

# Implementation of an Adaptive Antenna Array Algorithm for Anti-Jamming Techniques

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## Abstract

A smart antenna has the capability of suppressing jamming signal, they can improve Signal to Interference plus Noise Ratio (SINR). Antennae array processing utilizes information regarding locations of signal to aid in interference suppression and signal enhancement and is considered promising technology for anti-jamming. Simulation results are presented to compare the ability of Least Mean Square (LMS), Recursive Least Squares (RLS) and the conjugate gradient method algorithms to form beam in the direction of desired signal and place null to cancel out interference signal with the assumption of angle of desired signal and angle of interference. Analysis of these algorithms on SINR and number of iterations needed to get desired signal that is minimize the error faster than other adaptive algorithms are analyzed.

**Index Terms**— Anti-jamming, Adaptive antennas, Beam forming, Spatial filtering, Least Mean Square (LMS), Recursive Least Squares (RLS), Conjugate Gradient Method algorithms (CGM).

## 1 INTRODUCTION

Jamming in digital signal processing, telecommunication and related applications has been a major concern for system designers. The usual filtering techniques are not helpful as the jamming signal and desired signal are of same frequency. Many methods have been adopted to avoid jamming, which includes frequency hopping but it requires more bandwidth. Method of Spatial filtering can solve the problem without the need of additional bandwidth as signals are filtered on basis of their direction of arrival (DOA)[3][5].

Smart antennas have the capability of suppressing jamming signal and they can improve signal to interference plus noise ratio (SINR).

## 2 Smart Antennas

Smart antenna functionalities are controlled via algorithms based upon certain criteria. These conditions could be used for maximizing the signal to interference ratio (SIR), minimizing the variance, minimizing the mean square error (MMSE) and reduces the interfering signals.

The implementation of these algorithms can be performed electronically through analog devices but it is generally more easily performed using digital signal processing. This requires the array outputs to be digitized through the use of an A/D converter. This digitization can be performed at either IF or baseband frequencies. Since an antenna pattern (or beam) is formed by digital signal processing, it is often referred to as digital beam forming. [4][5].

When the algorithms used are adaptive, this process is referred to as *adaptive* beam forming. Adaptive beam forming is a subcategory under the more general subject of digital beam forming. Digital beam forming has been applied to radar, sonar and communications systems to name a few [2]. The chief advantage of digital beam forming is that phase shifting and array weighting can be performed on the digitized data rather than by being implemented in hardware. On receiving, the beam is formed in the digital processing rather than forming in space. The digital beam forming method cannot be strictly called electronic steering since no effort is made to directly shift the phase of the antenna element currents. Rather, the phase shifting is computationally performed on the digitized signal. If the parameters of operation are changed or the detection criteria are modified, the beam

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forming can be changed by simply changing an algorithm rather than by replacing hardware [1][2].

Adaptive beam forming is generally the more useful and effective beam forming solution because the digital beam former merely consists of an algorithm which dynamically optimizes the array pattern according to the changing electromagnetic environment.

Conventional array static processing systems are subject to degradation by various causes. An array SNR can be severely degraded by the presence of unwanted interfering signals.

The main objective of the project is to provide a very accurate anti-jamming technique to resolve and cancel the jammers and it should be an absolutely stable and efficient adaptive algorithm.

Table 2.1 Comparisons of Conventional methods for anti-jamming technique:

4	An Intelligent Anti-jamming Frequency Hopping System[10] IEEE,2010	Need large bandwidth for fast frequency hopping.
5	Adaptive Beam forming Algorithms for Anti-Jamming technique[16], March 2011	Simple and robust algorithms but convergence is more complex

### 3 Adaptive Antennas

The term adaptive antenna is used for a phased array, when the weighting on each element is applied in a dynamic fashion. The amount of weighting on each channel is not fixed at the time of the array design, but rather decided by the system at the time of processing the signals to meet required objectives. In other words, the array pattern adapts to the situation and the adaptive process is under control of the system. For example, consider the situation of a communication system operating in the presence of a directional interference operating at the carrier frequency used by the desired signal, and the performance measure is to maximize the output SNR [3].

The output SNR is maximized by canceling the directional interference using optimal antennas. The antenna pattern in this case has a main beam pointed in the desired signal direction, and has a null in the direction of the interference. Assume that the interference is not stationary but moving slowly. If optimal performance is to be maintained, the antenna pattern needs to adjust so that the null position remains in the moving interference direction. A system using adaptive antennas adjusts the weighting on each channel with an aim to achieve such a pattern. [3][5] etc.

S NO	TITLE OF THE PAPER	REMARKS
1	Anti-jam by fast Frequency Hopping NCFSK-myths and realities[1],IEEE Mar 1993	De-hopping is complex at receiver in real time communications
2	Optimization of base station antenna position based on propagation measurements[5],IEEE,1997	Fixed direction of antenna affects the desired signal strength
3	Optimum Power Control for Successive Interference Cancellation With Imperfect Channel Estimation[4],IEEE2003	Maintains a fixed received SNR is complex

## 4 Adaptive Beam forming

The fixed beam forming approaches, which included the maximum SIR, the ML method, and the MV method were assumed to apply to fixed arrival angle emitters. If the arrival angles don't change with time, the optimum array weights won't need to be adjusted. However, if the desired arrival angles change with time, it is necessary to devise an optimization scheme that operates on-the-fly so as to keep recalculating the optimum array weights.

The adaptive algorithm takes the fixed beam forming process one step further and allows for the calculation of continuously updated weights. The adaptation process must satisfy a specified optimization criterion. Several examples of popular optimization techniques include Least Means Square (LMS), Sample Matrix Algorithm (SMI), Recursive Least Squares (RLS), Constant Modulus Algorithm (CMA), Conjugate Gradient Method (CGM), and waveform diverse algorithms [5].

### 4.1 Least Mean Squares

The least mean squares algorithm is a gradient based approach which gives an excellent fundamental treatment of this approach. Gradient based algorithms assume an established quadratic performance surface. When the performance surface is a quadratic function of the array weights, the performance surface is in the shape of an elliptic paraboloid having one minimum. One of the best ways to establish the minimum is through the use of a gradient method [5][9]etc.

An  $M = 8$ -element array with spacing  $d = .5\lambda$  has a received signal arriving at the angle  $\theta_0 = 30^\circ$ , an interferer at  $\theta_1 = -60^\circ$ . Use MATLAB to write an LMS routine to solve for the desired weights. Both signals are nearly orthogonal over the time interval  $T$ . Let the desired signal  $d(k) = s(k)$ . Use the least mean square algorithm to solve for the optimum array weights. Assume that the initial array weights are all zero. Let step size  $\mu = .02$ .

- (a) Plot the resulting weights magnitude vs. iteration number.
- (b) Plot the desired signal  $s(k)$  and the array output  $y(k)$ .

(c) Plot the mean square error  $|e|^2$ .

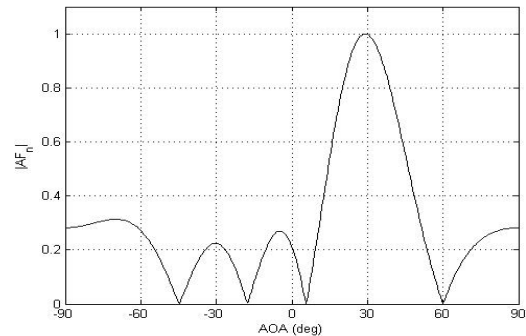


Figure 5(a) – AOA (Angle of arrival) Vs Array factor

This figure 5(a) indicates that the final weighted array which has a peak at the desired direction of  $30^\circ$  and a null at the interfering direction of  $60^\circ$ .

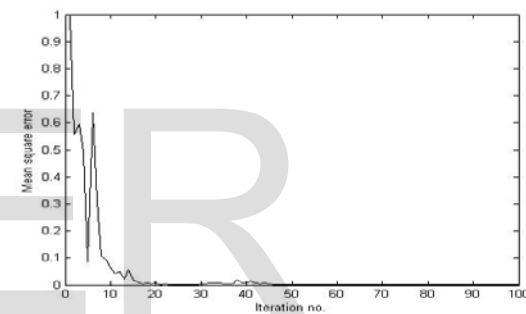


Figure 5 (b) - Number of Iteration Vs Mean square error

This figure indicates 5(b) the resulting mean square error which converges to near zero after 60 iterations.

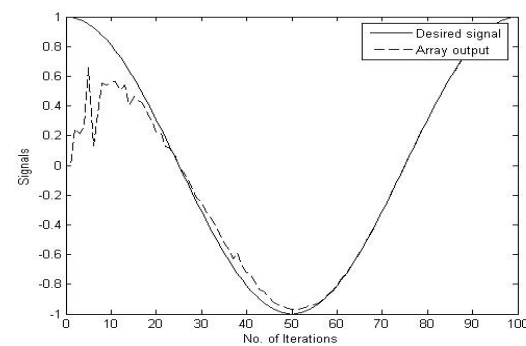


Figure 5(c) - Number of Iteration Vs signals

Figure 5(c) indicates that how the array output acquires and tracks the desired signal after about 60 iterations

## 4.2 Conjugate Gradient

The problem with the steepest descent method has been the sensitivity of the convergence rates to the eigen value spread of the correlation matrix. Greater spreads result in slower convergences. The convergence rate can be accelerated by use of the conjugate gradient method (CGM). The goal of CGM is to iteratively search for the optimum solution by choosing conjugate (perpendicular) paths for each new iteration. The CGM method has its early roots in the desire to solve a system of linear equations. The method of CGM produces orthogonal search directions resulting in the fastest convergence [5]. For the  $M = 8$ -element array with elements a half-wavelength apart, find the optimum weights under the following conditions:

The arriving signal of interest is  $s = \cos(\pi k/K)$ ; arriving at an angle of  $45^\circ$ .

One interfering signal is defined as  $I_1 = \text{randn}(1,K)$ ; arriving at  $-30^\circ$ .

The other interfering signal is defined as  $I_2 = \text{randn}(1,K)$ ; arriving at  $0^\circ$  and the noise has a variance of  $\sigma^2 = .001$ . Thus,  $n = \sigma * \text{randn}(1,K)$ . Use the CGM method to find the optimum weights and plot the resulting pattern.

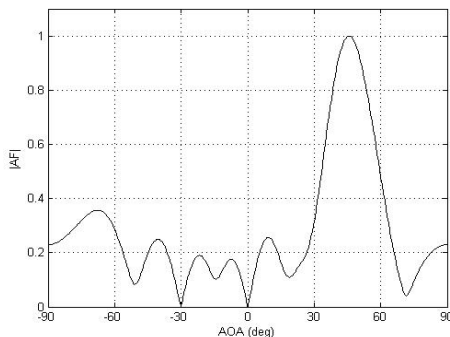


Figure 6(a) - Angle of Arrival(AOA) Vs Array factor

This figure 6(a) indicates that the final weighted array which has a peak at the desired direction of  $45^\circ$  and a null at the interfering direction of  $-30^\circ$ .

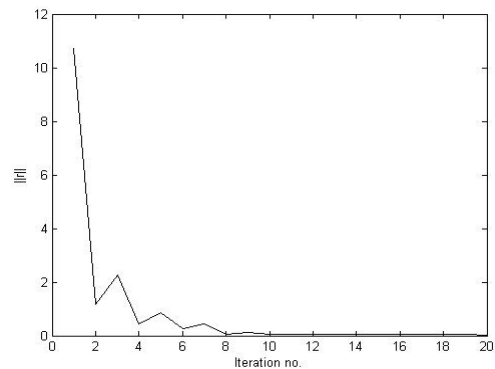


Figure 6 (b)-Number of Iteration Vs Mean square error

This figure indicates 6(b) that the resulting mean square error which converges to near zero after 20 iterations.

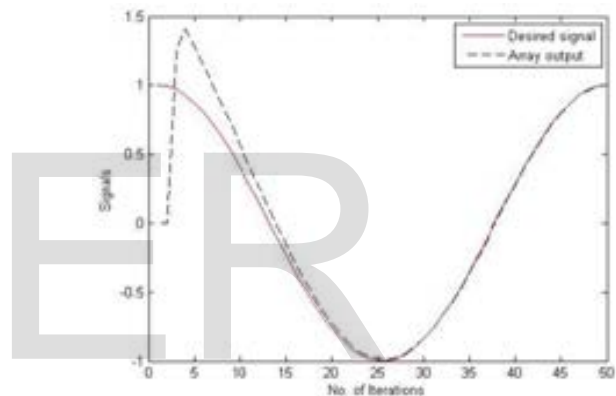


Figure 6(c)-No of Iteration Vs signals

This figure 6(c) indicates that how the array output acquires and tracks the desired signal after about 20 iterations.

## 4.3 Recursive Least Squares

Recursive Least Square (RLS) means calculate the required correlation matrix and required correlation vector recursively. Thus, future values for the array correlation matrix estimate and the vector correlation estimate can be found using previous values.

Let the array be an  $M = 8$ -element array with spacing  $d = 0.5$  with a received signal arriving at  $\theta_0 = 30^\circ$ , an interferer the angle =  $-60^\circ$ .

Let the desired signal  $d(k) = s(k)$ . In order to keep the correlation matrix inverse from becoming singular, add noise to the with variance  $\sigma^2 = .001$  and  $\alpha = .9$  as a forgetting factor

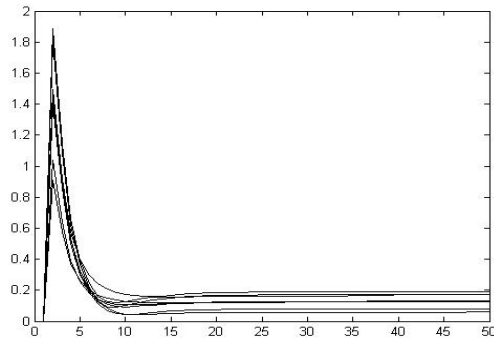


Figure 7 (a)-Iteration no Vs Mean square error

This figure 7(a) indicates that the mean square error which converges to near zero after 40 iterations.

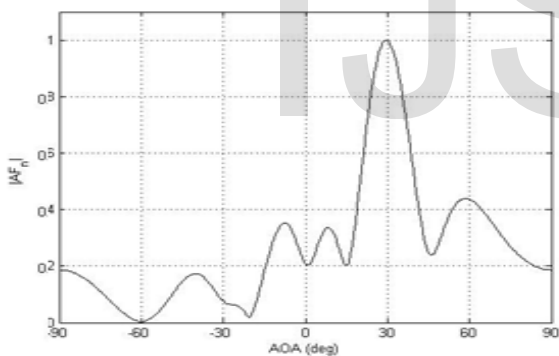


Figure 7 (b) AOA Vs Array factors

This figure 7(b) indicates that the final weighted array which has a peak at the desired direction of  $30^\circ$  and null at the interfering direction of  $-60^\circ$

From the three adaptive algorithms, Conjugate Gradient Method provides a very accurate anti-jamming system to resolve and cancel the jammers. Most adaptive algorithms provide the weight vector by solving a matrix equation that represents the communication channel as a function of various incident angles. The Conjugate Gradient Method (CGM) was introduced as an absolutely stable and efficient adaptive algorithm for solving the

matrix equation. This is because the convergence of the adaptive procedure is always guaranteed, with the required number of iterations being no larger than the rank of the channel matrix.

Table 7.2 Comparisons of adaptive algorithms

S.no	Adaptive Algorithms	No of array element (M)	Array spacing (d)	Iterations needed	Desired signal
1	LMS	M=8	$d=0.5 \lambda$	>60	Yes
2	CGM	M=8	$d=0.5 \lambda$	>20	Yes
3	RLS	M=8	$d=0.5 \lambda$	>45	Yes

Since the weight vector provided by the Conjugate Gradient is exactly singular. This will occur when the number Method represents the exact solution, barring numerical round-off and truncation errors of the matrix equation – the array output will produce a large value for the output signal-to-noise ratio, even if the input has a very low input signal-to-noise ratio. The rate of convergence of the Conjugate Gradient Method is at least 40 times faster than that of the conventional LMS (least mean square). The rate of convergence could therefore be much greater for the solution of complex problems. As a matter of fact, the Conjugate Gradient Method is guaranteed to converge with less number of iterations.

The method also converges even when the matrix of antenna elements is much greater than the number of jammers. The fast rate of convergence for the Conjugate Gradient Method is due to the fact that the step size is optimized at every iteration step, and the direction vector satisfies the conjugate condition at each iteration as well.

## 5 CONCLUSION

Simulation results are presented to compare the ability of these three algorithms to form beam in the direction of desired signal and place null in the direction of interference signal with the assumption of angle of desired signal and angle of interference. Dependency of these algorithms on SNR and number of iterations needed to get desired signal that is minimize the error faster than other adaptive algorithms are analyzed.

LMS algorithm is known for its simplicity and robustness. Moreover, there is always a tradeoff between the speed of convergence of the LMS algorithm and its residual error when a given adaptation step size is used. The LMS algorithm is a popular solution used in beam forming technique. This algorithm is easy to implement with low computation and performs pretty well. RLS algorithm usually converges with order of magnitude faster than LMS algorithm but the price paid is added complexity.

The rate of convergence of the Conjugate Gradient Method is at least 40 times faster than that of the conventional LMS (least mean square). The rate of convergence could therefore be much greater for the solution of complex problems. As a matter of fact, the Conjugate Gradient Method is guaranteed to converge with less number of iterations. Simulation result shows the Conjugate Gradient Method is most suitable adaptive algorithms for anti-jamming technique in military communications.

## 6 Future Works

In future, developing algorithm for angle of arrival estimation to desired signal and interference, combining these algorithms with adaptive antenna array system that is Conjugate Gradient Method which is to provide a very accurate anti-jamming technique to resolve and cancel the jammers and it will be an absolutely stable and efficient adaptive algorithm.

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