NUMERICAL ANALYSIS OF THE ELECTRODYNAMIC CHARACTERISTICS OF SOME RADIATORS FOR MIRROR ANTENNAS

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We investigate the fields produced by electrodynamic models of mirror-antenna radiators with reflectors in the shape of a disk or a disk with a scattering projection. The analysis is based on a numerical method which reduces the problem to integrodifferential equations and then solves them by computer. We consider the amplitude and phase structure of the field of an ideally conducting disk excited by a rectangular slit and an elementary oscillator perpendicular to the disk axis. We also consider the phase structure of the field of a reflector in the shape of a disk with a conical projection excited by an elementary oscillator.

Some mirror antenna designs employ radiators that comprise a reflector in the shape of a disk or a disk with a conical projection at the center (Fig. 1) and an excitation source on the reflector axis (see, e.g., [1]). Various characteristics of the radiator field are needed for the design of these antennas. Because of the small wave size of these reflectors (the radius $a$ is of the order of one and a half wavelengths), the asymptotic methods normally used for field computation in the theory of mirror antennas do not produce reliable results in this case. In our study, the electromagnetic reflector field is investigated by the method of [2, 3] which reduces the problem to integrodifferential equations of a special kind that are solved numerically. The results of the analysis show that the method of [2, 3] is quite efficient for solving problems of this kind.

In order to analyze the field of a radiator that produces the difference directional diagram of a monoimpulse parabolic antenna without radiation along the axis [4], we need to solve the problem of excitation of a disk by a rectangular slit with the distribution of equivalent currents corresponding to the field in a cross section of a waveguide carrying the wave $H_{20}$ (Fig. 1a). The time dependence of the fields is taken in the form $e^{i\omega t}$. We introduce Cartesian $(x, y, z)$ and cylindrical $(r, \varphi, z)$ systems of coordinates, as shown in Fig. 1a. The $b \times c$ rectangular slit is at a distance $h$ from the disk (see Fig. 1a). The density of equivalent magnetic $j^m$ and electric $j^e$ currents in this case can be expressed in the form

$$j^m = x^0 H \sqrt{\frac{\mu}{\varepsilon}} \sin \frac{2\pi x}{b}, \quad j^e = y^0 H \sqrt{1 - (\lambda/b)^2} \sin \frac{2\pi x}{b},$$

where $H$ is a dimensional factor proportional to the field strength in the waveguide, $\varepsilon$ and $\mu$ are the absolute dielectric permittivity and magnetic susceptibility of the surrounding medium, $\lambda$ is the wavelength.

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In order to solve this problem by the method of [2, 3], we need to know the distribution on the disk surface of the tangential cylindrical components $E_r^0$ and $E_{\varphi}^0$ of the field set up by the equivalent currents. Introducing in the usual way the magnetic and electrical vector potentials of the currents (1) and expressing them in terms of the slit field $E^0$, we obtain formulas for the functions $E_r^0(r, \varphi, z)$ and $E_{\varphi}^0(r, \varphi, z)$ that contain integrals over the slit surface. By [2, 3], we should represent the components $E_r^0(r, \varphi, z)$ and $E_{\varphi}^0(r, \varphi, z)$ as Fourier series in the variable $\varphi$ and then solve for each harmonic the integrodifferential (or integral) equations in the induced currents on the disk.

This problem was investigated for the case $a = 1.5\lambda$, $h = \lambda$, $b = 1.25\lambda$, $c = b/4$. The calculations show that sufficient accuracy is achieved by retaining only the zeroth and the second harmonic for the component $E_{\varphi}^0$ and the second harmonic for the component $E_r^0$. The expressions for these field components on the disk surface have the form

$$E_{\varphi}^0(r, \varphi, 0) = E_{\varphi}^{(0)}(r) + E_{\varphi}^{(2)}(r) \cos 2\varphi,$$

$$E_r^0(r, \varphi, 0) = E_r^{(2)}(r) \sin 2\varphi,$$

where $E_{\varphi}^{(0)}$, $E_{\varphi}^{(2)}$, and $E_r^{(2)}$ are the corresponding Fourier amplitudes. Figures 2a and 2b compare the computations of the functions $E_{\varphi}^0(r, \varphi, 0)$ and $E_r^0(r, \varphi, 0)$ for two cases: in the first case (solid curve) the computations were performed by numerical integration, in the second case (dots) using representation (2). Figure 2 plots the absolute values of the functions $E_{\varphi}^0$ and $E_r^0$ on the disk surface for $r = 0.5a$ and $r = a$, $0 \leq \varphi \leq 2\pi$. We see that these results are very close to each other even for $r = a$. As $r$ decreases, the approximation accuracy of representation (2) improves.

Having solved this diffraction problem by the method of [2, 3] and determined the induced current density on the disk, we computed various characteristics of the secondary field $E(r, \varphi, z)$ produced by the disk.

In mirror antenna computations, we need to know the distribution of the radiator field in the region of the main mirror (in our case, at a distance of the order of $6\lambda$ from the disk). Figure 3 shows the field distribution in the plane $\varphi = 0$ (the difference directional diagram is produced in this plane) with the observation point moving along a circle of radius $R = 6\lambda$ centered at the origin. Figure 3 plots the dependence of the normalized amplitude of the field $E$ on the direction to the