introduced to minish sensitivity of the algorithm depending on the received signal. In this paper a new variable step μ is proposed as follows:

$$\mu(n) = \frac{\alpha \left(1 - e^{-\beta |e(n)e(n-1)|}\right)}{x^H(n)x(n)} \qquad ...(5.1)$$

$|e(n)e(n-1)|$ is introduced to adjust the weight at the stage of beginning to converge with big error, so the step μ(n) is big too. But for the noise is not relative and it has little impact on μ(n), the steady state error caused by noise for the adaptive algorithm will be effectively reduced and the algorithm will has good performance with faster convergence rate and less error. The unitary method introduced minishes sensitivity of the algorithm depending on the received signal a certain extent.

SIMULATION RESULTS

Simulation results of Direction of arrival for Modified LMS are shown.

A GUI has been built to ease the simulation (Komal and Kulkarni, 2010). A Layout of the GUI is depicted in Figure 3. The user can input the signal parameters including angle(s) of arrival , their signal power, number of data snapshots , element of linear array and distance between elements.

Case 1: Figure 4, It is considered that there are three desired users with signals arriving at angles -40,0,60 degrees with the different signal strength. The signal coming from 0 is the expected signal, the others are interference. Number of snapshots

Figure 4: Direction of Arrival for N=16, d=0.5
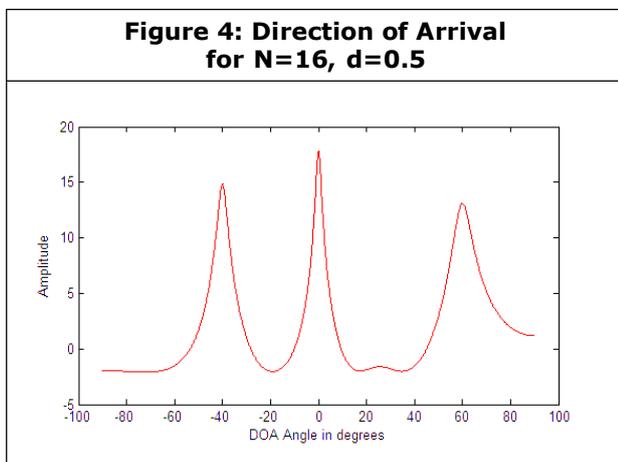
are 2000, number of array elements N=16 with spacing between elements, d =0.5λ.

Case 2: Figure 5, It is considered that there are three desired users with signals arriving at angles
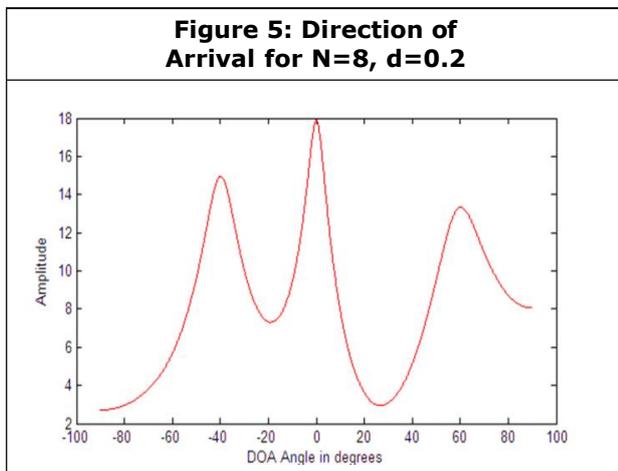
Figure 5: Direction of Arrival for N=8, d=0.2

-40,0,60 degrees with the different signal strength. The signal coming from 0 is the expected signal, the others are interference. Number of snapshots are 2000, number of array elements N=16 with spacing between elements, d =0.2λ.

Case 3: Figure 6, It is considered that there are three desired users with signals arriving at angles -40,0,60 degrees with the different signal strength. The signal coming from 0 is the expected signal, the others are interference. Number of snapshots are 2000, number of array elements N=8 with

Figure 6: Direction of Arrival for N=8, d=0.2
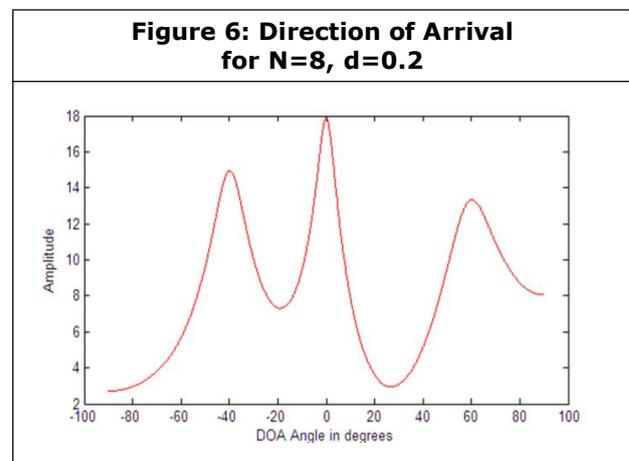
spacing between elements, d =0.2λ.

It has been noticed from results that sharper beams are directed towards desired signals as more elements are used in antenna array .Also, spacing between array elements has an effect on beamformer performance such that very small or very large spacing between array elements can degrade beamformer performance. From different numerical calculation it has been observed that element spacing of 0.5λ is a good value.

Conclusion from Table 1

As we will change the power of arriving signal the amplitude will change according to it. From different numerical calculation it has been observed that element spacing of 0.5λ and distance between the array elements 16 is a good

Table 1: Tabular Results for DOA				
N	d	θ	Intensity	Results
16	0.5	-40	4	Amplitude of received signal will high at angle -40 as compared to the signal received at 0 and 60
		0	2	
		60	3	
16	0.5	-40	1	Amplitude of received signal will high at angle 0 as compared to the signal received at-40 and 60
		0	6	
		60	4	
16	0.2	-40	3	As we reduce distance between elements the received signal at angles -40 ,0,60 gets overlapped with other angles and it becomes difficult to recognizes at which angle the signal is received and . System error is more and error is not steady.
		0	6	
		60	2	
8	0.2	-40	3	As we reduce number of array elements the received signal at angles -40 ,0,60 gets overlapped with other angles and it becomes difficult to recognizes at which angle the signal is received . System error is more and error is not steady.
		0	6	
		60	2	
8	0.5	-40	3	As we reduce number of array elements the received signal at angles -40 ,0,60 gets overlapped with other angles and it becomes difficult to recognizes at which angle the signal is received . System error is more and error is not steady.
		0	6	
		60	2	

value and doesn't give overlapping of the signals, also system error is less and has steady state error, also faster convergence rate and can form deeper nulls in the direction of interference

Simulation Results of Error Curve for Modified LMS is shown

Case1: Figure 7 shows the error curve for desired users with signals arriving at angles -40,0,60 degrees with the different signal strength .Number of snapshots are 2000, number of array elements N=16 with spacing between elements, d =0.5λ.

Case 2: Figure 8 shows the error curve for desired users with signals arriving at angles -
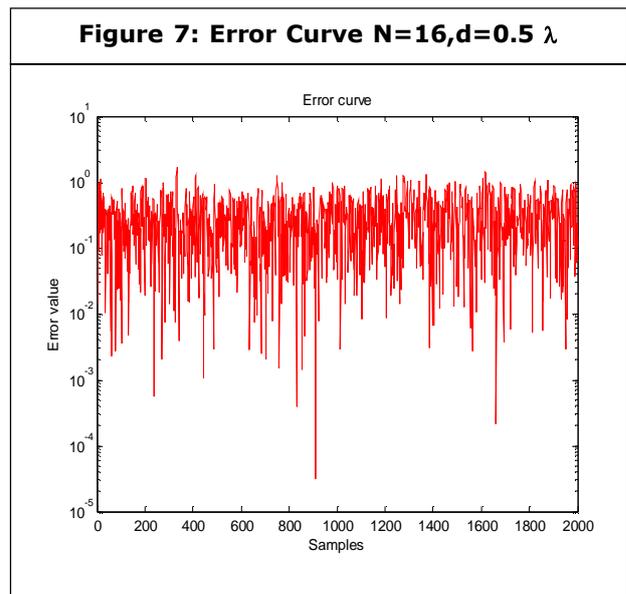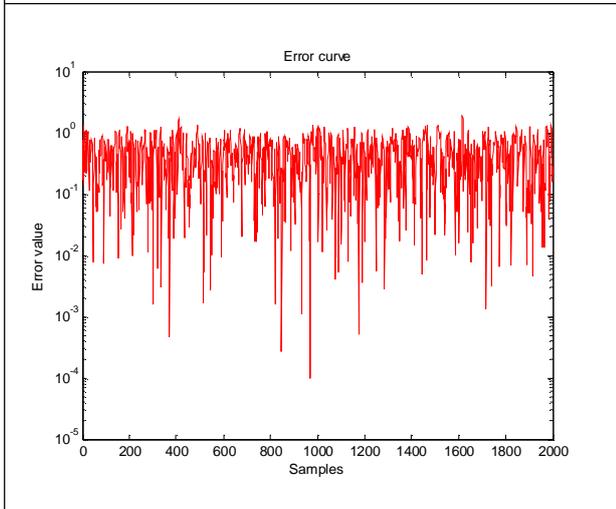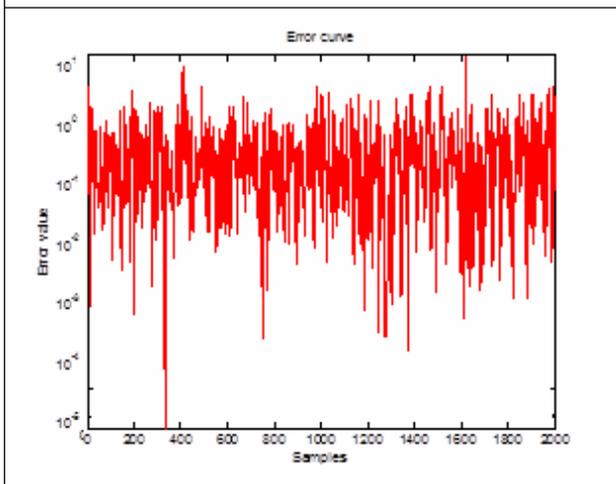

Figure 7: Error Curve N=16,d=0.5 λ

Figure 8: Error Curve N=16, d=0.2 λ

40,0,60 degrees with the different signal strength .Number of snapshots are 2000, number of array elements N=16 with spacing between elements, d =0.2λ.

Case 3: Figure 9 shows the error curve for desired users with signals arriving at angles -40,0,60 degrees with the different signal strength. Number of snapshots are 2000, number of array

Figure 9: Error Curve N=08, d=0.2 λ

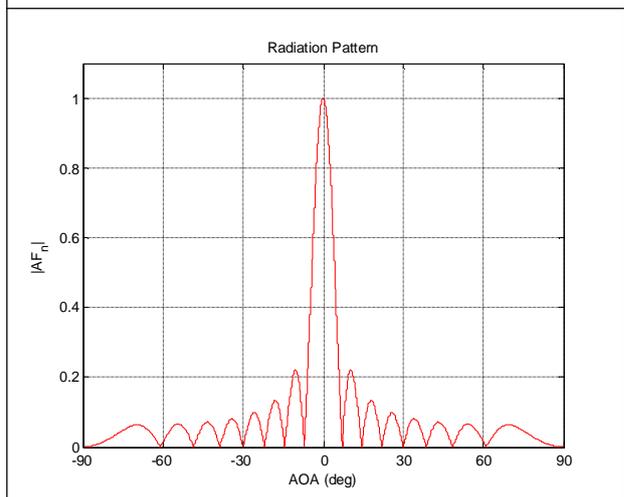elements N=8 with spacing between elements, d =0.2λ.

It has been noticed from results that the error curve plot for case 1 shows system error is less

and steady for desired users with signals arriving at angles -40,0,60 degrees with the different signal strength .Number of snapshots are 2000, number of array elements N=16 with spacing between elements, d =0.5λ.

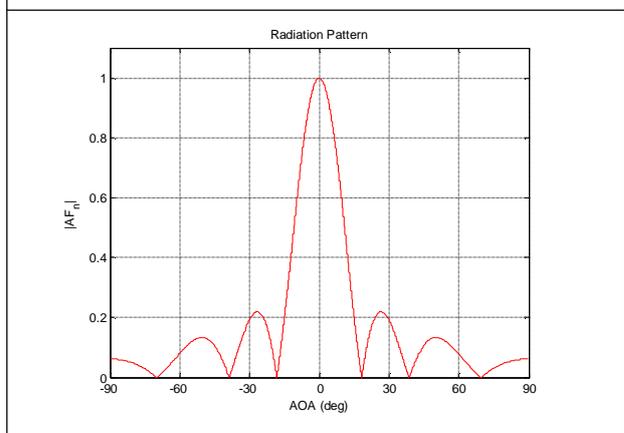## Simulation Results of Radiation Pattern for Modified LMS is Shown

Case 1: Figure 10 shows the radiation pattern for desired users with signals arriving at angles -40,0,60 degrees with the different signal strength. Number of snapshots are 2000, number of array

Figure 10: Radiation Pattern for N=16, d=0.5 λ

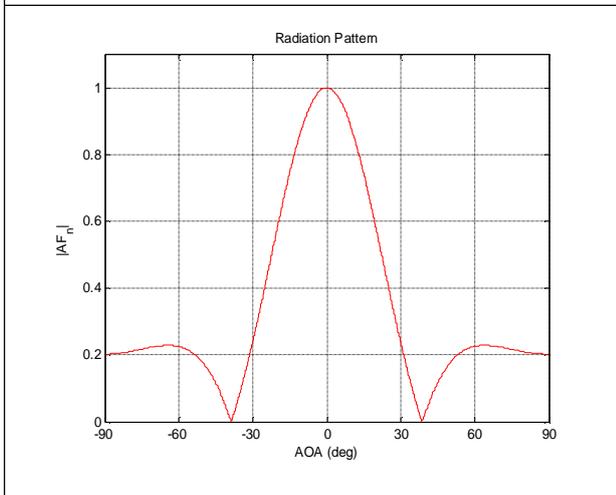elements N=16 with spacing between elements, d =0.5λ.

Figure 11: Radiation Pattern for N=16, d=0.2 λ

Case 2: Figure 11 shows the radiation pattern for desired users with signals arriving at angles -40,0,60 degrees with the different signal strength. Number of snapshots are 2000, number of array elements N=16 with spacing between elements, d =0.2λ.

Case 3: Figure 12 shows radiation pattern for desired users with signals arriving at angles -40,0,60 degrees with the different signal strength. Number of snapshots are 2000, number of array

Figure 12: Radiation Pattern for N=08, d=0.2λ

elements N=8 with spacing between elements, d = 0.2λ.

It has been noticed from results that the radiation patter n for case 1 shows has faster convergence rate and can form deeper nulls in the direction of interference for desired users with signals arriving at angles -40,0,60 degrees with the different signal strength .Number of snapshots are 2000, number of array elements N=16 with spacing between elements, d =0.5λ.

Simulation Results of SNR Curve for Modified LMS is Shown

Case 1: Figure 13 shows the SNR curve for desired users with signals arriving at angles -40,0,60 degrees with the different signal strength.
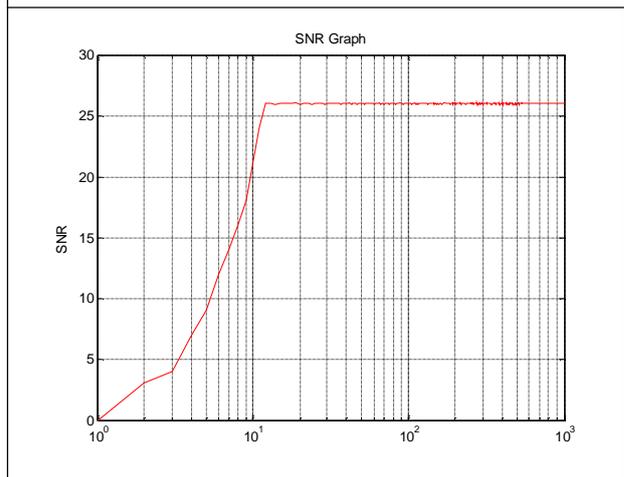
Figure 13: Radiation Pattern for N=08, d=0.2 λ
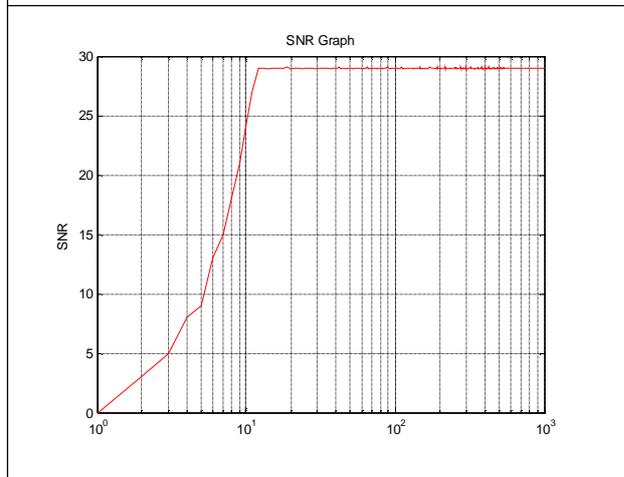
Number of snapshots are 2000, number of array elements N=16 with spacing between elements, d = 0.5λ.

Case 2: Figure 14 shows the SNR curve for desired users with signals arriving at angles -40, 0, 60 degrees with the different signal strength. Number of snapshots are 2000, number of array elements N=16 with spacing between elements, d =0.2λ.

Figure 14: Radiation Pattern for N=16, d=0.2 λ

Case 3: Figure 15 shows SNR curve for desired users with signals arriving at angles -40,0,60 degrees with the different signal strength .Number
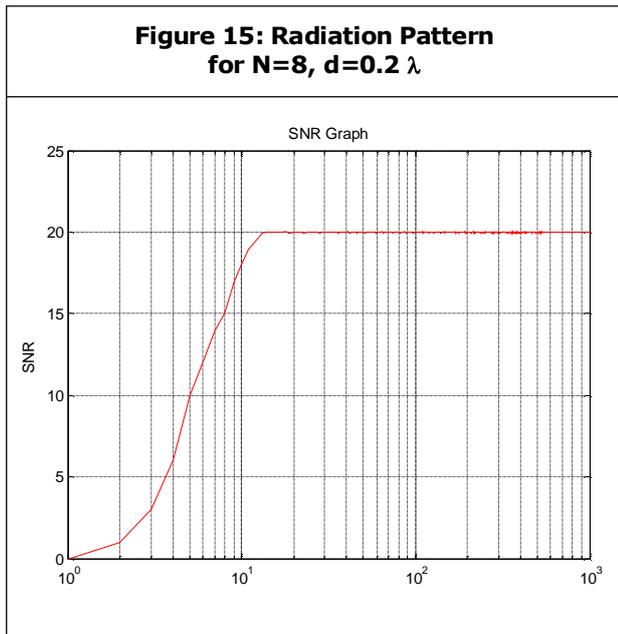
Figure 15: Radiation Pattern for N=8, d=0.2 λ

of snapshots are 2000, number of array elements N=8 withs pacing between elements, d =0. 2λ.

It has been noticed from results that the SNR curve for case 1 we can see that when the snapshot is about 30 the traditional LMS algorithm has obtained the optimal weight for desired users with signals arriving at angles -40,0,60 degrees with the different signal strength. Number of

snapshots are 2000, number of array elements N=16 with spacing between elements, d =0.5λ.

Conclusion from Table 2

The error curve plot that is obtained for Modified LMS algorithm is steady below 10^0 but error curve plot that is obtained for Traditional LMS algorithm is steady above 10^0. So we can conclude that the error curve plot shows that system error is less for Modified LMS as compared to Traditional LMS algorithm.

Conclusion from Table 3

Form beam pattern we can conclude that main beam aims at the expected signal and the nulls aim at the interference for N=16 and d=0.55. When we reduce the distance or number of elements beam pattern is change main beam are not aims at the expected signal.

Conclusion from Table 4

The SNR curveplot that is obtained for Modified LMS algorithm and when the snap shots is about 12 the new algorithm has obtained the optimal weight for N=16 and d=0.55. When we reduce

N	d	θ	Intensity	Results (Error Curve)
				Table 2: Tabular Result for Error Curve
16	0.5	-40	3	System error is less and steady for desired users with respective signals arriving
		0	6	
		60	2	
16	0.2	-40	3	system error is less but error is not steady for desired users with respective signals arriving
		0	6	
		60	2	
8	0.2	-40	3	system error is less but error is not steady for desired users with respective signals arriving
		0	6	
		60	2	

Table 3: Tabular Result for Beamforming

N	d	θ	Intensity	Results (Beamforming)
16	0.5	-40	3	In addition from the beam pattern in the figure 9 we can draw the conclusion that the main beam aims at the expected signal and the nulls aim at the interference. In addition, the modified algorithm can form much deeper nulls comparing with the traditional one and has better performance of restraining the interference.
		0	6	
		60	2	
16	0.2	-40	3	As we reduce the distance between the elements beam pattern is change main beam are not aims at the expected signal
		0	6	
		60	2	
8	0.2	-40	3	As we reduce the distance between the element and number of array elements beam pattern is change main beam are not aims at the expected signal
		0	6	
		60	2	

Table 4: Tabular Result for SNR Curve

N	d	θ	Intensity	Results (SNR Curve)
16	0.5	-40	3	The figure12 shows the relationship between SNR and snap shots In the figure12 we can see that when the snap shots is about 12 the new algorithm has obtained the optimal weight
		0	6	
		60	2	
16	0.2	-40	3	The figure13 shows the relationship between SNR and snap shots In the figure13 we can see that when the snap shots is about 13 the new algorithm has obtained the optimal weight,SNR is also less
		0	6	
		60	2	
8	0.2	-40	3	The figure14 shows the relationship between SNR and snap shots In the figure14 we can see that when the snap shots is about 15 the new algorithm has obtained the optimal weight, SNR is also less
		0	6	
		60	2	

the distance or number of elements, SNR curve is reduced.

CONCLUSION

This paper discussed the adaptive beamforming traditional LMS algorithm. Modified LMS algorithm is proposed by making step size variable. The performance of modified LMS algorithm is analyzed in this paper for different number of array element and different spacing between elements are considered for simulation. This paper studied the results for direction of arrival for Modified LMS it was found that for case 1 sharper beams are directed towards desired signals as more elements are used in antenna array, the error curve plot for case 1 shows system error is less

and steady, the radiation pattern for case 1 shows has faster convergence rate and can form deeper nulls in the direction of interference. The result obtain for error curve, beamforming, SNR curve plot achieves faster convergence and lower steady state error than traditional LMS algorithm.

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