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COUPLING COEFFICIENTS OF ROTATING RECTANGULARE DIELECTRIC RESONATORS IN CUT-OFF RECTANGULARE WAVEGUIDE

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КОЕФІЦІЕНТИ ЗВ'ЯЗКУ ОБЕРТАЕМИХ ПРЯМОКУТНИХ ДІЕЛЕКТРИЧНИХ РЕЗОНАТОРІВ В ПОЗАМЕЖНОМУ ПРЯМОКУТНОМУ ХВИЛЕВОДІ

Досліджуються коефіцієнти взаємного зв'язку прямокутних діелектричних резонаторів, розташованих в позамежному прямокутному металевому хвилеводі при обертанні їх осей.

The rotation of the axes of dielectric resonators opens up additional possibilities for controlling the scattering parameters of various devices based on them [1-5]. The purpose of this report is to investigate mutual coupling coefficients of rotating rectangular DRs in the cut-off waveguide.

In this work, we calculated mutual coupling coefficients k_{12} of two identical rectangular dielectric resonators located in the cut-off waveguide with the possibility of rotation about one of the axes of the coordinate system (fig. 1, 2, a, d):

$$k_{12} = -k_{12}^{0} \sum_{t=(0)}^{\infty} f_t^1(\mp i\Gamma) f_t^2(\pm i\Gamma)^* e^{-\Gamma \Delta z} .$$

Here k_{12}^{0} - is the factor that depends only on the parameters of the resonators; t - multi index; Γ - longitudinal wave number of the cut-off waveguide; $\Delta z = |z_1 - z_2|$ - longitudinal distance between the centers of the resonators. The functions $f_t^s(\pm i\Gamma) = f_t^s(\pm i\Gamma; \alpha_s; \beta_s; \gamma_s)$ determine the dependence of the coupling on the angles of rotation $(\alpha_s; \beta_s)$ of the resonator relative to the waveguide ($s = 1, 2$).

We investigated the values of the maximum variation coupling coefficients when changing the angles of resonator rotation. The dimensions of the DR corresponded to the condition of excitation of the main magnetic oscillations in them H_{111}. The dielectric constant of each DR was assumed to be equal $\varepsilon_{1r} = 36$; relative sizes $\Delta = L / a_0 = 0,4$; $B = b_0 / a_0 = 1$, where a_0, b_0 - is the transverse dimensions, and L - is the height of the DR. The cross section of the rectangular waveguide was equal to $a \times b = 20 \times 15$ mm; H_{111} oscillation frequency $f_0 = 7$ GHz. Transverse coordinates of both resonators in the waveguide $x_{1,2} = a / 2$; $y_{1.2} = b / 2$.

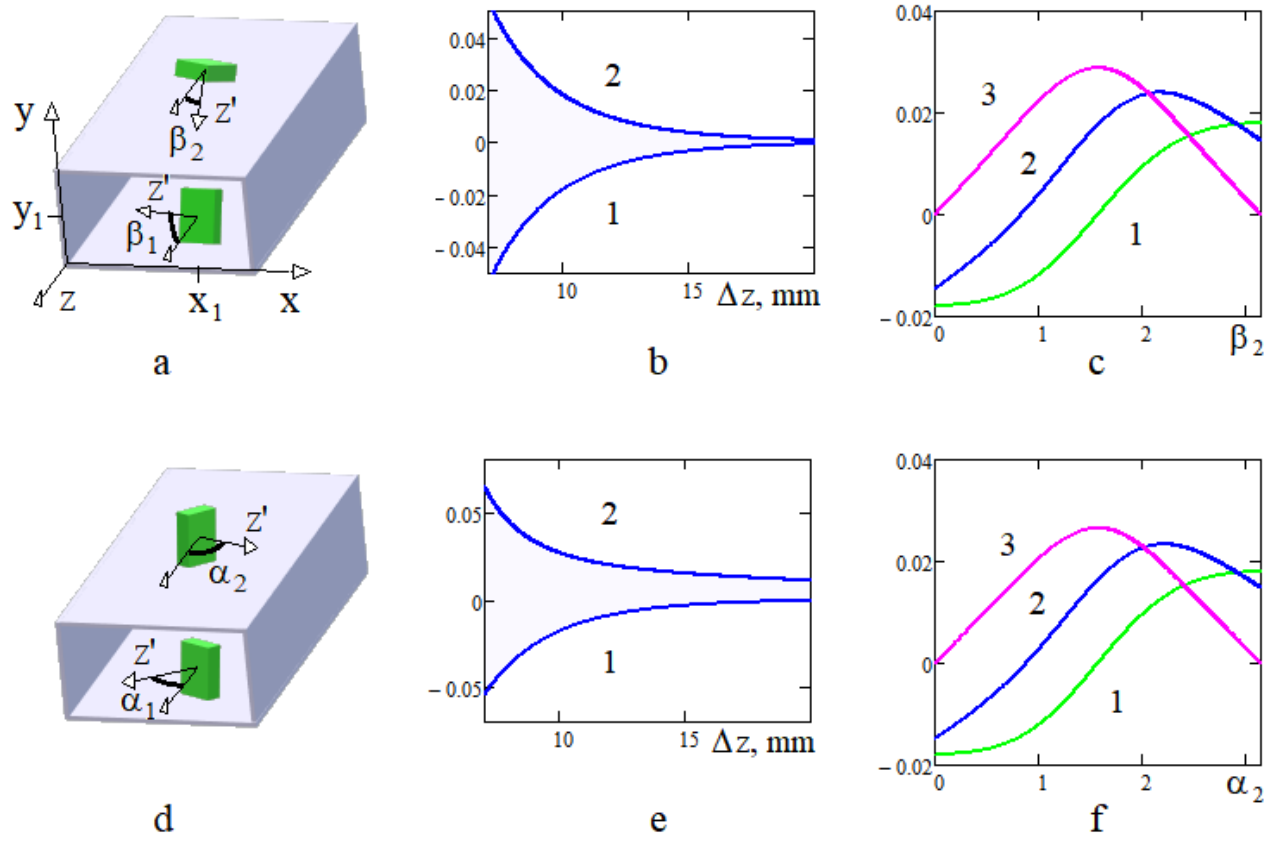

Fig. 1. Rectangular dielectric resonators rotating relatively the x (a) and y axis (d) in the rectangular waveguide. Variation of the mutual coupling coefficients at different longitudinal distances between the centers of rotating dielectric resonators in the waveguide (b (e)). Dependence of the mutual coupling coefficient on the angle of rotation of the second resonator.

Despite the fact that the functions $f_t^s(\pm i\Gamma)$ are complex, the mutual coupling coefficients in most cases remain real when the resonator axes rotate (see, for example, fig. 2, c).

In fig. 1, 2, b. e the dependences of the coupling coefficients on the longitudinal distance between the resonator centers are shown for $\alpha_1,\beta_1 = 0$ and $\alpha_2,\beta_2 = 0$ - 1; $\alpha_2,\beta_2 = \pi$ - 2.

In fig. 1 and 2, c, f show the dependences of the coupling on the angle of rotation of the second resonator α_2,β_2 for $\alpha_1,\beta_1 = 0$ - 1; $\alpha_1,\beta_1 = \pi/4$ - 2; $\alpha_1,\beta_1 = \pi/2$ - 3 ($\Delta z = 10$mm).

As can be seen from the data obtained, the maximum variation of the coupling coefficients is determined by the distribution of the natural oscillation field of the resonators in the transverse plane (x', y') of local coordinate system. For natural oscillations of a rectangular DR H_{111}, the spatial distribution of the field is close to the dipole and uniform in the plane (x', y'), therefore, the rotation of the resonator in this plane has little effect on the coupling coefficients. A good example of this effect is the rotation of resonators about the longitudinal axis of the waveguide shown in Fig. 2, c.

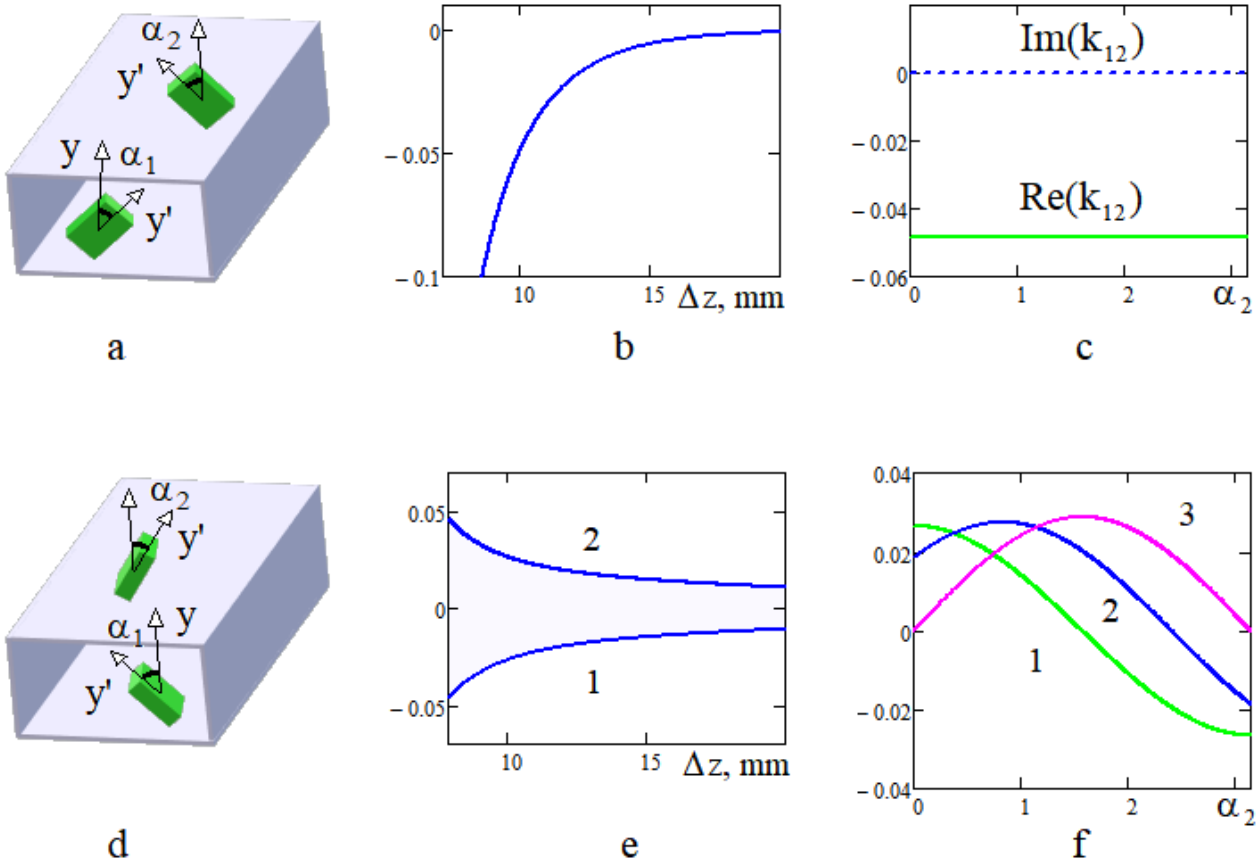

Fig. 2. Rectangular dielectric resonators rotating relatively the z (a, d) axis for different initial positions in the waveguide. Variation of the mutual coupling coefficients at different longitudinal distances between the centers of rotating dielectric resonators in the waveguide (b, e). Dependence of the mutual coupling coefficient on the angle of rotation of the second resonator.

The obtained analytical relations for the mutual coupling coefficients make it possible to significantly expand the possibilities of designing and optimizing the parameters of wide range of band-pass and band-stop filters for microwave and millimeter-wave communication systems.

References

1. Fesenko V.I., Kupriianov A.S., Sherbinin A., Trubin A.A., Tuz V.R. All-dielectric Vogel metasurface antennas with bidirectional radiation pattern, Journal of Optics, UK, 22, 035104, 2020, pp. 1- 8.
2. Trubin A.A. Adaptive planar antennas on lattices of rotating Dielectric Resonators. 14 Int. Scientific Conf. Modern Challenges in Telecommunications. Kiev, 2020, pp. 89-91.
3. Shi T., Wang Y., Deng Z.-L., Ye X., Dai Z., Cao Y., Guan B.-O., Xiao S., Li X. All-Dielectric Kissing-Dimer Metagratings for Asymmetric High Diffraction // Adv. Optical Mater. WILEY-VCH Verlag, 2019, pp. 1901389 - 1901389.
4. Pidgurska T.V. Trubin A.A. Dual-bandpass filter built on rectangular dielectric resonators // Radioelectronics and Communications Systems / 2015. Vol. 58. PP.174–180.
5. Wang K., Titchener J. G., Kruk S.S., Xu L., Chung H.-P., Parry M., Kravchenko I. I., Chen Y.-H., Solntsev A. S., Kivshar Y. S., Neshev D. N., Sukhorukov A. A. Quantum metasurface for multi-photon interference and state reconstruction / *Science* vol. **361** (6407), pp. 1104-1108. http://science.sciencemag.org/content/361/6407/1104