

JAMMER SUPPRESSION BY AMPLITUDE CONTROL - AN ALTERNATIVE APPROACH

T.B. Vu
 School of Electrical Engineering & Computer Science
 University of New South Wales
 Sydney Australia

Introduction

Jammer suppression in the sum pattern of a phased array has received much attention in the literature to date. More recently, a method of suppressing RF interference or jammers by amplitude control only was presented (1), (2). With this method, the suppression of the jammers and the maximization of the desired signal for any given jammer configuration can be carried out by first steering the antenna main beam to the signal by using phase-shifters, and then suppressing the jammers with the aid of attenuators. Thus, the minimization of the effect of unwanted interference is achieved in a straightforward manner. In addition, the resulting current distribution is symmetrical about the center of the array, so that the number of attenuators required is halved.

As shown in reference (1), when the number of elements in the phased array is small, the required current amplitude distribution may be obtained by expanding the factorized form of the expression for the array factor. However, as the number of elements becomes large, the expansion process can be cumbersome, so, in that case, the required distribution may be obtained from that of a known case (e.g. from that of an eight-element array) by using an iterative equation. In this paper, an alternative method of interpreting the problem is used, by which an explicit expression for the current amplitude distribution is obtained for any arbitrary number of elements and jammers.

Formulation of the problem

It is well known that, if the center of the array is chosen as the origin of the coordinates, the expression for the array factor of an N-element uniform linear array is given by

$$AF = AF(\psi) = \frac{\sin \frac{N\psi}{2}}{\sin \frac{\psi}{2}} \quad (1)$$

where, with reference to figure 1, we have

$$\psi = \frac{2\pi}{\lambda} d \cos \theta + \alpha \quad (2)$$

α = progressive phase-shift

Figure 2 shows a plot of AF when $N=8$ for ψ varying from $-\pi$ to $+\pi$. It is seen that AF is a maximum when $\psi = 0$. In addition, the zeroes of AF lie symmetrically about $\psi = 0$, i.e.

$$\psi_k = \pm \frac{2k\pi}{N} \quad (k=1,2,\dots,4 \text{ in this case})$$

These zeroes are the same as those on the unit circle discussed in reference (1). Thus, for a given antenna array, N is fixed so that ψ_k are also fixed. This means that the directions of all the nulls in a uniform linear array are fixed once α is chosen, i.e. once the main beam is designed to steer to a given direction.

In order to steer the nulls to the directions of jammers, a non-uniform current distribution must be used. It was shown in reference (1) that this can be achieved by controlling the current amplitude distribution only (i.e. without using phase-shifters) by ensuring that the zeroes of the array factor always occur in conjugate pairs. This condition is interpreted in this paper as that the symmetry of the zeroes of the array factor about $\psi = 0$ be maintained. In what follows, we shall show a new method of calculating the current amplitude distribution required for the complete cancellation of jammers.

New method of calculating current amplitude distribution

Consider the functions $A_i = AF(\psi - \psi_i)$ and $B_i = AF(\psi + \psi_i)$. It can be seen that A_i and B_i are mirror images of one another about $\psi = 0$; in addition, they have a peak value at $\psi = \psi_i$ and $\psi = -\psi_i$ respectively.

Thus, if there are M jammers located at $\psi = \psi_m$ ($m = 1, 2, \dots, M$), then we can synthesize an array factor AF_T with zeroes at $\pm \psi_m$ by combining AF with M pairs of (A_i, B_i) in the correct proportion, that is

$$AF_T = 0 \quad \left| \quad \begin{array}{l} \psi = \psi_m \\ (m = 1, 2, \dots, M) \end{array} \right. \quad (3)$$

where

$$AF_T = AF + \sum_{n=1}^M c_m (A_m + B_m)$$

$$= \frac{\sin \frac{N\psi}{2}}{\sin \frac{\psi}{2}} + \sum_{m=1}^M c_m \left[\frac{\sin \frac{N(\psi - \psi_m)}{2}}{\sin \left(\frac{\psi - \psi_m}{2} \right)} + \frac{\sin \frac{N(\psi + \psi_m)}{2}}{\sin \left(\frac{\psi + \psi_m}{2} \right)} \right] \quad \dots (4)$$

As a result, the problem of suppressing the M jammers reduces to finding the set of constant coefficients c_m by solving the system of M linear equations given above.

Once c_m are found, the required current amplitude distribution can be calculated by recalling that, when $N=2n$, another form of the expression for AF of equation (1) is

$$AF = \sum_{k=1}^n e^{j(k-\frac{1}{2})\psi} + \sum_{k=1}^n e^{-j(k-\frac{1}{2})\psi} \quad (5)$$

where the first term on the right hand side represents the contribution, from n elements above the center of the array. The second term is the contribution from the n elements below the center. Since $A_i = AF(\psi - \psi_i)$ and $B_i = AF(\psi + \psi_i)$, we have

$$A_i = \sum_{k=1}^n e^{j(k-\frac{1}{2})(\psi - \psi_i)} + \sum_{k=1}^n e^{-j(k-\frac{1}{2})(\psi - \psi_i)}$$

$$B_i = \sum_{k=1}^n e^{j(k-\frac{1}{2})(\psi + \psi_i)} + \sum_{k=1}^n e^{-j(k-\frac{1}{2})(\psi + \psi_i)}$$

As a result, the expression for AF_T becomes

$$AF_T = \sum_{k=1}^n e^{j(k-\frac{1}{2})\psi} \left[1 + 2 \sum_{i=1}^M c_i \cos(k-\frac{1}{2})\psi_i \right] + \sum_{k=1}^n e^{-j(k-\frac{1}{2})\psi} \left[1 + 2 \sum_{i=1}^M c_i \cos(k-\frac{1}{2})\psi_i \right] \quad (6)$$

Thus, the required current amplitudes of the k^{th} elements above and below the array center are equal. In addition, as the corresponding phase terms in AF and AF_T are exactly the same, the suppression of jammers requires amplitude control only. Similar results are obtained if N is odd.

Figure 3 shows the computed pattern where $N=8$, $d=\frac{\lambda}{2}$, desired signal. At $\theta=112^\circ$, and directions of jammers are 28° , 80° and 89° respectively. As expected the results are the same as that of reference (1), despite the fact that they are obtained in different ways.

References

1. T.B. Vu, Proc. IEEE, Vol. 131, part H, 8/1984, pp.242-246.
2. T.B. Vu, 1984, AP-S/URSI Intern. Symp. Digest, pp.811-814.

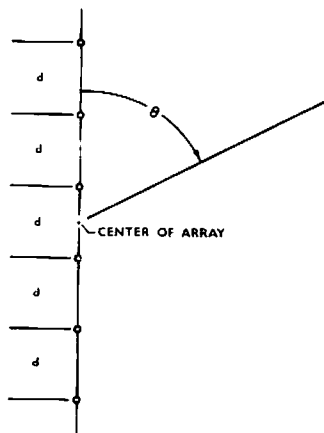


Figure 1

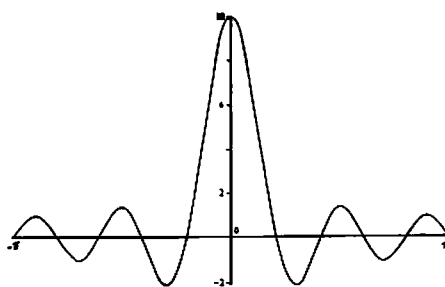


Figure 2

Figure 3

