Iterative FFT Algorithm for Thinning Planar Array

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Abstract—**A new method for the synthesis of thinned periodic planar arrays with the constraint of maximum sidelobe is described in this paper. This way mainly depends on an inverse Fourier transform relationship which exists between the array factor and element excitations. Arrays can be thinned by setting the amplitudes of the element excitations to 1 and others to 0 during every iteration cycle. This paper will give the whole process of thinning planar array and specify key parts.**

Index Terms — **Planar array, low sidelobe, IFT**

1. Introduction

Over several years, some papers have studied the iterative Fourier technique (IFT) used for synthesis of antenna array [1-5]. The IFT can cope with the design constraints of the number of the elements of arrays and their aperture. In addition, it had been confirmed in Ref. [5] that a partial or even complete recovery of the original sidelobe performance is available using the IFT if the array has defective elements. This paper provide an example of a planar array consisting of 200 elements. The simulated results confirm the great efficiency and the robustness of the IFT.

2. Creating Geometry of Thinned Array

A thinned array with a thinning rate of f is described as Fig. 1, the size of which is $M \times N$, thus the number of its rest elements is $T = f \times M \times N$. Its array factor (AF) can be expressed as

$$AF(u,v) = \sum_{m=1}^{M} \sum_{n=1}^{N} A_{mn} \exp\{jk(md_x u + nd_y v)\} \quad (1)$$

Here A_{mn} is the complex excitation of element (m,n), k is the wavenumber, $u = \sin(\theta)\cos(\varphi)$ and
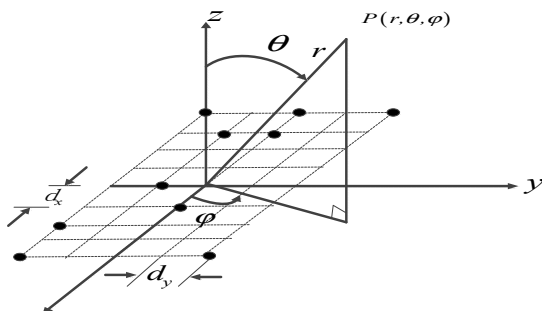

Fig. 1. Geometry of rectangular planar thinned array

$v = \sin(\theta)\sin(\varphi)$ are the direction cosines. Since (1) describes a discrete inverse 2-D Fourier transform from the element excitation A_{mn} of the planar array to its AF, then the

element excitations can be obtained by applying a direct 2-D Fourier transform on AF. Since the goal of the optimization is to minimize the peak of sidelobe level, the optimization model is as follows

$$\begin{cases} \min\left\{\max\left|\dfrac{F(u,v)}{F_{\max}}\right|\right\} \\ s.t.\ 1 \le m \le M, 1 \le n \le N \\ A_{00} = 1, A_{1N} = 1, A_{M1} = 1, \\ A_{MN} = 1, \sum_{m=1}^{M}\sum_{n=1}^{N} A_{mn} = T \end{cases} \quad (2)$$

where $F_{\max}$ represents the peak of mainlobe, if the element located $\{m,n\}$ is thinned, $A_{mn} = 0$, or $A_{mn} = 1$. Assume elements on the corners of the rectangular can't be thinned.

The detailed steps of the process of using IFT to realize thinning the rectangular planar array are as follows [4].

First, given the maximum number of iterations, the size of array, the thinning rate, the constraint of sidelobe etc.

Second, initialize the element excitations using a random setting with 0/1. "0" illustrates there is no element; to the contrary, "1" illustrates yes and the number of "1" is T as Fig. 2.

Third, compute AF from $\{A_{mn}\}$ using a $K \times K$ point 2-D inverse FFT with $K > \max(M, N)$ by applying zeros padding as Fig. 3.

Fourth, adapt AF to the prescribed maximum PSL constraints, when seek the samples exceeding the constraint of maximum PSL in the region of sidelobe of AF and then set them a value about 40 dB smaller than maximum PSL as Fig. 3. How to determine the region of sidelobe? First, you must intercept two sectional view $u = 0$ and $v = 0$ from the three dimensional graph of AF, then find the two valleys of each sectional view on both sides of their mainlobe and nearest to mainlobe of all valleys, finally, the region of sidelobe range from them to both sides of the AF pattern.

Fifth, Update $\{A_{mn}\}$ for the adapted AF using a $K \times K$ point 2-D forward FFT.

Sixth, Truncate $\{A_{mn}\}$ from $K \times K$ samples to the $M \times N$ samples .

Seventh, Set the T samples with largest amplitudes of $\{A_{mn}\}$ to 1 and the others to 0.

Eighth, compare the element excitations of the present iteration with that of the previous one. In case of a difference, continue ninth, or exit the iteration.

Ninth, repeat step 2 to 8 until the maximum PSL are met or the maximum number of iterations is reached.

3. Simulation Results

Next, the optimization results of symmetric rectangular planar thinned arrays are presented as Fig. 4 and Fig. 5. Basic parameters are set as follows: the size of array is 10×20, all elements are isophoric, the grid spacing is 0.5λ, $K = 256$, $u \in [-1,1]$, $v = [-1,1]$, the total number of iteration is 100. In addition, the corners of the planar array can't be thinned. The thinning rate is 54%, the constraint of maximum sidelobe is -24.00dB, the PSL after optimization is -21.12as Fig. 6. It takes about 8 seconds to complete a run. Compared with the array with the same size in Ref. [6], which optimize the rectangular planar thinned array with the same thinning rate by genetic algorithm, the PSL obtained is -14.40dB, IFT reduce 6.72dB.
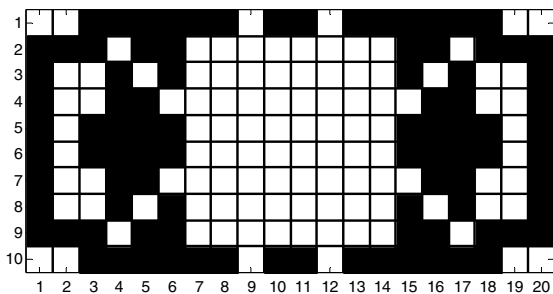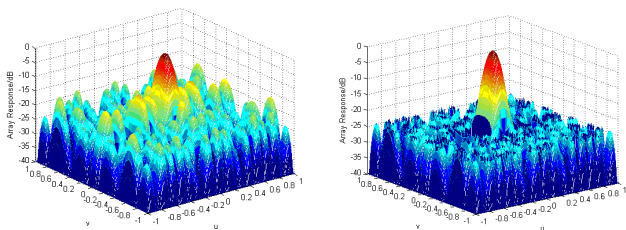

Fig. 2. Initialization of element distribution

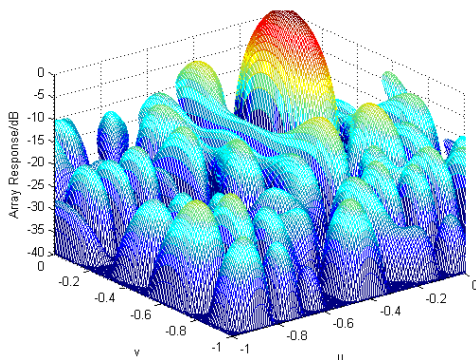Fig. 3. Initial array pattern and array pattern after adaption

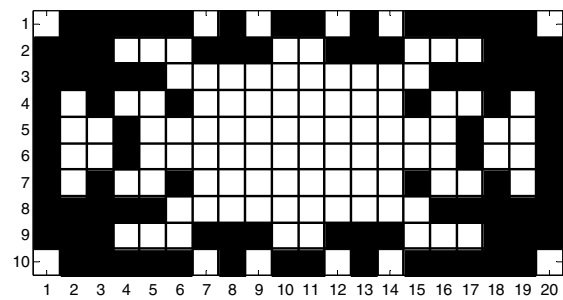Fig. 4. Array pattern after optimization

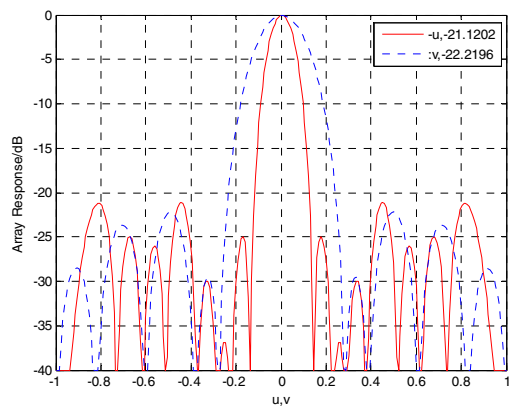Fig. 5. Element distribution after optimization

Fig. 6. Section diagrams of two directions

4. Conclusion

IFT has unique advantages in solving optimization of thinned array. It is used to quickly realize the optimization of rectangular planar thinned arrays, which provides useful inspiration for solving such problems and valuable reference for engineering application. Simulation results show the efficiency and robustness of the proposed method. In addition, the optimization method can be directly applied to the optimization design of large planar thinned arrays.

Acknowledgment

References

[1] X. K. Wang, Y. C. Jiao, and Y. Y. Tan, "Synthesis of Large Planar thinned Arrays Using a Modified Iterative Fourier Technique," *IEEE Trans. Antennas Propagat.*, vol. 62, no. 4, pp. 1564-1571, Apr. 2014.

[2] X. K. Wang, Y. C. Jiao, and Y. Y. Tan, "Gradual thinning synthesis for linear array based on iterative Fourier techniques," *Progress in Electromagn. Res.,*, vol. 123, pp. 299-320, 2012.

[3] W. P. M. N. Keizer, "Linear array thinning using iterative FFT techniques," *IEEE Trans. Antennas Propagat.*, vol. 56, no. 8, pp. 2757-2760, Aug. 2008.

[4] W. P. M. N. Keizer, "Large planar array thinning using iterative FFT techniques," *IEEE Trans. Antennas Propagat.*, vol. 57, no. 10, pp. 3359-3362, Oct. 2009.

[5] W. P. M. N. Keizer, "Low sidelobe patterns synthesis using iterative FFT techniques code in MATLAB," *IEEE Antennas Propagat*. Mag., vol. 51, no. 2, pp. 137-150, Apr. 2009.

[6] Randy L. Haupt, "Thinned Array Using Genetic Algorithm," *IEEE Trans. Antennas Propagat.*, vol. 42, no. 7, pp. 993-999, July. 1994.