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A FAST ALGORITHM OF SIDELOBE SECTOR NULLING USING PHASE-ONLY CONTROL

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[Abstract] Sidelobe sector nulling using phase-only control is a nonlinear problem. It can be simplified to a set of linear equations. And by using the odd-symmetrity of phase perturbations, the unknowns are reduced by half. Calculations are sped greatly.

1.Introduction

Interest in the subject of phase-only pattern control of array antennas has been stimulated by growing importance of phased array antennas. Since the required phase controls are already available as part of a beam sterring system. The literature on the subject is farily sizable [1], yet the results to date leave some basic questions unanswered. In sidelobe sector nulling,R.A.Shore and D.A.Pierre [2] presented a usual performance measure, or a trade-off between the two objectives of lowered sidelobes and the preservation of the integrity of a design antenna pattern. Unfortunately, the final set of equtions is nonlinear in the variables and can be solved only by using the method of nonlinear optimization. The number of iterations required to solve the problem increases with the number of array elements and also with increasing weight placed on reduction of sector sidelobe power compared with minimization of weight perturbations. In this paper, the nonlinear problem is simplified to a set of linear equations. Calculations are sped greatly and real-time controls can be realized.

2.Analysis

For a linear array of N equispaced, isotropic elements with inter-element spacing d and phase reference at the array center, let the sidelobe sector in which the power is to be minimized be specified by the interval $[U_0-\xi, U_0+\xi]$, the performance measure, P, is defined to be

$$P=\mu \sum_{n=1}^{N} |W_n - W_{0n}|^2 + Pav(U_0, \xi) \tag{1}$$

where

$$\mathrm{Pav}(U_0,\varepsilon)=(1/2\varepsilon)\int_{U_0-\varepsilon}^{U_0+\varepsilon}|p(u)|^2\,du$$

$$=\sum_{n=1}^{N}\{\sum_{m=n+1}^{N}2a_n a_m \mathrm{Cos}[\phi_{onm}+\phi_n-\phi_m]\cdot \mathrm{Sinc}[(d_n-d_m)\varepsilon]+a_n^2\}$$

with

$$\phi_{onm}=\phi_{on}-\phi_{om}+(d_n-d_m)U_0$$

and

$$W_{on}=a_n\exp(j\phi_{on})$$

and

$$W_n=a_n\exp[j(\phi_{on}+\phi_n)]$$

with

$$d_n=(N-1)/2-(n-1)$$

A necessary condition for P to have a minimum is that the partial derivatives of P with respect to the phase perturbation be equal to zero; that is

$$\frac{\partial P}{\partial \phi_n}=0 \qquad n=1,2,\ldots,N \quad (2)$$

Thus the set of equations is obtained.

$$\mu a_n \mathrm{Sin}\,\phi_n-\sum_{\substack{i=1\\ i\neq n}}^{N}a_i \mathrm{Sin}(\phi_{oni}+\phi_n-\phi_i)\cdot g_{ni}=0 \qquad n=1,2,\ldots,N \quad (3)$$

with

$$g_{ni}=\mathrm{Sinc}[(d_n-d_i)\varepsilon]$$

This set of equations is nonlinear in the variables.It is necessary to find a set of phase perturbations that minimizes P using a nonlinear optimization method. For a larger array, it is difficult to solve the set of equations in short duration of CPU. But we can linearize the set of equations.

Preservation of pattern integrity demands that phase perturbations required to achieve lowered sidelobes be kept as small as possible. For small phase perturbations, the following approximations are tenable.

$$\mathrm{Cos}x \doteq 1 \qquad \text{for } x\ll 1$$

$$\mathrm{Sin}x \doteq x \qquad \text{for } x\ll 1 \quad (4)$$

By substituting (4) into (3), a set of linear equations is obtained.

$$\phi_n(\mu a_n-\sum_{\substack{i=1\\ i\neq n}}^{N}a_i g_{ni}\mathrm{Cos}\,\phi_{oni})+\sum_{\substack{i=1\\ i\neq n}}^{N}\phi_i a_i g_{ni}\mathrm{Cos}\,\phi_{oni}=\sum_{i=1}^{N}a_i g_{ni}\mathrm{Sin}\,\phi_{oni} \quad (5)$$

This is a N×N matrix equation. Because of the odd-symmetry of the phase perturbations,

$$\phi_{N-n+1} = -\phi_n \qquad n=1,2,\ldots,N \qquad (6)$$

the problem can be simplified to a N1XN1 matrix equation(N1=N/2).

$$[\ A_{mn}\ ]\cdot[\ \phi_n\ ] = [\ B_m\ ] \qquad (7)$$

$$A_{mn} = \begin{cases} a_n(g_{mn}\mathrm{Cos}\,\phi_{omn} - g_{ml}\mathrm{Cos}\,\phi_{oml}), & \text{for } m \neq n \\ a_m(\mu - g_{ml}\mathrm{Cos}\,\phi_{oml}) - \sum\limits_{\substack{i=1 \\ i \neq m}}^{N} a_i g_{mi}\mathrm{Cos}\,\phi_{omi}, & \text{for } m=n \end{cases}$$

with

$$l=N+1-n$$

$$B_{mn} = \sum_{i=1}^{N} a_i g_{mi}\mathrm{Sin}\,\phi_{omi}$$

3.Results

The linear algebraic equations (7) were solved by using Crout decomposition method. Calculations were performed for 20dB Taylor arrays of 16, 32 and 64 elements were interelement spacing $\lambda/2$. The look direction of the array was made 10 by presetting all phases, and the pattern sector for reduced sidelobe power was taken to be the interval [20°, 30°]. Figures 1, 2 and 3 show the unperturbed pattern and the perturbed pattern obtained with μ=0.5 for arrays of 16, 32 and 64 elements respectively. For a 16-element array,a loss of 0.55dB in gain is associated with a 44.2dB average power in the required sector, while for a 64-element array, only a 0.17 dB loss in gain is required to achieve a 57dB average power over the sector. As the number of elements increases, the power in the sector [20°, 30°] decreases and the perturbed pattern follows the original pattern more closely, especially in the near-in sidelobe region. Also, compared with (3), (7) was solved more quickly.

4.Conclusion

With restrictions on the size of the phase perturbations, the nonlinear problem was simplified to a set of linear equations. And also, by using the odd-symmetrity of phase perturbation, the unknowns were reduced by half. Therefore, solution of this problem was sped greatly.

Reference

1. R.A.Shore, "A Review of Phase-only Sidelobe Nulling Investigations at RADC ", RADC-TR-85-145
2. R.A.Shore and D.A.Pierre, "Sidelobe Sector Nulling with Minimized Phase Perturbations", RADC-TR-85-56

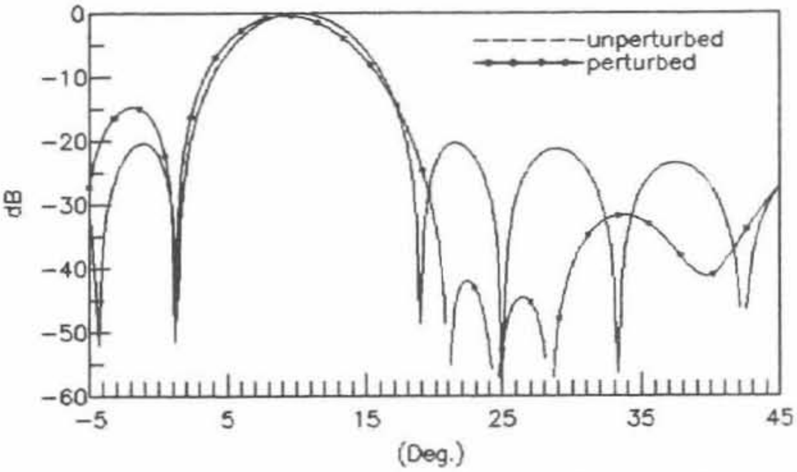

Fig.1 Unperturbed 20dB Taylor 16-element Array Pattern and Perturbed Pattern with Lowered Sidelobes

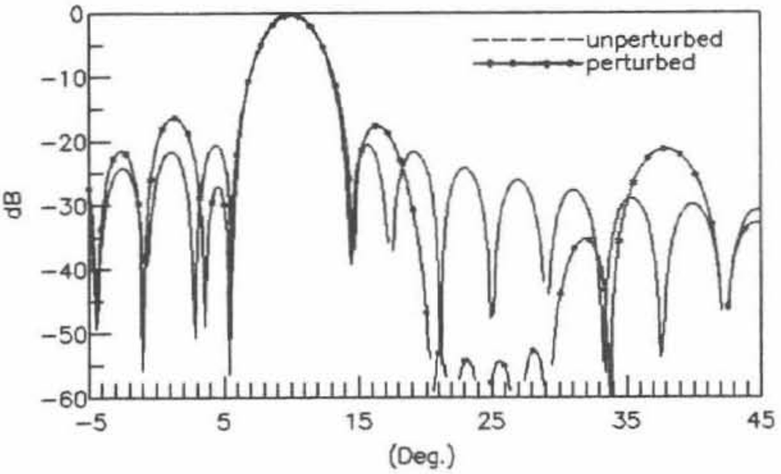

Fig.2 Unperturbed 20dB Taylor 32-element Array Pattern and Perturbed Pattern with Lowered Sidelobes

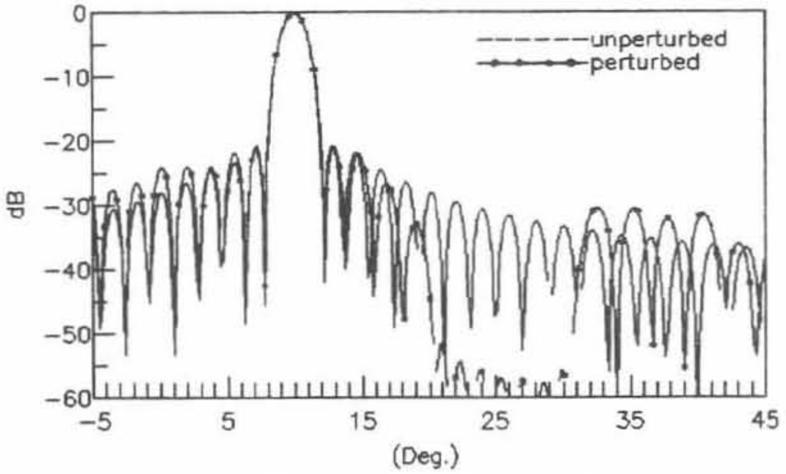

Fig.3 Unperturbed 20dB Taylor 64-element Array Pattern and Perturbed Pattern with Lowered Sidelobes