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Linear Antenna SLL Reduction using FFT and Cordic Method

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ABSTRACT: Radiators are the structures planned for radiating and receiving electromagnetic energy. It behaves as a intermediary structure between the guiding device such as waveguide, transmission line and the free space. Antenna array is a group identical element arranged in a regular fashion. In linear array, array elements are arranged in a straight line. In the thinning some of the elements of array are turned OFF, the main idea behind this is to reduce the cost, weight and SLL by using FFT as well as Cordic Method.

Keywords: SLL, Thinning, FFT, CORDIC, PS.

I. INTRODUCTION

Antenna array thinning involves turning OFF some of the array elements among the whole antenna array elements. This gives us the favorable results in cost, weight & side lobe level. Basically we connect the turned OFF elements to the matched load to avoid any type of radiation loss. In this paper we are going to use IFT (Iterative Fast Fourier Transform), PS (Pattern Search) and CORDIC (Coordinate Rotation Digital Computer).Here the amplitude tapering is performed by IFT and the resulted excitation amplitudes are used in CORDIC and PS to perform phase tapering. By the formula of AF (Array Factor) we comes to know that the array factor is complex in nature it depends on amplitude as well as phase so here this dependency of AF is used to achieve the optimum SLL. In the first method which is IFT the array element excitation is derived by AF and it is possible because there is a relation between Inverse Fourier Transform and AF. IFT method is based on the amplitude tapering i.e. in this method amplitudes are the key elements which are used to achieve the optimum SLL.

As we know if we excite same number of elements in any linear array by changing the sequence each of time we get different-different radiation patterns for same number of array elements, this concept is being utilized in this paper in amplitude tapering method.

The second and third method of this paper is based on phase tapering. In these methods the phase for each array element is calculated by setting a random excitation, we use the excitations of IFT method to get better results. Thus this paper provides optimum SLL by combining amplitude as well as phase tapering.

II. FORMULATION OF THINNING METHODS

(A) IFT Method: The far-field *F* in the direction of a linear antenna array consisting of M elements arranged along a line having uniform element spacing can be written as the product of the embedded element pattern *EF* and the array factor *AF* as

$$F(x) = EF(x).AF(x)$$

$$AF(x) = \sum_{m=0}^{M-1} Am\, e^{jkmdx}$$

Where A_m is the complex excitation of the m^{th} element, k (=2pi/ λ) is the wave number, λ is the wavelength, and x=cosθ and θ angular coordinate measured between far-field direction and the array axis.

The IFT method uses the property that for an array antenna having a uniform inter-element spacing of the elements, an inverse discrete Fourier transform relationship exists between the array factor (AF) and the element excitations. This property is used in an iterative way to derive the array element excitations from the prescribed AF. Array thinning is introduced by setting the amplitudes of the largest element excitations to unity and the others to zero during each iteration cycle of the IFT method. The number of elements that get an amplitude one is determined by the product of the array filling factor and the count of the array element positions.

(B) PS Method. In this section, Pattern Search (PS) Algorithm is introduced as a new tool for array thinning.

Pattern synthesis is known as the process of choosing the parameters of an antenna array to produce desired radiating characteristics. In the problem of array thinning, the number of all possible combinations is large and increases exponentially with number of array elements. Hence checking every possible combination to find the optimum one is nearly impossible. One needs a faster and more reliable method to find the optimum solution. No deterministic method can be found for array thinning; instead there are probabilistic methods which focus on density of "ON" elements in different parts of array and its effects on far-field pattern.

$$AP(\theta) = F(\theta)\sum_{n=1}^{N} an\, e^{j(n-1)(kdcos(\theta)+\beta)}$$

Where, N is number of array elements, A_n is amplitude of nth element, d is element spacing, $F(\theta)$ is element pattern and β is progressive phase shift.

(C) CORDIC Method. In this section, CORDIC is introduced as a tool for array thinning. CORDIC can be used to calculate a number of different functions. It is used here to calculate the estimated phase angle for the desired array elements. The very first we start with vector v_0

$$v_0 = \begin{bmatrix} 1 \\ 0 \end{bmatrix}$$

The rotation matrix becomes:

$$R_i = \frac{1}{\sqrt{1+tan^2\gamma_i}} \begin{bmatrix} 1 & -tan\gamma_i \\ tan\gamma_i & 1 \end{bmatrix}$$

The expression for the rotated vector $v_i = R_i v_{i-1}$ then becomes:

$$v_i = R_i = \frac{1}{\sqrt{1+tan^2\gamma_i}} \begin{bmatrix} 1 & -tan\gamma_i \\ tan\gamma_i & 1 \end{bmatrix} \begin{bmatrix} xi \\ yi-1 \end{bmatrix}$$

Where x_{i-1} and y_{i-1} are the components of v_{i-1}.

III. SYNTHESIS OUTCOMES

In the following, presented array thinning synthesis results refer to 50 elements linear antenna array for 80% of filling. The considered array features an embedded isotropic element pattern and the inter element distance d is equal to $\lambda/2$. Involved maximum number of iterations is 200.

Here we perform the iteration by all three methods to achieve the optimum SLL. First of all performance of completely filled array is plotted and then goes towards all three methods one by one .After completing synthesis by all these methods finally the result of all three are compared and plotted by the graph. In this paper performance of 50 element array at different-different filling percentage is also estimated and shown by the graph.

1. Evaluation of Completely Filled Array Synthesis Performance. In the first iteration, this vector would be rotated 45° counter clockwise to get the vector v_1. Successive iterations will rotate the vector in one or the other direction by size decreasing steps, until the desired angle has been achieved. Step i size is arctan($1/(2^{i-1})$) for i = 1, 2, 3, ….

More formally, every iteration calculates a rotation, which is performed by multiplying the vector v_{i-1} with the rotation matrix R_i

Using the following two trigonometric identities

$$v_i = R_i v_{i-1}$$

$$Ri = \begin{bmatrix} cos\gamma_i & -sin\gamma_i \\ sin\gamma_i & cos\gamma_i \end{bmatrix}$$

$$cos\alpha = \frac{1}{\sqrt{1++tan^2\alpha}}$$

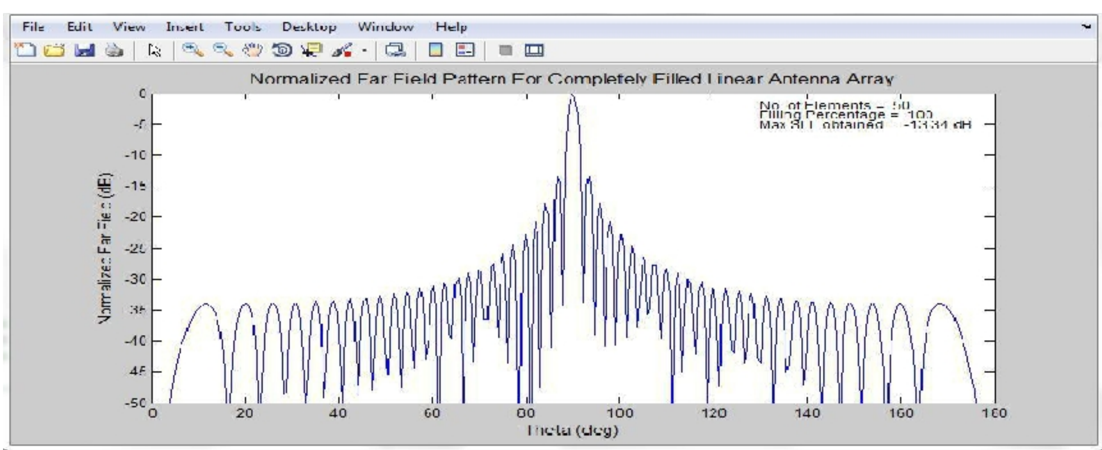

Fig. 1. Far Field pattern of a *50 elements completely filled array* with isotropic elements and main beam at broadside with *SLL= -13.34 Db.*

2. Evaluation of Thinned IFFT Synthesis Performance.

3. Evaluation of PS Synthesis Performance

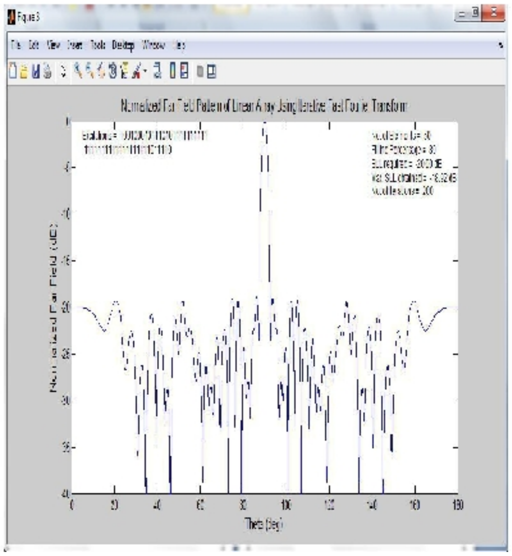

Fig. 2. Far Field pattern of a *50 elements* thinned array with isotropic elements and main beam at broadside using *IFFT technique with SLL*= -20.00 dB.

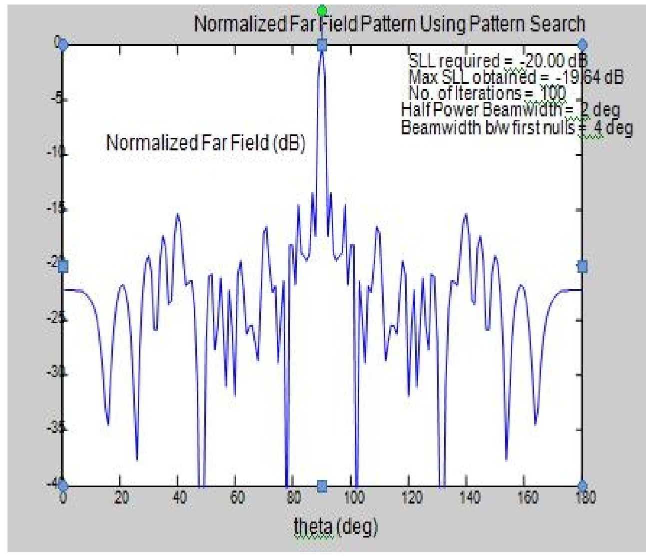

Fig. 3. Far Field pattern of a *50 elements* thinned array with isotropic elements and main beam at broadside using *PS algorithm with SLL* = -19.64dB.

4. Evaluation of Thinned Cordic Synthesis Performance

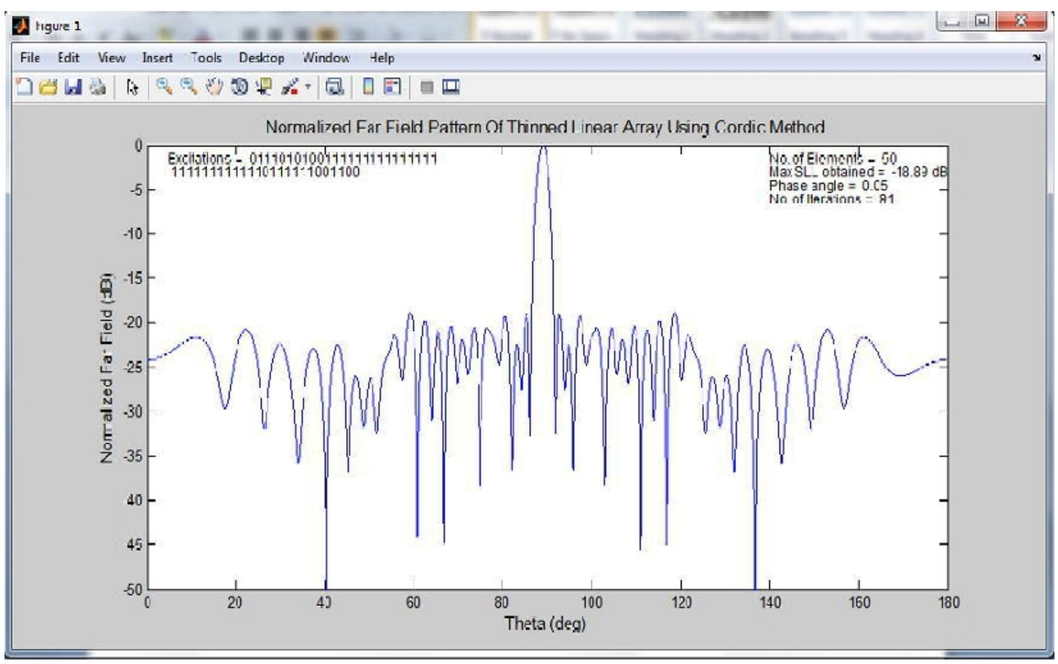

Fig. 4. Far Field pattern of a *50 elements* thinned array with isotropic elements using *CORDIC method with SLL=-18.89dB.*

5. Comparison Graph among all These Methods

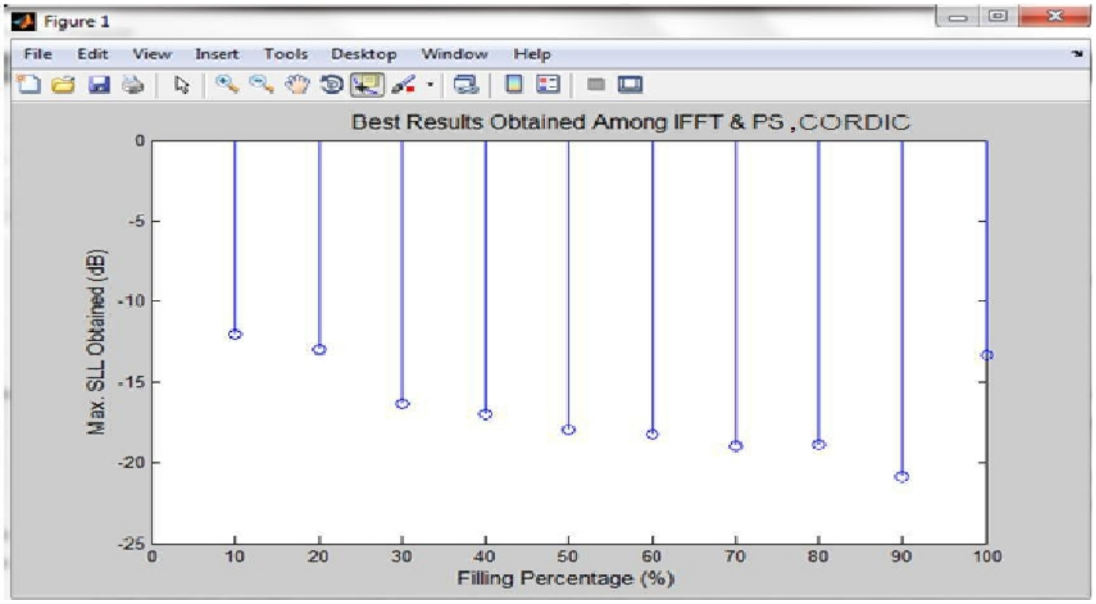

Fig. 5. Graph Showing Results Obtained Among IFFT & PS,CORDIC.

6. Evaluation of Thinned Combined FFT & Cordic Synthesis Performance.

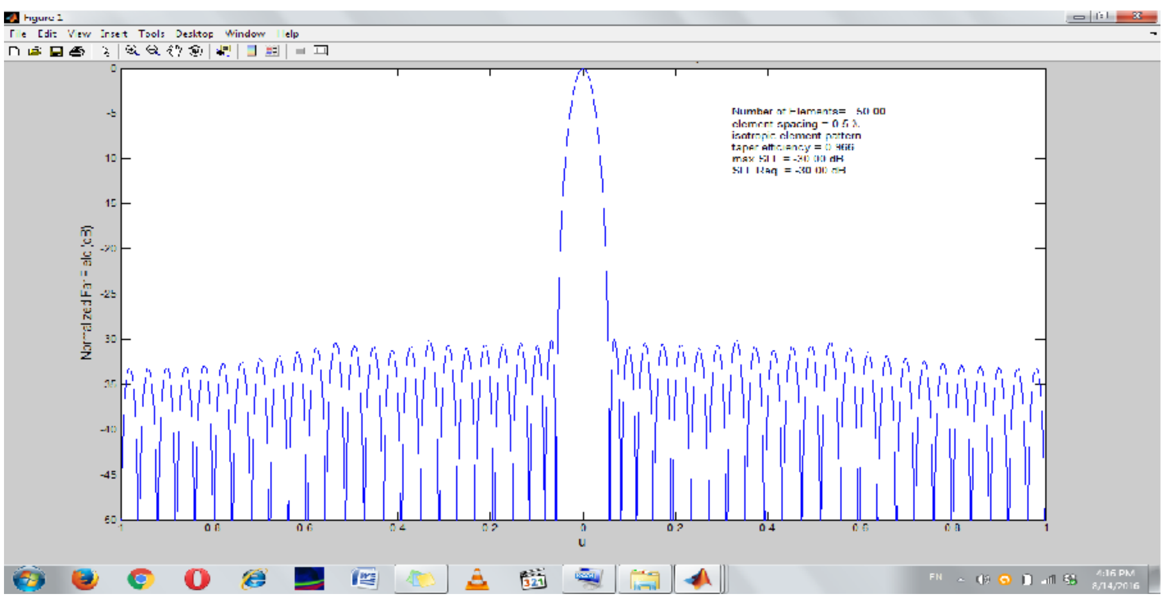

Fig. 6. Graph Showing Best Results Obtained for Combined method of FFT& CORDIC both.

IV. CONCLUSION

Following points can be concluded by these syntheses:

(i) For a fixed filling percentage, main beam level is always fixed, while first null level varies. This is due to change in the combination of ON/OFF elements' positions. Hence, this results in varying side lobe level.

(ii) Maximum SLL obtained increases with increase in filling percentage.

(iii) In most of the cases, maximum SLL obtained from thinned array is more than SLL obtained from completely filled array.

(iv) Also, max. SLL obtained increases with increase in number of elements.

(v) The directivity of antenna array increases as the numbers of iterations are increased.

(vi) Performance of PS and CORDIC is increased when we use the amplitude excitations obtained by IFT instead of any random number initialization.

(vii) Best result is obtained when we combined FFT & CORDIC method both simultaneously.

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