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Real Phase–only Nulling Algorithm (REPONA) for Adaptive Sum and Difference Patterns

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INTRODUCTION

This paper presents a real phase–only nulling algorithm which can reject jammers in sum and difference patterns simultaneously.

In phased array antenna, the phase is set for beam steering. If we use phase weighting method to set up nulls in field patterns, the required phases can be added to the scanning phases, and the signals from jammers can be suppressed.

In previous paper [1], we only deal with the sum pattern. Now, we will apply REPONA algorithm to both of the sum and difference patterns.

THEORETIC ANALYSIS

In H. Steyskal's paper [2], the process in which the weighting phases are obtained is to solve non–linear equations. In our paper [1], it can be found that the non–linear problem is converted into the linear problem. Here, the main idea is described.

Suppose there is a linear array antenna with $2N$ istropic elements which are placed with the interspacing d. Thus, the sum and difference patterns can be expressed as follows

$$E_s(u) = \sum_{n=1}^{2N} a_n \cdot \exp(j\ d_n u) \tag{1.a}$$

$$E_d(u) = \sum_{n=1}^{2N} b_n \cdot \exp(j\ d_n u) \tag{1.b}$$

where

$$u = \frac{2\pi d \sin\theta}{\lambda}$$

$$d_n = n - N - 0.5$$

and a_n, b_n represent the amplitude weight coefficients of sum and difference patterns respectively.

In addition, assum that the signal received from the mth snapshot at nth element of array is

$$x_{nm} = \eta_{nm} + \sum_{k=1}^{K} \alpha_k \cdot \exp[j\ (d_n u_k + \varphi_{km})] \tag{2}$$

where η_{nm} is the white noise, α_k and φ_{km} are the amplitude and phase from the kth jammer,

$$u_k = \frac{2\pi d \sin\theta_k}{\lambda}$$

where θ_k is the direction of the kth jammer.

To reject the K jammers, suppose that a small phase perturbation ψ_n is formed at the nth element. Let

$$\sum_{n=1}^{2N} a_n x_{nm} \cdot \exp(j\ \psi_n) = 0 \tag{3.a}$$

$$\sum_{n=1}^{2N} b_n x_{nm} \cdot \exp(j\ \psi_n) = 0 \tag{3.b}$$

i.e.

$$\sum_{n=1}^{2N} \eta'_{nm} + \sum_{n=1}^{2N} a_n \sum_{k=1}^{K} \alpha_k \cdot \exp[j\ (d_n u_k + \varphi_{km} + \psi_n)] = 0 \tag{4.a}$$

$$\sum_{n=1}^{2N} \eta''_{nm} + \sum_{n=1}^{2N} b_n \sum_{k=1}^{K} \alpha_k \cdot \exp[j\ (d_n u_k + \varphi_{km} + \psi_n)] = 0 \tag{4.b}$$

Now we let φ_{km} and ψ_n are asymmetric to the center of array antenna. Therefore, the above equations can be simplified

$$\sum_{n=1}^{2N} \eta'_{nm} + \sum_{n=1}^{2N} a_n \sum_{k=1}^{K} \alpha_k \cdot \cos(d_n u_k + \varphi_{km} + \psi_n) = 0 \tag{5.a}$$

$$\sum_{n=1}^{2N} \eta''_{nm} + \sum_{n=1}^{2N} b_n \sum_{k=1}^{K} \alpha_k \cdot \sin(d_n u_k + \varphi_{km} + \psi_n) = 0 \tag{5.b}$$

Apply Taylor's expansion to the above equations and keep the first two terms, we have

$$\sum_{n=1}^{2N} \eta'_{nm} + \sum_{n=1}^{2N} a_n \sum_{k=1}^{K} \alpha_k \cdot \cos(d_n u_k + \varphi_{km}) - \sum_{n=1}^{2N} a_n \psi_n \sum_{k=1}^{K} \alpha_k \cdot \sin(d_n u_k + \varphi_{km}) = 0 \tag{6.a}$$

$$\sum_{n=1}^{2N} \eta''_{nm} + \sum_{n=1}^{2N} b_n \sum_{k=1}^{K} \alpha_k \cdot \sin(d_n u_k + \varphi_{km}) - \sum_{n=1}^{2N} b_n \psi_n \sum_{k=1}^{K} \alpha_k \cdot \cos(d_n u_k + \varphi_{km}) = 0 \quad (6.b)$$

This is a linear simultaneous equations. It can be solved by using the Gram–Schmidt Orthogonalization.

COMPUTATION RESULTS

Two examples are given as follows.

(A) In Fig.1, there are 4 jammers whose positions are at $u=0.4$, -0.55, 0.7 and -0.85, respectively. The total number of linear array elements is 30. It is obvious that the nulling depth to suppress the interferences is below −100dB in sum pattern as shown in Fig.1(a), and the nulling depth to suppress interferences is also below −100dB in difference pattern as shown in Fig.1(b).

(B) In Fig.2, there are 3 jammers. The directions of jammers are at $u=0.56$, 0.59, 0.62. This is similar to the case that the jammers are very close to each other. In Fig.2(a) shows the sum pattern, and the nulling depth is about −100dB. In Fig.2(b) shows the difference pattern, and the nulling depth is about −100dB.

CONCLUSIONS

It can be seen from the above discussion that it is possible to simultaneously creat nulls in sum and difference patterns to suppress jammers through controlling the phases at each array elements.

The algorithm presented in this paper has an advantage that the real arithmetic operations are only used in computation. So this algorithm converges fast. In addition, the resulted phases can be added to the phases for the beam steering. And the production cost can be reduced.

REFERENCES

[1] GUO Yanchang and LI Jianxin, "Real phase–only nulling algorithm (REPONA) for pattern synthesis", 1990 IEEE AP–S Symposium Digest, pp.1704–1707.

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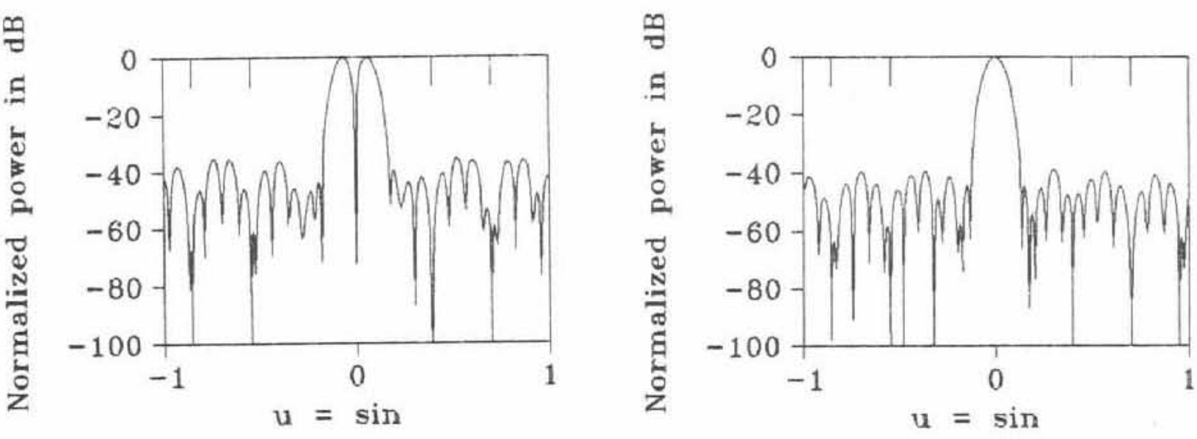
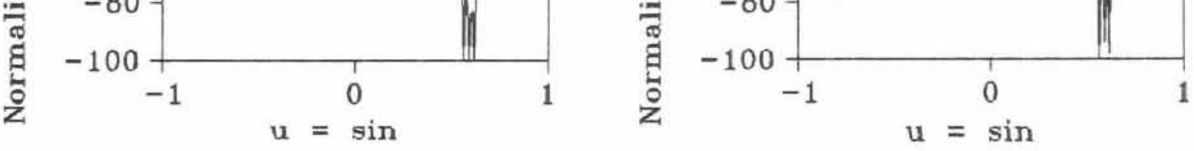


(a) (b)

Fig.1 Adaptive nulling simultaneously in sum and difference patterns with phase weighting(4 jammers). (a) Sum pattern; (b) Difference pattern.



(a) (b)

Fig.2 Adaptive nulling simultaneously in sum and difference patterns with phase weighting(3 dense jammers). (a) Sum pattern; (b) Difference pattern.