Reflectarray Design by Induced Electromotive Force Method

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***Abstract*—A design method of reflectarray by the induced electromotive force method is proposed. The effect of oblique incidence from a primary source to a reflectarray element is included in the design process of the reflectarray by the proposed method. The CPU time for design of the reflectarray by the proposed method is small because mutual coupling between reflectarray elements are ignored. The reflectarray which consists of a dipole and parasitic dipole element is designed by the proposed method and the performance of the proposed method is shown.**

I. Introduction

A parabolic reflector antenna has been widely used for radar and satellite communication systems [1]. Although the parabolic reflector antenna has high gain and large bandwidth, the parabolic reflector is bulky and heavy. Instead of the bulky parabolic reflector, planar reflectarray has been proposed as a high gain reflector antenna in recent years [2], [3]. The planar reflectarray consists of different sizes of elements so that the phase of the scattering field of all reflectarray elements is in-phase in desired scattering angle. Therefore, the phase variation of the scattering field of reflectarray element versus its dimension should be obtained exactly as long as possible for design of the desired reflectarray. Because the phase variation of the scattering field of reflectarray element versus its dimension depends on incident field, the model of incident field in the design process of reflectarray is important.

In previous researches, the normal incidence of plane wave has been assumed for calculating the phase variation of the scattering field of reflectarray element versus its dimension [4]-[6]. However, the normal incidence of the plane wave is incorrect when the primary source has strong directivity and is close to the reflectarray. Various techniques have been proposed for representing incident wave correctly in the design of reflectarray element. Zhou et. al used the measured far field pattern of corrugated horn antenna for representation of the incident field in a spectral domain method of moments (SD-MoM) [7]. Arrebola et. al introduced far field to near field transformation technique by using the measured far field pattern of feed horn antenna to realize incident field accurately [8]. Both of the techniques can realize incident field including directivity or near field of the primary source accurately but measurement of the far field pattern of the primary source is required in advance. Thus, an efficient numerical technique for representing incident field correctly in the design of reflectarray element has not been presented.

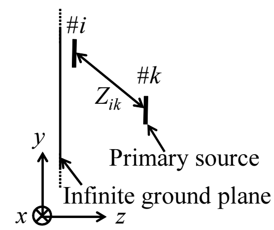

Fig. 1. Mutual impedance between dipole elements.

In this paper, a design method of reflectarray which consists of linear element is proposed. In the proposed design method, mutual impedance between the primary source and a reflectarray element is calculated exactly by the induced electromotive force method. Therefore, the effect of incident angle and distance from the primary source to a reflectarray element are both included in the phase of scattering field of the reflectarray element. CPU time of the proposed method is small because CPU time for calculating mutual impedance between linear elements is small and the effect of mutual coupling between reflectarray elements are ignored. An example of design of reflectarray which consists of dipole and parasitic dipole element shows the performance of the proposed design method.

II. Proposed Design Method

By using induced electromotive force method, mutual impedance between primary source and ith reflectarray element shown in Fig. 1 can be expressed as following equation.

$$Z_{ik} = -\int_{y_c-l_i}^{y_c+l_i} E_y \frac{I_i^* \sin k_0(l_i - |y - y_c|)}{I_k \sin(k_0 l_k) I_i^* \sin(k_0 l_i)} dy, \qquad (1)$$

where E_y is y components of incident field to ith reflectarray element, l_k and l_i are length of the primary source and the ith reflectarray element, respectively. y_c is y-coordinate of center of ith reflectarray element, I_k and I_i are curent of the primary source and the ith reflecrarray element, respectively.

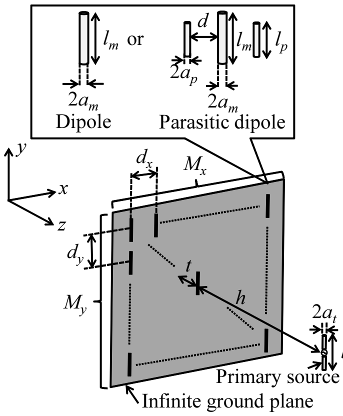

Fig. 2. Reflectarray consists of dipole and parasitic dipole elements.

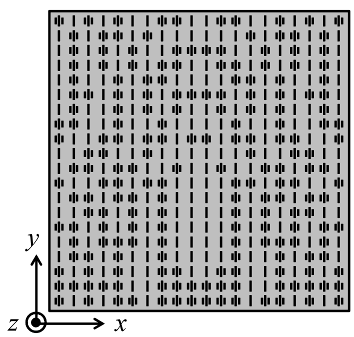

Fig. 3. Design example of a reflectarray.

In our proposed method, the current of reflectarray element in each position is obtained by using Eq. (1). Therefore, the effect of angle of incidence and distance from the primary source to a reflectarray element are both included in the phase of scattering field of the reflectarray element. For reduction of CPU time, mutual coupling between reflectarray elements is ignored in our proposed method.

III. Reflectarray Design Example

By using our proposed method, a reflectarray which consists of both dipole element and parasitic dipole element was designed. Structure and parameter definition of the reflectarray is shown in Fig. 2 and a dipole element is used as a primary source. Design example of a reflectarray is shown in Fig. 3. Mainlobe direction of the designed reflectarray is $(\theta_0, \phi_0) = (10^\circ, 0^\circ)$. Because the mainlobe of the designed reflectarray is scanned only θ direction, it is found that reflectarray is symmetric.

Scattering pattern of the designed reflectarray is shown in Fig. 4. Directive gain of the reflectarray is defined as follows.

$$G = \frac{|\mathbf{D}(\theta, \phi)|^2}{30 P_{in}} \qquad (2)$$

where $\mathbf{D}(\theta, \phi)$ is directivity function of reflectarray, P_{in} is the input power of primary source. As shown in Fig. 4, it is found that mainlobe of the designed reflectarray is in the direction of $(\theta_0, \phi_0) = (10^\circ, 0^\circ)$. Design of the reflectarray was carried out by using Intel Core i5 3.2 GHz CPU and CPU time required for design of the reflectarray was about 600 seconds.

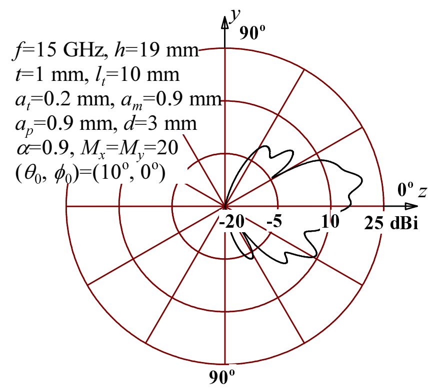

Fig. 4. Simulated scattering pattern of designed reflectarray.

IV. Conclusions

In this paper, a reflectarray design method which is based on the induced electromotive force method was proposed and a reflectarray which consists of linear element was designed. The effect of angle of incidence and distance from the primary source to a reflectarray element were both included in the design process of the reflectarray. Numerical simulation showed that the designed reflectarray has desired mainlobe direction.

ACKNOWLEDGEMENT

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