LOW SIDELOBE APERTURE DISTRIBUTION OF MULTI-STEP AMPLITUDE QUANTIZATION WITH PEDESTAL

Gao Tie(高 铁) Guo Yanchang(郭燕昌)
(Nanjing Research Institute of Electronic Technology, Nanjing 210013)

Abstract A low sidelobe aperture design method of multi-step amplitude quantization with pedestal is proposed, and general analysis and formulas are described. The computation results compared with our previous method "Multi-Step Amplitude Quantization(MSAQ)" on peak side-lobe level, aperture efficiency, normalized input power and sidelobe degradation with tolerance are given. It is shown that, under the same conditions, the method presented in this paper is better than the MSAQ.

Key words Low sidelobe; Aperture distribution; Multi-step amplitude quantization with pedestal; Aperture efficiency; Sidelobe degradation; Tolerance

I. Introduction

In designing and studying the solid-state active phased array antenna, how to reduce the number of types of T/R modules to minimum and design an array antenna with low sidelobe level is a challenge to the antenna designer. For reason given, a series of low sidelobe antenna aperture synthesis methods for solid-state active arrays are presented. In earlier study[1-3], the linear array and planar array of circular aperture were studied. The control technique of sidelobe level for linear array and planar array of circular aperture are studied using the thinning array and phase-only weighting methods under the conditions of solid-state modules. In this case, the excitation level only takes 0 or 1 or the phase weighting is only used. Then the types of T/R modules are decreased and the sidelobe level in the array pattern is reduced. However, for the array which is consisted of not too many elements, the array thinning and phase-only weighting techniques have weak control of the sidelobe level in the array pattern. Two-step and multi-step amplitude weighting methods were studied in Ref.[4-6] for which good results were obtained. Their major design ideas are as follows: The amplitude at element can take not only two values of 0 or 1, and also another one value or more values in the interval (0,1). It is expected to improve the sidelobe level in the antenna pattern. However, these studies are concerned with the linear array or planar circular aperture array and a set of simultaneous integral equations should be solved to obtain the optimized quantization steps. Besides, if the problem about two dimensional plane is reduced to a one dimensional problem using the symmetry of the circular aperture antenna, more difficulties will be encountered for a two dimensional complex aperture antenna to be approximated. J. J. Lee[7] proposed that the rectangular planar aperture can be approximated with an elliptical one. A series of elliptical steps with the same axis ratio and different quantization steps are used to satisfy the requirement of equal sidelobe level in all directions of the antenna. Evidently, the efficient areas of the array
will decrease (about 21.4%) if the rectangular aperture is approximated with an elliptical aperture. To solve the problem, the multi-step amplitude quantization weighting method for the rectangular aperture was proposed [8]. The major concept is as follows: The value that the element in the array can take is limited to a few levels $[C_0, C_1, C_2, \cdots, C_{K-1}, C_K]$. The optimized quantization steps are obtained using the nonlinear optimization. Then the best aperture distribution is found with the statistical method. The approach gives better result with a trade off among the number of T/R modules in the rectangular aperture antenna, the sidelobe level and the aperture efficiency. However, the value of $C_0$ is always zero in the above approach and the levels at some elements around the corners of the rectangular aperture will be zeros because a two dimensional separable current distribution is used as an approximated function.

In order to increase the aperture efficiency of the array, improvement is made to this approach [8]. The value of $C_0$ is no longer taken as zero but a nonzero value. In this case, the method of designing two dimensional rectangular aperture distribution of multi-step amplitude quantization with pedestal is studied. And the theoretical computation formulas and the obtained results are given. As examples of application, in this paper the comparison between the algorithm in Ref. [8] and the new one is also given for the array aperture synthesis of $60 \times 30$ solid-state active elements in the rectangular lattice with equal spacings. Comprehensive analysis is made to the sidelobe level, the aperture efficiency, the normalized input power and the sidelobe degradation due to the phase and amplitude errors from two algorithms. It can be seen that the proposed method has special advantages in the practical engineering.

II. Theoretical Analysis of Multi-Step Amplitude Quantization with Pedestal

For simplicity, consider a planar rectangular array in which $M \times N$ elements are arranged along the $X$ and $Y$ axes with equal spacing $d_X$ and $d_Y$. When the element pattern is ignored, the ideal field pattern is

$$E_0(u, v) = \sum_{m=1}^{M} \sum_{n=1}^{N} I_{mn} e^{j(mu + nv)}$$

where

$$u = \frac{2\pi}{\lambda} d_X \left( \sin \theta \cos \varphi - \sin \theta_0 \cos \varphi_0 \right)$$

$$v = \frac{2\pi}{\lambda} d_Y \left( \sin \theta \sin \varphi - \sin \theta_0 \sin \varphi_0 \right)$$

$I_{mn}$ is the ideal amplitude coefficient of the $mn$-th element, it can be sampled from aperture distribution $F(X, Y)$, $\lambda$ and $(\theta_0, \varphi_0)$ are the wave length and scanning angle. We use a random variable $J_{mn}$ to replace $I_{mn}$, the $J_{mn}$ quantized values can be $C_0, C_1, \cdots, C_K$. Then the field pattern can be expressed as

$$E(u, v) = \sum_{m=1}^{M} \sum_{n=1}^{N} J_{mn} e^{j(mu + nv)}$$

For simplicity, dividing region $[C_0, 1]$ into $K$ intervals $[C_0, C_1], [C_1, C_2], \cdots, [C_{K-1}, C_K]$,