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Improvement in Angle of Separation in Smart Antenna by LMS-MPSO Algorithm

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Abstract: As the growing demand for wireless communications is constantly increasing, the need for better coverage, improved capacity, speed of convergence and higher transmission quality rises. Hence more efficient use of the radio spectrum is also required. A smart antenna system is capable of efficiently utilizing the radio spectrum. one of the challenges faced in the smart antenna system is performance degradation due to angle separation between the desired and interferer signals. This paper deals with Antenna parameters and adaptive algorithm which can reduce the effect of angle separation. Adaptive Beamfoming algorithms: LMS, CMA and MPSO based on angle separation are presented herein. All the three algorithms performance when the separation increases ,becomes narrow. Increasing number of array and spacing between array elements alleviate these problems, but it increase computational complexity and introduce grating lobes. Among these algorithms MPSO algorithm has low computational complexity and less grating lobes, so LMS-MPSO algorithm which works based on angle separation is an excellent solution to this performance degradation

Keywords: Smart antenna, DOA, Adaptive algorithm, Modified Particle swarm optimization(MPSO), CMA,LMS.

I.INTRODUCTION

A smart antenna is an antenna array system that is aided by a processing system to process the signals received by the array by using suitable array algorithms to improve wireless system performance. A smart antenna system consists of an antenna array, RF hard ware, and a computer controlled unit to change the array pattern [2]. Smart antennas have two main functions: direction of arrival estimation (DOA) and Beamforming.Beam forming is the method used to create the radiation pattern of the antenna arrays by adding constructively the phase of the signals in the direction of desired targets and nulling the pattern of undesired sources. In Beam forming, both the amplitude and phase of each antenna elements are controlled. Combined amplitude and phase control can be used to adjust side lobe levels and steer nulls. when the desire and the interferer signal have the same frequency, having spatial deference, a better way to cancel the interferer, steer the beams towards the desire direction to enhance signal to noise ratio is called Beam forming [1]. Adaptive beam forming techniques dynamically adjust the array pattern to optimize some characteristic.

Adaptive Beam forming algorithm can be classified as training and blind algorithm. Trained algorithms use training signal to adapt the weights of the array and minimize mean square error. The processor in the adaptive array has a pre-stored training signal and the array adapts its weights when the training signal is transmitted by the transmitter. Thistechnique requires synchronization. These algorithms work very well, but the only cost paid is the excess transmission time or wastage of bandwidth. The trained algorithms are classified based on their adaptation criteria and they are least-mean squares method (LMS), sample matrix inversion (SMI) or least-squares method (LS) and recursive least-squares method (RLS). All these techniques minimize the squared error. The fundamental assumptions behind these minimization techniques is that the error vector follows a Gaussian probability density function

Unlike training algorithm blind algorithm do not require training signals to adapt their weights. Therefore these algorithms save transmission bandwidth. Blind algorithms can be classified as property restoral algorithms, channel estimation algorithms, and dispread and respread algorithms. Property restoral algorithms restore certain properties of the desired signal and hence enhance the SINR. The property that is being restored may be the modulus or the spectral coherence. Blind property restoral algorithms can be classified as Constant Modulus (CM) algorithm, Spectral self-Coherence Restoral (SCORE) algorithms, and decision directed (DD) algorithms.

The Least Mean Square (LMS) algorithm has been used to optimize the side lobe level in the pattern synthesis of uniform or non-uniform phased array [2], [3]. The modified particle swarm algorithm with LMS is reported to generate adapted pattern of a phased array with prescribed nulls and multi-lobe beam forming [4]. If the inter-element

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spacing of array is made non-uniform or random, the optimum weights are to be estimated for generation of desired adapted pattern. This requires an efficient adaptive algorithm. In the present paper, the steering vector and the signal covariance matrix are modified according to the non-uniform spacing in order to estimate the optimum weights for the generation of adapted pattern for linear array. Uniform excitation is employed to compute the radiation pattern. The optimum weights are estimated using the modified PSO-LMS algorithm for the generation of adapted pattern. The array factor of the array is determined assuming that each element is an isotropic source. The signal environment consisting of multiple interfering sources in the presence of multiple desired radar sources is considered. The modified improved LMS algorithm is employed to generate the adapted pattern.

The adapted pattern consists of accurate and deep nulls towards each of the probing sources with sufficient gain towards the desired signals. The simulation results demonstrate the efficiency of the algorithm in the active cancellation of multiple probing sources for non-uniform and non-uniform linear arrays. Spacing between the antenna elements is an important factor in the design of an antenna array. Grating lobes appears in the antenna pattern if the elements are more than λ/2 apart, where λ is the wavelength of the signal which is given by 3 x /fc, fc is the carrier frequency [1]. Mutual coupling is an effect that limits the inter-element spacing of an array. If the elements are spaced closely, the coupling effects will be larger and generally tends to decrease with increase in the spacing. The mutual coupling effect depends on the array geometry and the radiation pattern of element in the array. For d <λ/2 the mutual impedance tends to increase considerably, so it is advisable to maintain at least λ/2 spacing between arrays of dipoles. Therefore the elements have to far enough to avoid mutual coupling and the spacing have to be smaller than λ/2 to avoid grating lobes.

The antenna arrays with uniform inter-element spacing are known for better angular resolution, narrow beam width and low side lobe level [1]. The antenna arrays with Non-uniform inter-element spacing are becoming familiar for so many applications now a days.

II..MATHEMATICAL MODEL

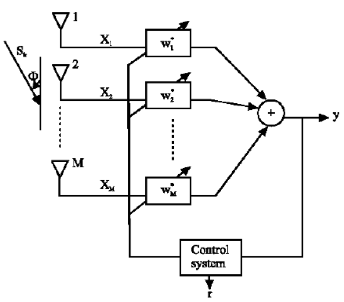

Fig 2.1 Simple Smart antenna

Let adaptive array antenna has M-elements as shown in fig 2.1 .Output signal is given by

$$\mathbf{y(n)= w^{H}(n)x(n)} \qquad \text{- - -(2.1)}$$

Where w(n)=weight vector
X(n)=input signal vector
w^H(n)=complex conjugate of w(n)

If the antenna receives a desired signal $S_0(n)$ and k interfering signals sk(n) with the presence of random noise N then

$$\mathbf{x(n)=S_0(n)a_0+}\sum_{k=1}^{K} S_k(n)\, \mathbf{a_k+N} \qquad \text{- - -(2.2)}$$

Where N=(m × 1) matrix

a_k =steering vector of k th signal

The steering matrix for proposed antenna is given by

$$a_k=\begin{bmatrix} 1 \\ ej\beta\cos\phi k \\ ej2\beta\cos\phi k \\ \vdots \\ \vdots \\ . \\ ej(m-1)\beta\cos\phi k \end{bmatrix} \qquad \text{- - - (2.3)}$$

$\beta = 2\pi/\lambda$ =wave number

$\lambda = wavelengthofthedesiredsignal$
$d = Distencebetweentwoantennaelements$
$\phi_k = Azemuthangleofkthsignal$

$$W=\begin{bmatrix} & |W_1| \\ |W_2| & e^{j\beta d\cos\phi_0} \\ & \vdots \\ |W_M| & e^{j(M-1)\beta d\cos\phi_0} \end{bmatrix} \qquad \text{- - - (2.4)}$$

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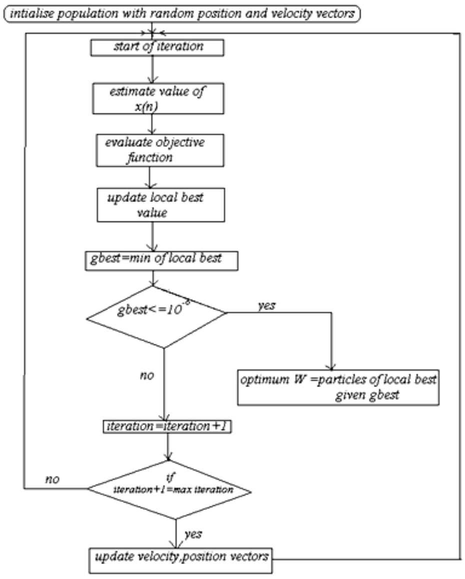

Fig 2.2 Flow chart of MPSO

As start of the algorithm population matrix of PXM is generated where M is the number of elements of the smart antenna. P is the value chosen in random. Particle matrix is given by [1]

Par= $|w_1| \quad |w_2| \quad |w_3| \ldots\ldots |w_m|$ **(3.2)**

The objective function can be Relative Mean error between the array and reference signal given by

Relative Error $= \dfrac{|r(n) - w^H(n)x(n)|^2}{|r(n)|^2}$ **(3.3)**

Initial population (pop) can be random matrix. Each element in each particle moves about the search space with a certain velocity. Initial velocity matrix (vel) is expressed by (PXM) random matrix. Each particle is assumed by objective function min value of fitness (error) function is considered as global cost (gbest) and particle (gpar) respectively..They are initialized by equating mean error to cost vector and local population matrix (lpop) by pop matrix. Updating of velocity, pop is as follows.

$\mathbf{Vel_{i+1}(m,n)=vel_i(m,n+c_1xr_1(lpop_i(m,n)lpop_i(m,n)}$
$\mathbf{+c_2xr_2(gpar(n)-pop_i(m,n)}$ **- - - (3.4)**

c_1,c_2 are learning factor ,r_1 and r_2 are independent uniform random numbers, I is current iteration = 1…….P and n=1,2……..M.
Particle position can be updated using the expression

$\mathbf{pop_{i+1}=pop_i+vel_{i+1}\ \Delta t}$ **(3.5)**

Δt is time interval between two iteration. Treated as unity.

New pop is assessed to the fitness fuction the new best local cost vector can be updated as below.

Lcosti+1(m)=min(lcosti(m),lcosti+1(m)) **(3.6)**

New best local population can be formulated as

$\mathbf{Lpop_{i+1}(m)=\{pop_{i+1}(m)cost_{i+1}(m) \leq cost_i(m)}$
$\mathbf{Loop_y(m)\ \ otherwise}$ **-- - (3.7)**

Similarly gcost is compared with best local cost which over low is traded as gcost .It is compared before the iteration completed. Now the gcost is checked with margin of 10^{-6}.if needed the process continuous until it satisfied.

Modified particle swarm optimization (MPSO) differs in some respects from the original PSO to reduce the duration of the estimation process .PSO moves through the problem space changing its velocity and position by the experience of the lbest (local best cost) and gbest (global best).In each generation if new position of particles is better than its best position ever visited, then its current position is considered as the best one and gbest is updated. In PSO if a new best position of a particle is found, the gbest position is updated after the generation.

The introduced MPSO updates the gbest position in a different way with the one used in original PSO. In MPSO the gbest position is updated if there is a best position with in new generation that outperforms the current gbest position. The same is represented in the flow-chart .Concern results are shown in next session of this paper.

CMA Algorithm is blind estimation method for channel estimation.No trail signals required.
Let received signal with noise and interference is
$X_k = as_k + n_k$
The source is unknown but has constant modulus:
$|s_k| = 1$ for all k.
Weight vector W is given by $y_k = w^H x_k = \hat{s}_k$

W is selected such that $|y_k| = 1$ for all k.
Cost function is given by $J(w)=E[(|y_k|^2-1^2)]$
It is clear that CMA is similar to LMS but update error is $[(|y_k|^2-1)\, y_k$.

III.RESULTS

The results show the amplitude response of uniform and non uniform 8-element array.
Fig3.1 shows the response of LMS algorithm whose nulls are deep at side lobes at 60 and 120 angles. Inter spacing element is d=0.3λ.
Fig3.2 shows response of LMS algorithm with nulls at 60 and 120 angles indicates the low separation angle than Fig3.2.The above two results shows the lower inter element spacing increases the angle of separation in LMS algorithm. Fig3.3&Fig3.4 shows the response of similar antenna with CMA algorithm which is basically blind algorithm with more convergence speed. For inter spacing d=0.3 the angle separation is 10 to 15 degrees. For d=0.5 angle separation is 10 to 12 degrees.But increased number of side lobes are observed compared to Fig 3.3.
Fig3.5&Fig3.6 shows the response of MPSO algorithm for similar array. Being stochastic algorithm, MPSO proved its high convergence speed than two other algorithms. Fig3.6 with narrow main lobe and angle of separation less than Fig 3.5.But trails by grating lobes.For d=0.3 the response is good with angle of separation less than 10 degrees.How ever MPSO is superior to LMS and CMA.

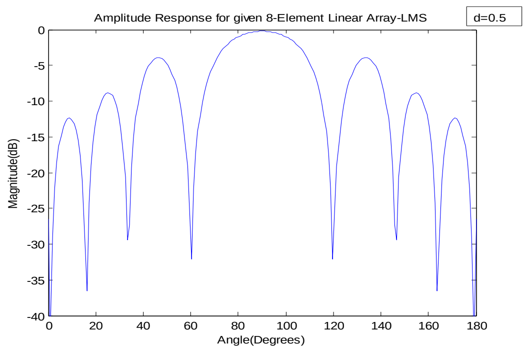

Fig.3.1

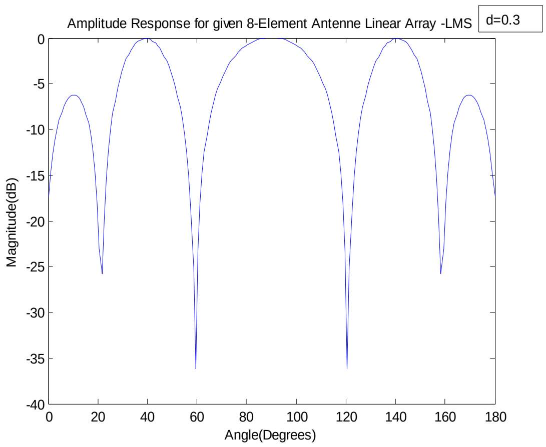

Fig3.2

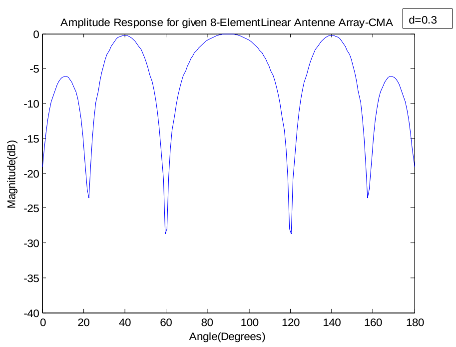

Fig.3.3

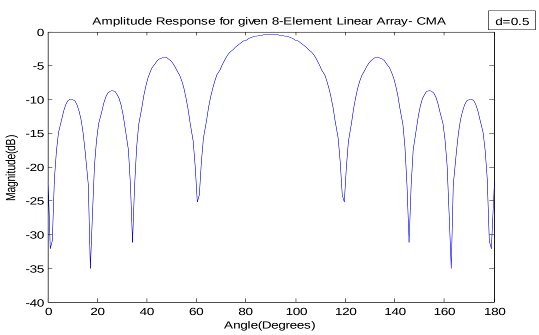

Fig3.4

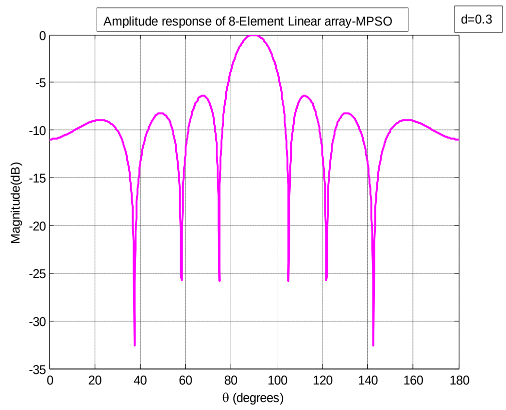

Fig.3.5

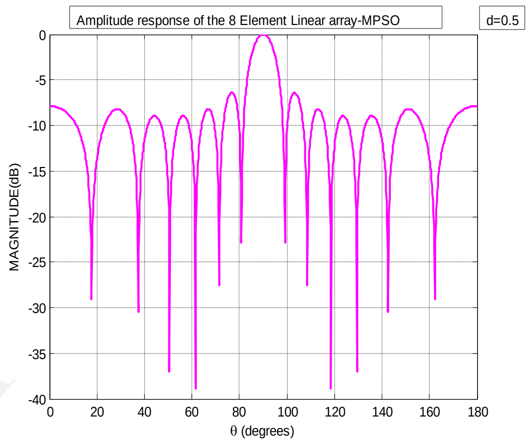

Fig3.6

IV.CONCLUSION

The paper analyses the low angle of separation, better directivity and higher convergence speed among the LMS,CMA and MPSO algorithms.

Angle of separation is good in CMA next to MPSO .But side lobes are more in MPSO with lower elevation. Convergence speed is also good in MPSO.The highlight considered here is angle of separation decreased with decrease in inter spacing of elements. A good trade off is observed in LMS and MPSO between inter spacing distance and angle of separation.

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