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SCATTERING OF PLANE WAVES ON ONE-DIMENSIONAL LATTICES OF SPHERICAL DIELECTRIC RESONATORS

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РОЗСІЮВАННЯ ПЛОСКИХ ЕЛЕКТРОМАГНИТНИХ ХВИЛЬ НА ОДНОВИМІРНИХ РЕШІТКАХ СФЕРИЧНИХ ДІЕЛЕКТРИЧНИХ РЕЗОНАТОРІВ

Розглядається задача розсіювання плоских електромагнітних хвиль на одновимірних решітках діелектричних резонаторів (ДР) сферичної форми з нижчими коливаннями магнітного типу H_{1m1}. На основі теорії збурень, побудована електромагнітна модель решіток. Аналізуються особливі випадки розсіювання на лінійних та кільцевих структурах. Розглянуті решітки можуть використовуватися як елементи антен в пристроях зв'язку або інтернету речей оптичного та інфрачервоного діапазонів довжин хвиль.

Today, spherical dielectric resonators (DRs) are considered as one of the main elements of various devices in the infrared and optical ranges [1-4]. Despite the fact that the fields of this type of resonators are described by relatively simple analytical expressions, the calculation of more complex structures, based on them, faces significant computational difficulties. At the same time, obtaining exact analytical solutions usually leads to cumbersome computational structures [5]. Analytical modeling using perturbation theory also makes a number of difficulties arising from the high sensitivity of the output parameters to the relative frequencies of partial resonators, as well as the uncertainty in the choice of basis functions for a spherical DRs. At the same time, the construction of electromagnetic models of such structures provides valuable information about the behavior of systems of various shapes lattices under different scattering conditions.

In this report, we considered the problem of scattering of plane waves on various one-dimensional lattices of spherical DRs with fundamental magnetic oscillations of partial resonators H_{1m1} $(m = 0, \pm 1)$. On the basis of perturbation theory [6], an electromagnetic model of scattering on one-dimensional and quasi-one-dimensional ring lattices is constructed, taking into account the excitation of degenerate oscillations of the main type in the system of resonators. Various particular cases of wave scattering are considered, which are of interest for the development of antenna field spatial converters for access points of optical and infrared communication systems.

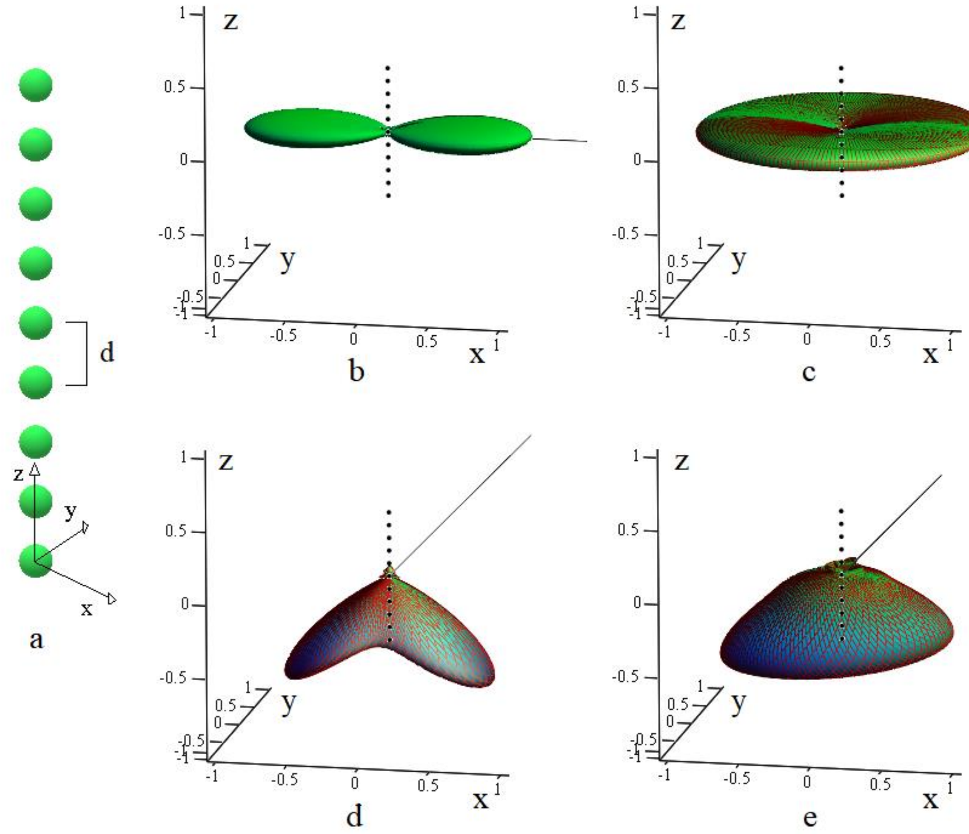

Fig. 1. Linear lattice of spherical DRs. Angular dependences of the squared modulus of scattering amplitude $\left|f\left\langle\theta_k,\varphi_k\middle|\theta,\varphi\right\rangle\right|^2$ for $k_0d=1/4$; $\varphi_k=\pi$; $\theta_k=\pi/2$ (b, c); $\theta_k=3\pi/4$ (d, e) for p scattering - (b, d); for s-scattering (c, e). (Straight lines show the direction of the incident wave, and the dots show the spatial arrangement of the resonators).

Expanding the scattered field of the lattice in terms of natural oscillations of the system of resonators [6], we took into account the coupling coefficients of all types of oscillations H_{1m1} $(m=0,\pm1)$ [7], differing from each other by the field rotation, near the lowest resonance frequency f_0.

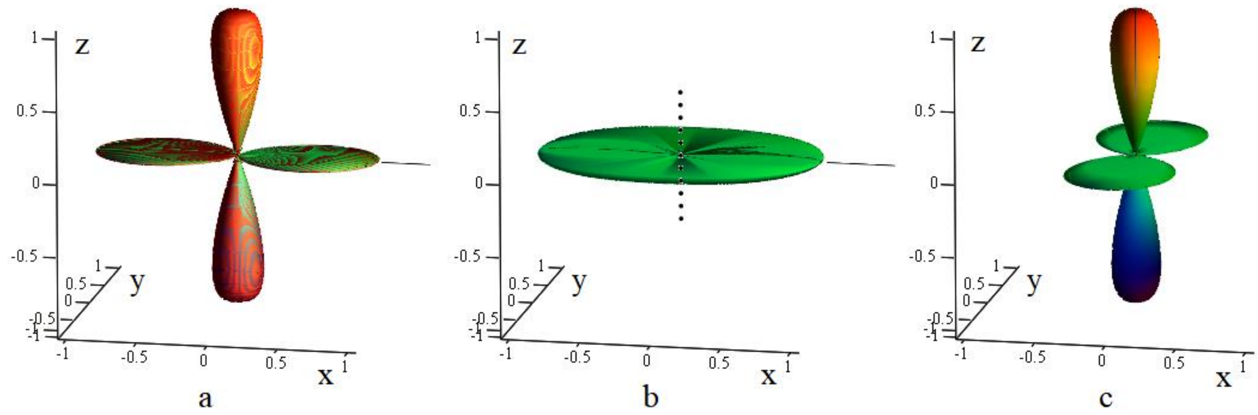

Fig. 2. Angular dependences of the squared modulus of scattering amplitude for $k_0d=1$; $\varphi_k=\pi$; $\theta_k=\pi/2$; (a, b) and for $\theta_k=\pi$ (a, c) for p scattering - (a) for s-scattering (b, c).

The noted relationship between degenerate oscillations with different values of azimuthal indices in the spatial structures of spherical DRs redistributes the lattice field in most cases, having a noticeable effect on its characteristics (see, for example, fig. 3, e). At the same time, the maximum spatial symmetry of spherical DRs makes lattices, built on their basis, as responsive as possible for different directions of incidence for waves of different polarizations, which is especially attractive for building access points in communication systems.

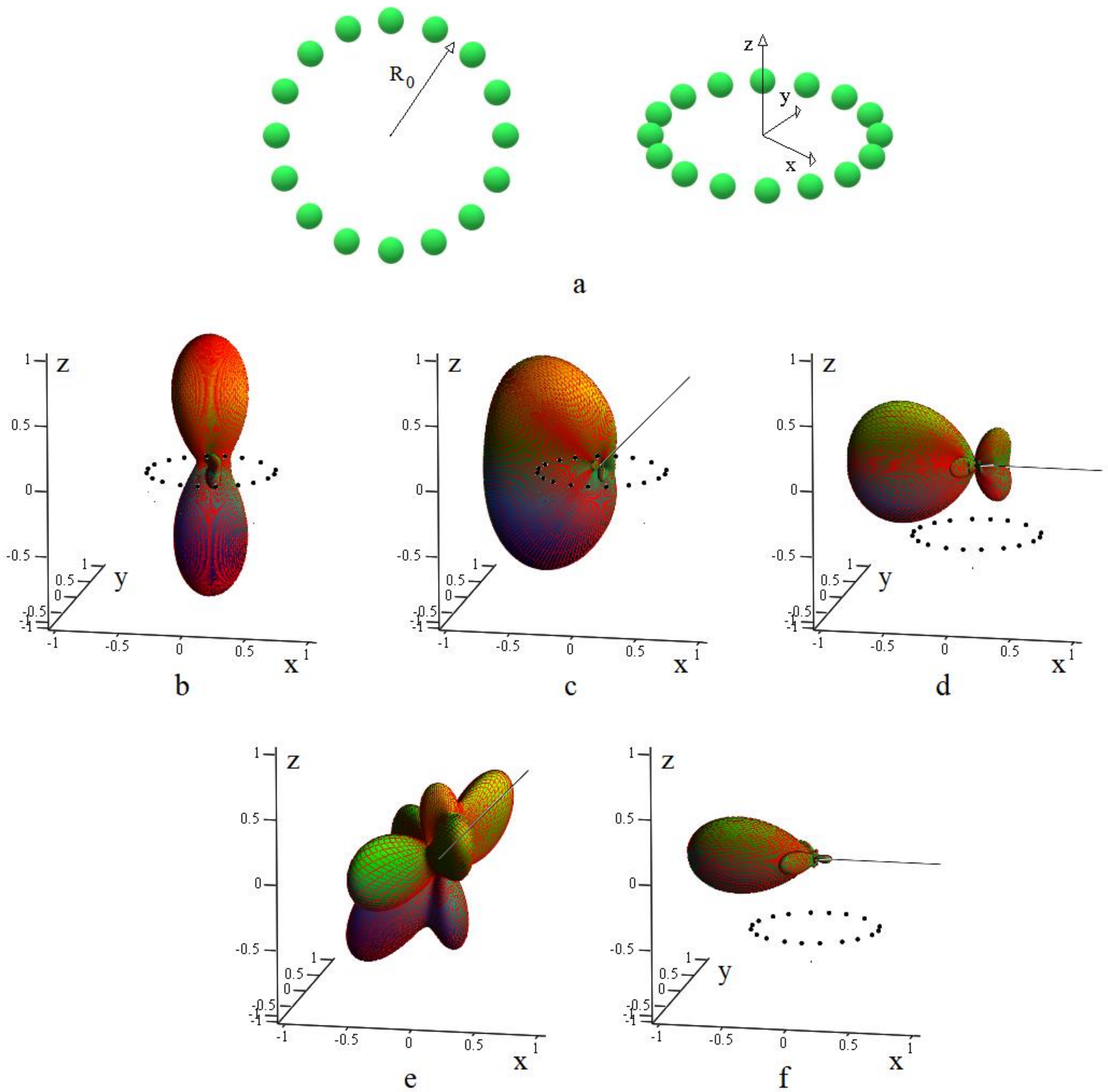

Fig. 3. Ring lattice of 16 Spherical DR (a). Angular dependences of the squared modulus of scattering amplitude for $k_0R_0 = \pi$; $\varphi_k = \pi$; $\theta_k = \pi$ (b); $\theta_k = 3\pi/4$ (c, e); $\theta_k = \pi/2$ (d, f); for p scattering - (b - d) for s-scattering (e - f).

The constructed model made it possible to calculate and analyze the scattering features of p and s type plane waves for different angles of incidence. On fig. 1-3 points show the conditional spatial arrangement of the lattices. The direction of propagation of the incident wave is shown by a solid line, defined by wave vector $\vec{k}_0$. It was assumed that all resonators are made of a dielectric with $\varepsilon_{1r} = 36$.

As follows from the calculations, in the case of s-scattering, the incident plane wave is transformed by a linear grating into a uniformly distributed wave in azimuth (fig. 1, c; fig. 2, b) compressed in the vertical direction. In the case of p-scattering, the incident wave is scattered in directions determined by its polarization with respect to the spatial arrangement of the lattice (fig. 1, b, d; fig. 2, a; fig. 3, b - d). Interestingly, in the case of p-scattering on a linear lattice with $k_0 d = 1$, the theory predicts the same distribution of the field for two different directions of the incident wave: $\theta_k = 0$; and $\theta_k = \pi$.

Thus, the data obtained show that linear and ring lattices based on spherical DRs have a more complex field structure associated with the excitation of several types of degenerate oscillations of these type resonators. The considered structures are of practical interest for use in access and transmission systems of optical and infrared communication systems.

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