

Realization of Chebyshev-Like Radiation Pattern in an Aperture Antenna with Plural Circular-Arrays Technology

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Abstract—Chebyshev-like radiation pattern with constant and low sidelobe levels was realized in an aperture antenna using plural circular-arrays technology. The excitation level was determined by quadratic distribution with an edge level of -30dB. Next, the excitation coefficients of Dolph-Chebyshev linear array were used as the coefficients of a 4 circular-arrays antenna. The sidelobes are as low as the linear array, but are not constant.

I. INTRODUCTION

Dual-reflector antennas have been well studied to realize desirable radiation patterns by designing the field distribution on the aperture [1] [2]. However, particular radiation patterns such as Chebyshev radiation pattern are difficult to realize in a circular aperture antenna as the field distribution on the reflector must include a significant one.

As for array antennas, the relation between excitation distribution and radiation pattern has been extensively studied [3][4]. Especially, an array antenna with plural circular-arrays is attractive to realize the equivalent radiation pattern in a circular aperture antenna [5].

In this paper, we try to realize Chebyshev-like radiation pattern using plural circular-array technology. The design method is the optimization of the excitation coefficients of circular arrays. The relation between a linear array and a plural circular-arrays antenna is studied, and will be applied to the extension from a linear array to an aperture antenna. The discrepancy will be discussed.

II. DESIGN PRINCIPLE AND ANTENNA CONFIGURATION

The radiation pattern $F_A(\theta, \phi)$ of plural circular-arrays with radiating elements located at (r_m, ϕ_n) is expressed by,

$$F_A(\theta, \phi) = \sum_{m=0}^M \sum_{n=1}^N A_{mn} \exp \{ jkr_m \sin \theta \cos (\phi - \psi_n) \} \quad (1)$$

where m and n represent the circular array number and the element number on the circle, respectively, and A_{mn} is the excitation of the element (m, n) on the m -th circle. Radiators are assumed to be isotropic without coupling.

The A_{mn} is taken from the m -th coefficient of a concerned linear array. First, the excitation A_{mn} are determined from a continuous field distribution of the following quadratic distribution with -30dB edge level.

$$f(r) = 1 - \alpha (r/a)^2 \quad (2)$$

where a : the radius of an circular aperture, r : the radial location of a point in concern, and α : a parameter of an edge level. The equality between a continuous field distribution in a reflector antenna and discrete excitation distribution in a plural circular-arrays was formerly derived as follows [5],

$$\{f(r_m, \psi_n) \Delta r 2\pi\} r_m = N_m A_{mn} \quad (3)$$

where N_m is the number of elements on the m -th circle.

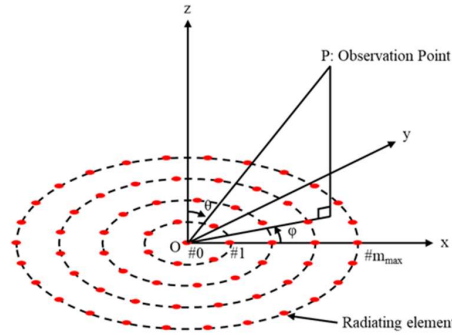


Figure 1. Configuration of the proposed array antenna and the relevant coordinate system.

Next, a linear Dolph-Chebyshev array [6] is studied. The excitation coefficients of the linear Chebyshev array are used as the excitation coefficients to four circular arrays. The nine elements should be considered in radial direction. Actually, the elements are on a line only +x axis so that the right half of the linear array is completely coincident with the linear array. However, the left half may have error to cause a discrepancy between the radiation patterns of the linear and plural circular-arrays antenna.

III. SIMULATION RESULT

The obtained radiation pattern of a 4 circular-arrays antenna with quadratic coefficient distribution is shown in Fig. 2. The radiation pattern shows an excellent symmetry on both angles in reference to $\theta = 0$ deg. The side-lobes are quite low and constant, about -29dB, which may be called Chebyshev-like pattern. The main beam width is 25deg in the first null.

For comparison purpose, the correspondent plural circular-arrays antenna with uniform excitation is presented in Fig. 2. The main beam width is 60% of the proposed antenna. The first side-lobe is -17dB, which is the same as the theoretical value of an aperture antenna with uniform field distribution [4].

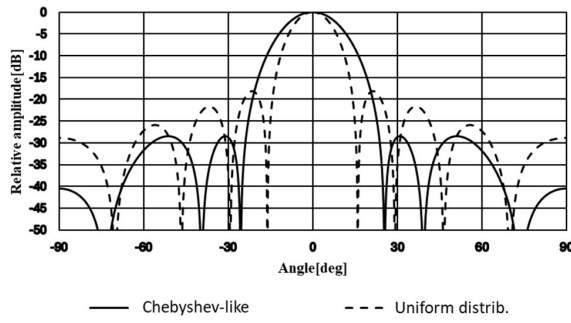


Figure 2. The radiation pattern of a Chebyshev-like aperture antenna with the comparison to an antenna with uniform distribution ($m=4$).

A linear array with the coefficients that are the same as those of the 4 circular-arrays was taken up. The radiation pattern is shown in Fig. 3. The first sidelobe is -20 dB, which is much higher than the pattern in Fig. 2. The second and third sidelobes decrease the levels gradually. However, overall sidelobes are similar in shape so that a simple relation may exist between the two patterns.

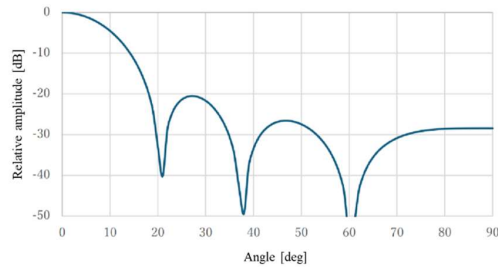


Figure 3. The radiation pattern of a linear array antenna with the same excitation coefficients as the 4 circular-arrays antenna.

Next, a linear array antenna with the coefficients of Dolph-Chebyshev array was studied. The sidelobe level is designed as -30dB. The radiation pattern is shown in Fig. 4 with red broken lines. The sidelobes have constant level of -30dB, but the sidelobe width (between nulls) increases with angle: 9deg, 12deg, 22deg.

The coefficients are given to each circular-array of the 4 circular-arrays antenna. The radiation pattern is shown in Fig. 4 with black solid lines. The sidelobes are not constant in terms of the level and beam width. However, the highest sidelobe is -almost the same value as the linear array: -29dB, and the 3 sidelobes show correspondence in terms of each location and shape. It suggests that a transformation relation exists between a linear array antenna and a plural circular-arrays antenna with Chebyshev distribution.

The radiation patterns of a plural circular-arrays antenna with quadratic distribution (in Fig. 2), and that with Chebyshev distribution (in Fig. 4) both present quite low sidelobes. We compare each data of excitation coefficients as follows:

Quadratic:

0.037 0.458 0.759 0.940 1 0.940 0.759 0.458 0.037

Chebyshev:

0.262 0.465 0.723 0.924 1 0.924 0.723 0.465 0.262.

The edge levels or the excitations of the outermost element of the former is much lower than that of the latter. It can be said that Chebyshev distribution can realize quite low sidelobes despite of high edge level.

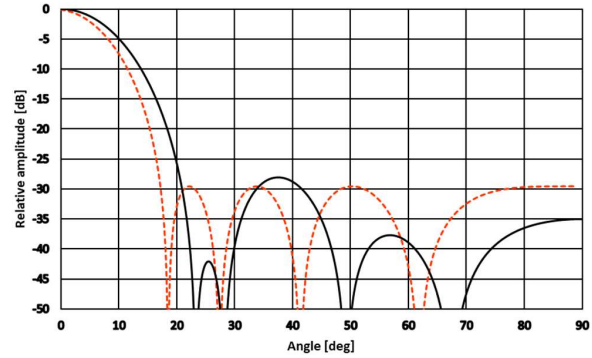


Figure 4. The radiation patterns of a linear array antenna (red broken line) and a 4 circular-arrays antenna (black solid line), both with the excitation coefficients of Dolph-Chebyshev array.

IV. CONCLUSIONS

Chebyshev-like radiation pattern in a plural circular-arrays antenna was obtained adopting the quadratic excitation distribution. The first and second sidelobe are about -29dB. A linear array antenna with the same excitation coefficients has higher sidelobes, but the sidelobe shapes have similarity.

A plural circular-arrays antenna with the coefficients of Dolph-Chebyshev array has sidelobes as low as a Dolph-Chebyshev linear array antenna, but not constant. This fact indicates the existence of transformation relation.

The excitation coefficients of Chebyshev distribution are much higher than those of quadratic distribution.

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