CONFORMAL RESONATOR ANTENNA SYNTHESIS ACCORDING TO A PRESCRIBED AMPLITUDE PATTERN

M.I. Andriychuk, Yu.P. Topolyuk. Institute of Applied Problems of Mechanics and Mathematics of the Ukrainian Academy of Sciences. Lvov, USSR.

1. The present paper deals with two problems of synthesizing a resonator antenna with a cylindrical or a spherical outer surface. Such an antenna is a resonant cavity [1,2] confined within the outer boundary S and the inner one S_0. On the outer boundary the following conditions are satisfied

$$E_\tau^- = E_\tau^+ = -i\rho\nu_\tau(H_t^- - H_t^+),\quad E_t^- = E_t^+ = i\rho\nu_t(H_\tau^- - H_\tau^+), \qquad (1)$$

where the "-" and "+" superscripts stand for a function's values on both sides of S ; the τ and t subscripts stand for orthogonal tangent directions; ν_τ , ν_t are the desired components of transparency distribution in these directions, ρ is the transparency scale which determines the Q-factor of a resonator. The inner boundary is a metallic or impedance surface, the form of which is to be defined.

The antenna is synthesized in such a way, that the pattern components of the generalized natural oscillations [3] are close in magnitude to the prescribed amplitude pattern. At the first stage an equiphase tangent electrical field of the oscillation on S is sought for. For this purpose the functional

$$\sigma = (F - |f|, F - |f|)_f \qquad (2)$$

is minimized, where F is a prescribed, speaking generally, vector amplitude pattern; $|f|$ - is the created amplitude pattern, $(\cdot,\cdot)_f$ is a scalar product in the pattern space. The pattern f and the field distribution u on S are related as

$$f = Au, \qquad (3)$$

where A is the known linear bounded operator.

The Euler equation for the functional σ assumes the form

$$A^* A u = Re(A^*[Fe^{i \arg f}]), \qquad (4)$$

where A^* is the operator adjoint to A in the sense of identity $(A^*f, u)_u = (f, Au)_f$; $(\cdot,\cdot)_u$ is the scalar product in the field space on S.

The equalities (3),(4) make up a set of non-linear equations in relation to u. The set is solved by the successive approximation technique. Phase diagrams $\arg f$ in the right-hand part of (4) are taken from the previous approximation, so that at each step a linear problem is solved [4]. Meanwhile the value of σ decreases monotonously. The functional (2) can be minimized in relation to u by various gradient techniques as well [5]. When necessary, summands can be addedl to the functional, which describe various additional requirements [6]. Correspondingly it will make equation (4) more complicated.

At the second stage similarly to [4,7] the outer boundary transparency, the form of the inner surface S_0 are found, and when necessary the impedance distribution is found, too.

2. For a cylindrical antenna the problem formulated is reduced to a two-dimensional one; e.g. $\tau = z, t = \theta$; $E_z|_{\tau=a} = u$, $E_\theta = 0$; $\nu_z = \nu$, $\nu_\theta = 0$; a is the cylinder radius, θ is the polar angle in the cross-section plane. The pattern f describes the asymptotic properties of the function E_z on the infinity, F describes the required amplitude distribution.

Let us present the desired field u and pattern f as Fourier series expansion. Then the operators A and A^* become diagonal. The equiphase condition of the field on S is satisfied due to the real values of the function's u Fourier coefficients. The equation (4) turns into a set of non-linear equations in relation to these coefficients. The form of the inner metallic boundary S_0 is determined on the condition $u^+|_{S_0} = 0$, where u^+ is the inner field determined by the technique of ref. [7].

For a spherical antenna an axially symmetric problem has been considered. The field is represented by means of Hertz function. The amplitude pattern F is prescribed as

$$F = \{F_\theta(\theta,\varphi), F_\varphi(\theta,\varphi)\}, \quad F_\theta(\theta,\varphi) = \bar{F}_\theta(\theta)\cdot|\cos\varphi|,$$

$$F_\varphi(\theta,\varphi) = \bar{F}_\varphi(\theta)\cdot|\sin\varphi|, \quad 0 \le \theta \le \pi, \quad 0 \le \varphi \le 2\pi;$$ $\bar{F}_\theta(\theta), \bar{F}_\varphi(\theta)$ are real-value positive functions.

Then the functional (2) assumes the form

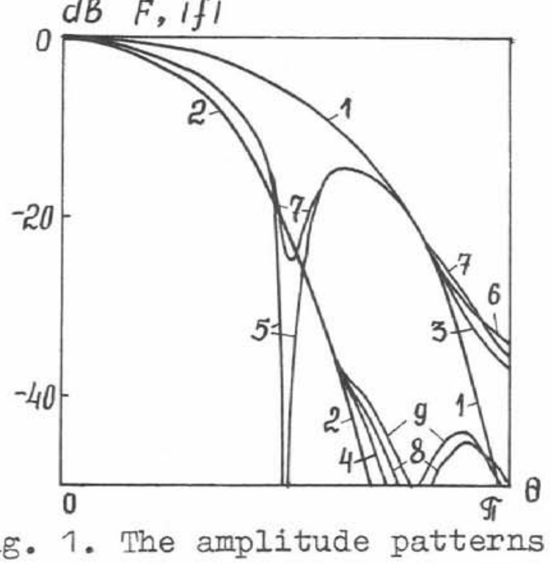
$$\sigma = \int_0^{\pi} \{(\bar{F}_\theta - |f_\theta|)^2 + (\bar{F}_\varphi - |f_\varphi|)^2\} \sin\theta \, d\theta \quad (5)$$

The operators A and A^* are made diagonal by expanding the Hertz functions in terms of spherical harmonics. The equation (4), as above, turns into a set of non-linear algebraic equations in relation to the real-value expansion coefficients.

Similarly to [4], the inner boundary S_0 is sought for in the form of an anisotropic surface of revolution having the property $E_\varphi^+|_{S_0} = 0$. This equality is made use of to find S_0. The impedance of the surface is defined by the condition $W(\theta) = iH_\varphi^+/E_\tau^+|_{S_0}$, where τ is the direction along the generatrix.

The algorithm has been generalized for the case of prescribing the energy diagram $\hat{F}^2 = \bar{F}_\theta^2 + \bar{F}_\varphi^2$ instead of $\bar{F}_\theta$, $\bar{F}_\varphi$. Then $\bar{F}_\theta$, $\bar{F}_\varphi$ are accordingly redistributed at each step.

3. Numerical calculations have been made for four problems: A, B (cylindrical antenna) and C, D (spherical antenna).



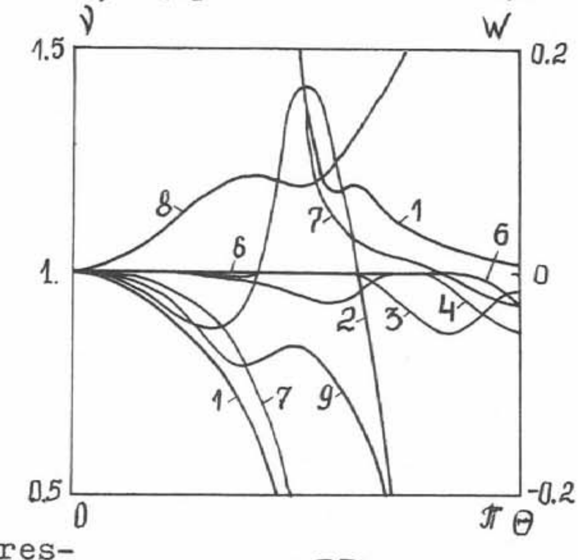


Fig. 1. The amplitude patterns prescribed and obtained. A: F – 1; $|f|$ – 3. B: F – 2; $|f|$ – 4. C: $\bar{F}_\theta$ – 1, $\bar{F}_\varphi$ – 5; $|f_\theta|$ – 6, $|f_\varphi|$ – 7. D: $\bar{F}_\theta$, $\bar{F}_\varphi$ – 2; $|f_\theta|$ – 8, $|f_\varphi|$ – 9.

Fig. 2. The transparencies of the outer boundaries and the impedances of the inner ones. A: ν – 3. B: ν – 4. C: ν_θ – 6, ν_φ – 7, W – 1. D: ν_θ – 8, ν_φ – 9, W – 2.

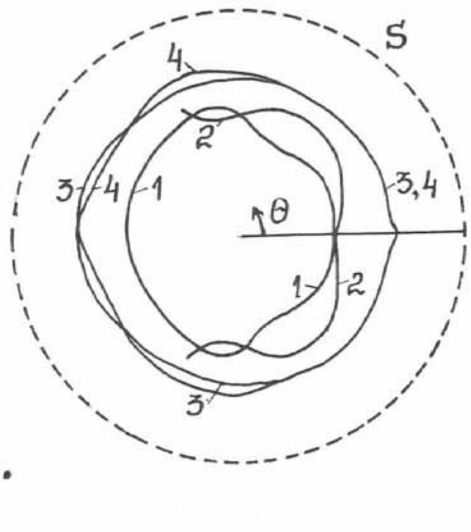


Fig. 3. The forms of the inner boundaries. A – 3. B – 4. C – 1. D – 2.

In the problems A,B,C $ka = 10$, in the problem D $ka = 7$. The prescribed amplitude patterns were: A – $F(\theta) = \cos^2 \frac{\theta}{2}$; B – $F(\theta) = \cos^8 \frac{\theta}{2}$; C – $\bar{F}_\varphi(\theta) = \bar{F}_\theta(\theta) / \cos\theta /, \bar{F}_\theta(\theta) = \cos^2\frac{\theta}{2}$; D – $\bar{F}_\theta(\theta) = \bar{F}_\varphi(\theta) = \cos^8 \frac{\theta}{2}$.

The numerical results are shown on fig. 1-3. With those θ values where the field and currents become small, the precision of the calculations decreases. Practically this part of the antenna doesn't contribute to the pattern formation. The corresponding curves on fig. 2,3 terminate in these places. In the problems A,C the prescribed patterns have been successfully synthesized up to the level of -25 dB, while in the problems B,D it has been possible up to the level of -35 dB.

R E F E R E N C E S

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