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EXCITATION OF THE WHISPERING-GALLERY-MODES AT THE SHIELDED HEMISPHERICAL DIELECTRIC RESONATOR

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Dielectric resonators (DR) with whispering gallery modes (WGM's) are used at the wide range of frequencies (from microwave to optical). These modes are formed by the grazing traveling waves in quasioptical DR (D > $10\lambda_d$, where D is diameter of resonator) inside dielectric with small incidence angles, their reflection factor being close to 1. WGM's electromagnrtic fieldes are localized between the external and inner caustics. Near this region the electromagnetic fields are evanescent. Therefore these modes have a high value of Q-factor. Variouse advanteges of the DR with WGM's suggest their utilization in the microwave and millimeter wave devices such as the filters [1], power combiners [2], solid-state oscillators [3], sensors for study of various materials [4].

One of the most important limits of the DR using is the problem of their coupling with other elements and circuits because of the open nature of these resonators and parasitic wave radiation. The open nature of the DR with WGM's leads to the system sensitiveness to the external medium and elements. It can display in non-control modification frequency and Q-factor value of the WGM's and influence at other circuits. One of this problem solution is the shielding of the DR [5,6].

The problem of the open DR (ODR) compatitibility with other circuits may be solved by the design way in the case of the absorber screen using. Absorbing screen worsens of the shielded dielectric resonator (SDR) characteristics (size, mass, Q-factor value) in comparison with the ODR.

The perspective of the SDR construction with the coaxial situated cylindrical DR and with reflective screen is represented in the famous theoretical papers [5,6]. The high Q-factor modes determined by the occurence of the localization of their fields in dielectric exist in this system. The investigations find the problem of the excitation of these modes in real condition, which are arised through the dense spectrum of the SDR modes and difficulty introduction of the couplers in the field of the WGM's. Besides it can note that the calculation of the characteristics of the own modes of the cylindrical resonators is possible by the approximation method.

In this paper we investigate the problem of the excitation high Q-factor WGM's of the hemispherical SDR the field of which is localizating in the dielectric and compared characteristics of the WGM's SDR with characteristics of the WGM's hemispherical ODR.

The excitation of the high Q-factor WGM's of SDR was investigating experimentally in resonator which is shown in Fig.1 (insect). Teflon dielectric hemiball 1 ($\varepsilon = 2.08$, radius R_d = 39 mm) and metallic hemisphere 2 (radius R_s = 42 mm) are situated on the local flat mirrors 3, 4 with coupling slot with the external waveguide. In the experimental model of SDR there was a possibility to easy change the position of the radiation source and passive slot on the radial coordinate. In this case it's a possible the effective coupling of the radiation source with the resonator field, the first; the cleaning of the modes spectrum, the second; measurement of the radial field distribution, the third. The WGM's $TM_{nml}(E_r \neq 0)$ or $TE_{nml}(E_r = 0)$ (n,m,l are field variations along the polar, azimuthal and radial coordinaters accordingly) are excited in the investigated resonator.

The characteristics measurements of the lowest (l=1, m=1) WGM's are carried out by the sweep generator in the frequency range 27-37 GHz. The highest WGM's are suppresed by the methods which are described in papers [3,7]. The coupling values are installed on the frequency characteristic of the VSWR (voltage standing wave ratio) and are controlled by the smaller absorber body method. The values of the own Q-factor are determined by the full resistance method [8].

The frequency dependences of the VSWR in the channel with the investigated resonators are obtained for the coupling slots with the different width by direct measurements. The dependence of the relative amplitude A/A_m of resonance from the standardized radial coordinate of the passive slot center to the dielectric hemiball radius r_o/R_d for the TM WGM's of the ODR (circuits) and SDR (points) is shown at Fig. 1. As can be seen the modes fields of these resonators are concentrated in dielectric between the caustics of WGM's of ODR. The frequency dependence of unloaded Q-factor TM WGM's of the ODR (circuits) and SDR (points) is shown at Fig. 2. The monotonous decreasing of Q-factor of the hemispherical ODR,when the frequency is decreased, is connected with the own radiative losses increasing. The Q-factor of the ODR WGM's at the high frequency border is approximated to the level which is closed by the dielectric Q-factor (in this case dielectric Q-factor is equal 5.6×10^3). The unloaded Q-factor of the WGM's of the hemispherical SDR is approximetly constant in the investigated frequency range and it is determined only dielectric losses.

Thus, the WGM's are excited effectively at the hemispherical SDR through the coupling slot. Their fields are localized inside dielectric. Therefore unloaded Q-factor of the WGM's of SDR is determined only by the dielectric losses in the wide frequency range. However the unloaded Q-factor of the ODR modes with the frequency decreasing is decreased because of the radiative losses increasing. It allows to reduce the sizes of dielectric at SDR with comparison ODR with constant Q-factor.

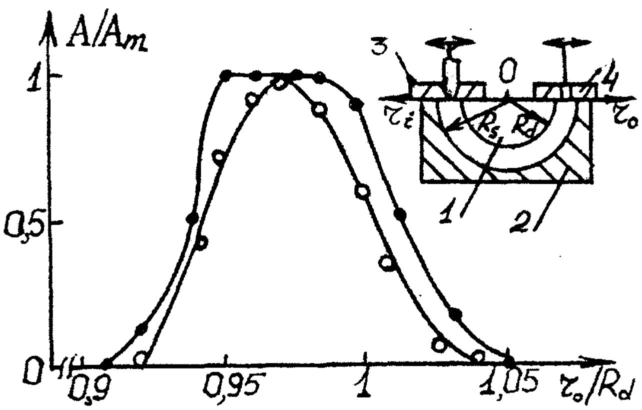

Fig.1. The dependence of the relative amplitude A / A_m of resonance from the standardized radial coordinate of the passive slot center to the dielectric hemiball radius r_0 / R_d for the TM WGM's of ODR (circuits) and SDR (points).

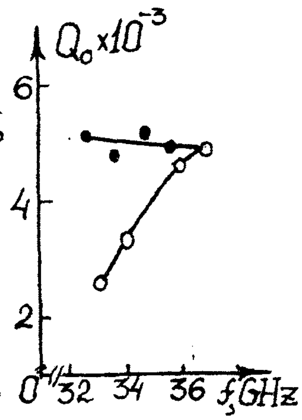

Fig.2.The frequency dependence of unloaded Q-factor for TM WGM's of ODR (circuits) and SDR (points).

References

1. D.Gros, P.Guillon, "Whispering gallery dielectric resonators modes", IEEE Trans. Microwave Theory Tech., Vol.38, No.11, pp. 1667-1673, 1990.
2. X.H.Jiao, P.Guillon, Ph. Auxemery, Cros, "Dielectric resonators suitable for use in planar intergrated circuits at short millimeter wavelengths", IEEE Trans. Microwave Theory Tech., Vol.37, No.2, pp. 432-437, 1989.
3. S.N.Kharkovsky, A.Ja.Kirichenko, A.E.Kogut, "Solid-state oscillators with whispering-gallery mode dielectric resonators", Microwave and Optical Techn. Letters, Vol. 12, No.4, pp. 210-213, 1996.
4. V.B.Braginsky, V.S.Ilchenko, K.S.Bagdasarov, "Experimental observation of fundamental microwave absorption in high-quality dielectric crystals", Physics Letters A, Vol.120, No.6, pp. 300-305, 1987.
5. V.F.Vzyatyshev, V.I.Kalinichev, V.I.Kuimov, "Physical phenomena in shielded dielectric rod resonator and problem of its design", Radio Engineering and Electronics Physics, Vol.30, No.4, pp. 705-712, 1985.
6. E.N.Ivanov, D.G.Blair, V.I.Kalinichev, "Approximate approach to the design of shielded dielectric disk resonators with whispering galleru modes", IEEE Trans. Microwave Theory Tech., Vol.41, No.4, pp. 632-637, 1993.
7. A.E.Kogut, V.V.Kutuzov, Yu.F.Filipov, S.N.Kharkovsky, "Whispering-gallery modes of the quasioptical hemisphere dielectrical resonator" (in Russian), Izv. Vuz. Radioelectronika, Vol.40, No.2, pp. 19-26, 1997.
8. E.L.Ginzton, "Microwave measurements" (in Russian), In. Lit., Moscow, pp. 620, 1960.