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SCATTERING OF PLANE WAVES ON CUBIC SHAPE DIELECTRIC RESONATORS

Trubin A. A.
Institute of Telecommunication Systems,
Igor Sikorsky Kyiv Polytechnic Institute, Ukraine
E-mail: atrubin9@gmail.com

РОЗСІЮВАННЯ ПЛОСКИХ ХВИЛЬ НА КУБІЧНИХ ДІЕЛЕКТРИЧНИХ РЕЗОНАТОРАХ

Досліджуються характеристики розсіювання у відкритому просторі електромагнітних хвиль на плоских решітках діелектричних резонаторів кубічної форми при збудженні основних вироджених магнітних типів коливань.

Lattices of rectangular dielectric resonators are actively studied as a basis for creating wide class of new devices [1-10]. Dielectric cubic resonators are more easily realized in optical integral devices, and also have a more rarefied spectrum of natural oscillations arising due to degeneracy. At the same time the presence of degeneracy significantly complicates the description of the behavior of lattices of cubic DRs in various structures. The development of the physical theory of scattering by complex structures of DRs [11, 12] made it possible not only to clarify their properties in various structures, but also showed the effectiveness of this approach to a unified method for describing various devices in the microwave and optical ranges. The purpose of this report is to calculation and analysis of field scattered by plain lattices of cubic DRs with lowest natural oscillations of magnetic type H_{111}.

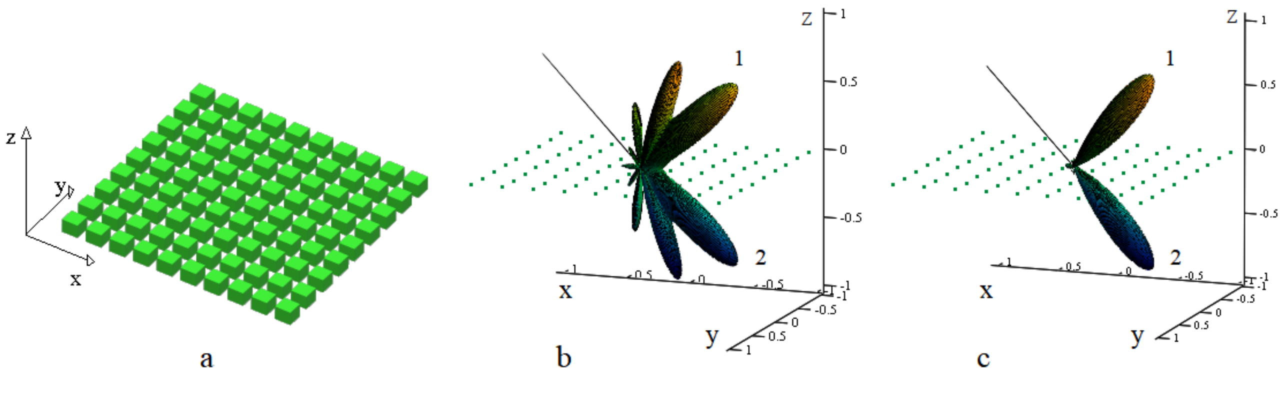
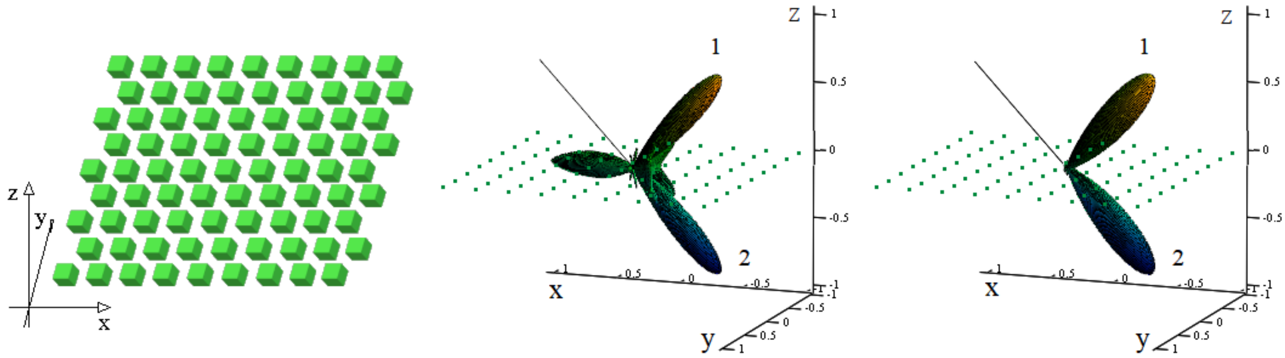


Fig. 1. A square lattice of a cubic shape DR (a). Angular distribution of the squared modulus of the scattering amplitude for a plane wave of the p-type (b), s-type (c) on the square lattice with H_{111} degenerate oscillations for $\vartheta_{\pi} = 3/4\pi$; $\varphi_{\pi} = 0$. Relative dielectric constant of the resonators $\varepsilon_{1r} = 36$.

To calculate the scattered field by the DR lattice, we used the perturbation theory [11]. The mutual coupling coefficients of cubic DRs were calculated by the formulas [12] taking into account the presence of a threefold degeneracy of each of the lattice resonators.



a b c

Fig. 2. A hexagonal lattice of a cubic DRs (a). The squared modulus of the scattering amplitude for a plane wave of the p-type (b), s-type (c) on the 10×10 cubic DR lattice ($\vartheta_\pi = 3/4\pi$; $\varphi_\pi = 0$; $\varepsilon_{1r} = 36$).

The scattering field of the lattice in the wave zone in the direction towards the observation point (θ,φ) represented as:

$$\vec{E}(\theta,\varphi) - \vec{E}^{+}(\theta_\pi,\varphi_\pi) = \vec{e}_0 f\left\langle\theta_\pi,\varphi_\pi\middle|\theta,\varphi\right\rangle E_0\frac{e^{-ik_0 r}}{k_0 r}\,, \qquad (1)$$

where $\left(\vec{E}^{+},\vec{H}^{+}\right)$ field of a plane wave incident on a lattice; $\vec{e}_0 = \vec{e}_0(\theta_\pi,\varphi_\pi\,|\,\theta,\varphi)$ - is the unit vector, defining the polarization of the scattered electric field in the wave-zone; $(\vartheta_\pi,\varphi_\pi)$ - is the incident wave direction in the spherical coordinate system of the lattice; $f\left\langle\theta_\pi,\varphi_\pi\middle|\theta,\varphi\right\rangle$ is the scattering amplitude.

In fig. 1, 2, b, d shows the angular dependences of the squared modulus of the scattering amplitude for a plane p-type wave (b); s-type (c) on a lattice (a) of 10×10 DRs, respectively. The dots in (b, c) conventionally show the centers of the resonators; the straight line shows the direction of propagation of the incident wave $\left(\vec{E}^{+},\vec{H}^{+}\right)$: $\vec{k}_0$. The relative distance between the centers of adjacent resonators is $\lambda_0/4$ (λ_0 is the wavelength in free space at the frequency of H_{111} resonant oscillations). As can be seen from the above data, petal 1 (fig. 2, b) is directed at an angle of "reflection" to the surface of the grating. Petal 2 is directed along the vector $\vec{k}_0$, whence, taking into account (1) and when the polarization of the incident and scattered waves coincides, it defines the lattice "shadow" resulting from reflection [11].

The emergence of a coupling between degenerate oscillations of cubic resonators can lead to the appearance of additional scattering lobes (fig. 1, 2, b). Resonators in a hexagonal lattice are more weakly coupled to each other than in a cubic lattice; therefore, additional lobes in it are less noticeable. As can be seen from the data in Fig. 1, 2, b, additional lobes appear more often in the case of p-scattering. In this case, additional petals also lie in the plane of incidence.

The proposed theory can be used to calculate and analyze complex antenna structures, power dividers, filters, multiplexers, and other communication devices in the microwave, infrared and optical wavelength ranges.

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