Non-Uniform Antenna Array Geometry for Signal Estimation

Vinod Kumar, Sanjeev Kumar Dhull

Abstract: The non-uniform array performance depends upon the various factors like number of array elements, signal to noise ratio and spacing between them. The non-uniform array provides better accuracy and resolution than uniform linear array. The main objective of the paper is to find the best algorithm using Genetic Algorithm in which a novel non uniform circular array has been proposed in order to detect the signal directions. The Music algorithm and ESPRIT algorithm shows better results on the optimized non-uniform array.

Keywords: Signal to Noise Ratio, DOA Estimation, ESPRIT, Genetic Algorithm, Music, Non-uniform.

I. INTRODUCTION:

Signal estimation is the key problem from the last decades. The estimation of signal involve direction finding from various sources. The major uses of DOA estimation are in the Military and civilian use. The signal estimation is used in many applications like radar, sonar, seismology and mobile communication. [1], [2]. Firstly, in 1967, Burg purposed a method which is based on the maximum entropy. The use of spectrum estimation involves in this method. In this AR, MA, ARMA models are used to estimate the spectra. This types of models required complex calculations. After that the researchers designed a new approach which is based on the spectrum estimation by using the EVD. The most famous algorithm MUSIC and its variants are developed in several years. After that, ESPRIT algorithm was developed to overcome the limitations of MUSIC algorithm of heavy computations [3], [4]. Various variants of ESPRIT model were designed by the researchers. When antenna receive the signal from the unknown direction, the source is unknown to the receiver. An another concept came in to the picture of blind DOA estimation. This method estimates some parameters in unknown cases and widely used. K. Reaz et al. [3] has discussed the various variants of Pencil beam, MUSIC, ESPRIT in details. The simulation done by the researcher is based on the RMSE, Angular error and some bounds. The matric pencil algorithm gives better results in less number of snapshot. After that the research is in the field of antenna configuration design [5-8].

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In the present research, a non- uniform new antenna configuration has been implemented in which GA has been utilized to find the optimum signal direction in terms of azimuth and elevation angles. The purposed configuration is better in terms of estimation time and accuracy. Four algorithms have been implemented in this array and the signal directions is estimated. In section II, discuss the algorithm used in the present study. Section III, purposed a new antenna configuration in this present study and also the comparison between these algorithm is studied. The present research has been concluded in the last section

II. PROPOSED NON- UNIFORM CONFIGURATION

In this research GA based Non- uniform antenna configuration has been designed. Consider P far-field narrowband signals which are uncorrelated to each other falls on the array from $\{\theta_1, \theta_2 \ldots\ldots\ldots\ldots, \theta_p\}$ directions. The sine values obtained from the directions are expressed as $\{u_1, u_2 \ldots\ldots\ldots\ldots, u_p\}$ where $u_i = \sin\theta_i$ (i=1,2,........P). The data received from array at time is given below using time constraints $t(1 \le t \le K)$ are:

$$X(t) = \sum_{i=1}^{P} a_x(u_i)s_i(t) + N_x(t) = A_x S(t) + N_x(t) \quad (1)$$

Where X(t) is M×1 dimensional received data vectors, $a_x(u_i) = \left[1, e^{j\pi M u_i}, \ldots\ldots\ldots\ldots, e^{j\pi N(M-1)u_i}\right]^T$ is the steering vector for array X corresponding to u_i, $A_x = \left[a_x(u_1), a_x(u_2), \ldots\ldots\ldots, a_x(u_p)\right]$ is steering matrix for X array, S(t) = $\left[s_1(t), s_2(t), \ldots\ldots\ldots\ldots s_p(t)\right]$ the source signals waveform vector, $N_x(t)$, M ×1 dimensional additive white Gaussian noise vectors.

2. Genetic algorithm (GA)

GA is search free optimizational technique which includes basic principles of genetic with some specific set of natural selection. The basic use of GA is to find at the optimal solution for difficult problems. The optimization is a process in which we make some better thing. A difference set of inputs need to be utilized with a set of output variables. For maximization or minimization, one or more objective function is used by the variation in input set of parameters (variables). The possible set of values (solutions) can be obtained in the possible search space which will give an optimum solution for a specific search space. In GA, there is need of population with possible solutions for a given specific problem. After that these solutions undergo recombination and mutations which will produce new fetal, this process will continue till the best solution over multiple generations. In this, each individual has been assigned with a fitness value which is actually based on objective function. As per the fitness value, more fit individual has more chance to make fitter individuals [4], [5], [15]. Base on this GA, the proposed design array structure is given below in figure 1 in which the size of population is 100 with 1000 iterations and randomly generated initial array structure of 20 elements on XY plane. The total spacing between the elements is 157.0796 mm. The signal generated from the various directions is received at each array element and combined to produce the output. The array factor is given by the formula:

$$AF = \sum_{n=1}^{N} a_n \frac{e^{-jkr}}{r}$$

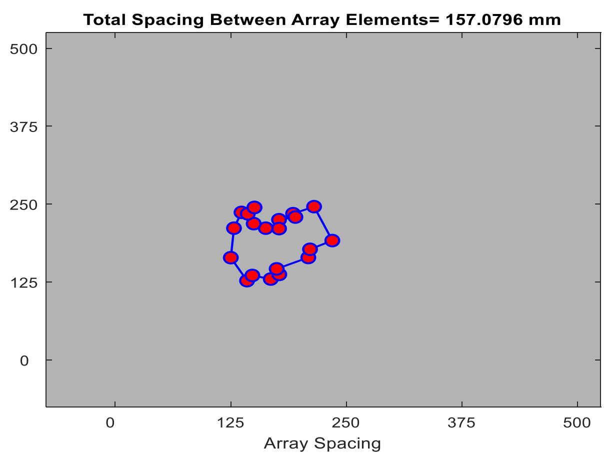

Fig. 1: *Non−Uniform Array structure of 20 Elements*

3. Steps Involving in Optimization of Array

Input : Config (XY,dist), Cost Function, Population, Crossover 90%, Mutation 10%, iterations

for NumIterations
for population
Selection = Cost (Config) ==> MSE ==> Small MSE 10%
Crossover = offspring are created in hope of producing better config
Mutation = Changing the configuration XY pos in hope of producing better config
Population for next iteration
end
end

The DAO array distance matrix is shown in the given figure.

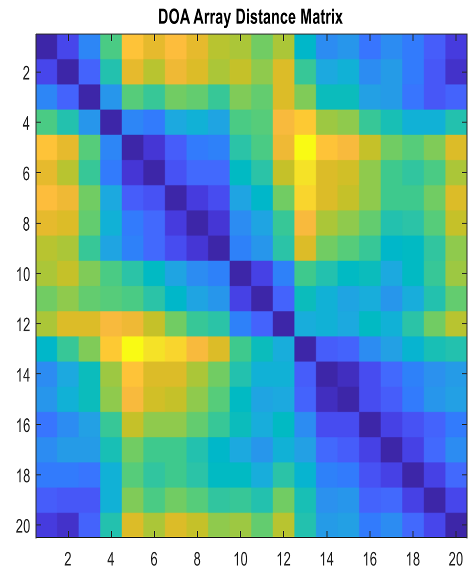

Fig. 2: *DOA Array Distance Matrix*

I11. RESULTS & DISCUSSION

The array optimization error is show in the figure 3. From the graph it is clear that the up to 100 iterations, the MSE is varying and there is no change in the MSE after 100 iterations.

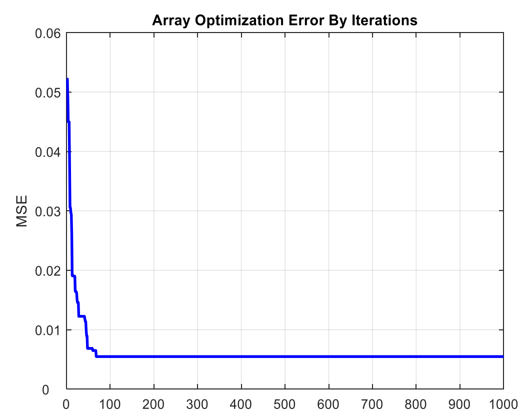

Fig. 3: *Array Optimization Error by Iterations*

The figures 4 to 7 shows the histogram of the DOA algorithm on the proposed non−uniform array with 5 number of signals incoming from the different direction. The signals are easily detected using these algorithm, but the accuracy of Music and ESPRIT algorithm is better than the other algorithm in terms of sharp peaks .

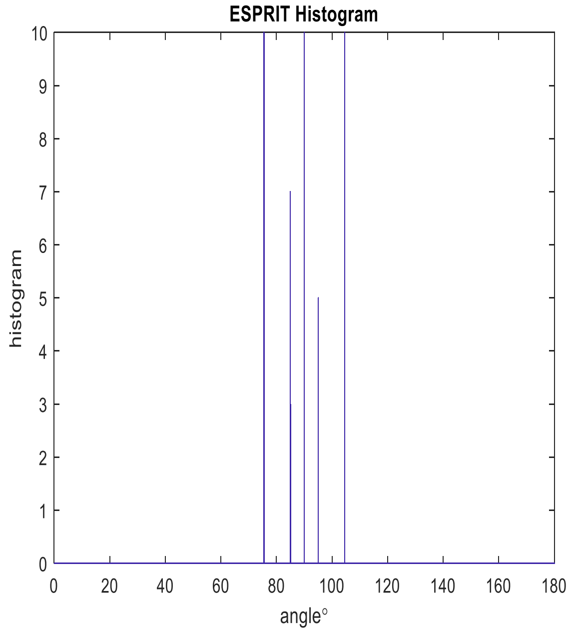

Fig . 4 : *ESPRIT Histogram*

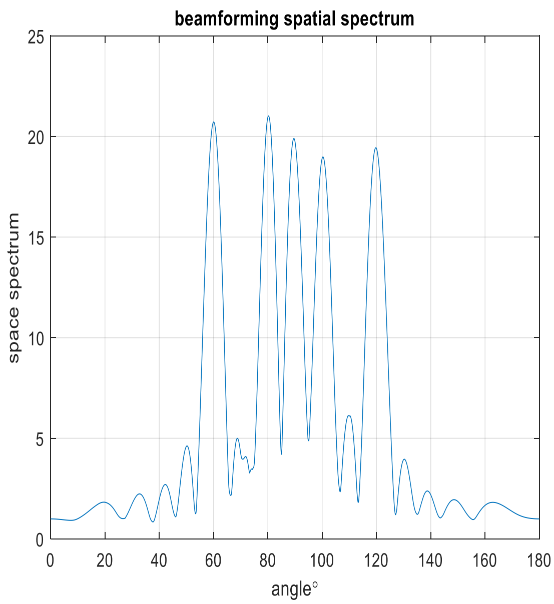

Fig . 5 : *Beamforming Spatial Spectrum*

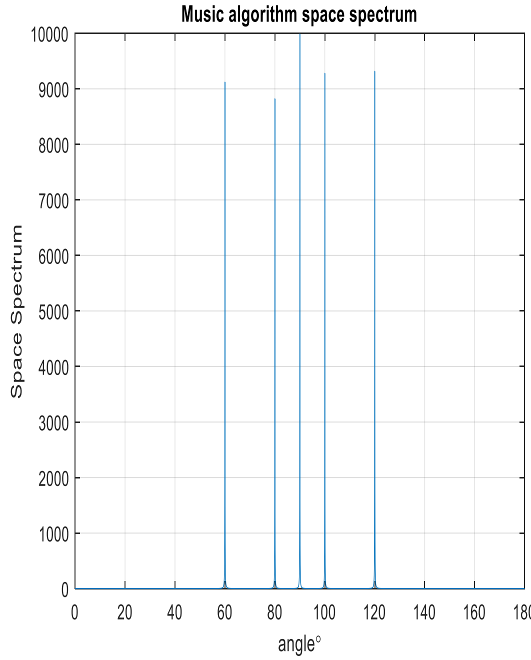

Fig . 6 : *Music Algorithm Space spectrum*

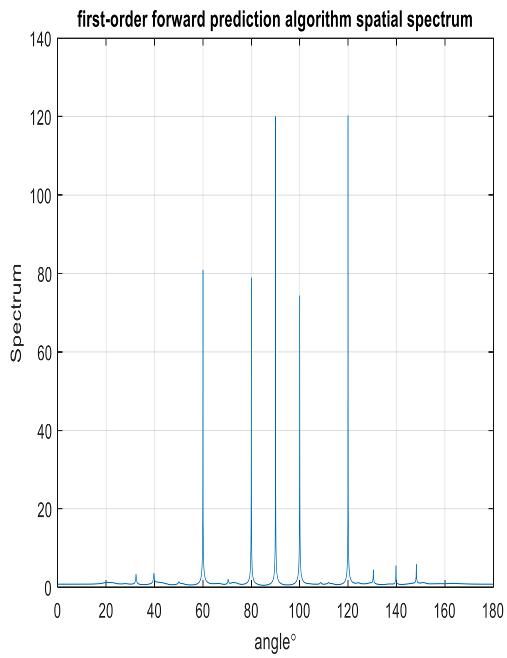

Fig . 7 : *First Order Forward Prediction Algorithm Spatial Spectrum*

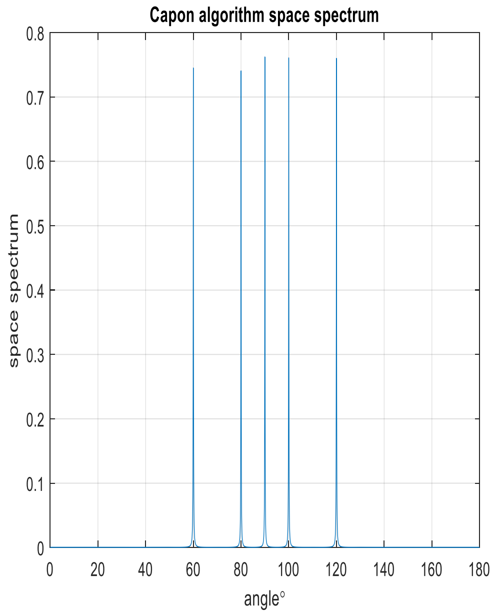

Fig. 8 : Capon Algorithm Space Spectrum

IV. CONCLUSION

In the present research, a new GA based non-uniform Antenna Array Configuration has been designed with an objective to achieve accurate direction of signal arrival or signal estimation at a specific azimuth and elevation angles. In this proposed array configuration, the parameters involved are number of snapshots, array elements, SNR and element spacing. The Music algorithm and ESPRIT algorithm shows better results on the optimized non-uniform array.

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