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Increasing Q-Factor of Planar Dielectric Resonators with Whisper Gallery Modes

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Abstract—Planar dielectric resonators (DR) with height significantly lower than the operating wavelength are investigated as a new class of disk dielectric resonators of the millimeter wavelength range with whispering gallery (WG) modes. It is known that in the open state, such resonators based on the WG modes are not excited due to high radiation losses. It is shown that the solution of this problem is the partial shielding of the disk dielectric structures with a plane-parallel screen by placing the disk between two flat conducting mirrors. It has been established that by introducing an air gap between the flat base of the dielectric disk and one of the conductive mirrors, it is possible to increase the quality factor of the planar DR almost twice. One of the reasons for this is the partial displacement of the resonant field of the WG modes from the dielectric region to the air gap, where the dielectric losses are lower. In addition, an increase in the air gap in the range of optimal values, comparable to half the working wavelength, leads to a decrease in ohmic losses. The above causes an increase in the quality factor of planar DR as an air gap is extended.

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INTRODUCTION

A special place in the series of dielectric resonators (DR) with whispering gallery (WG) modes is occupied by planar resonant structures due to their small dimensions. This term, "planar dielectric resonators," is commonly used in foreign scientific literature and refers to classic disk DRs with height lower than diameter [1–6]. In the domestic literature, "disk DR" is used the accepted terminology for such devices [4, 5].

It is known that in order to excite WG modes in such open resonators, the inequality $H \geq \lambda_d/2$ needs to be satisfied, where H is the height of the dielectric disk, λ_d is the wavelength in the dielectric material [1, 5]. However, the possibilities of lowering the size (height) of disk DRs to excite operating modes are not fully understood and the use of this terminology may be much wider. Therefore, this terminology is proposed to describe planar dielectric resonant structures. It is based on the ratio of the height of the resonator to the operating wavelength rather than the ratio of its geometric dimensions. From a physical point of view, it is this interpretation of the term "planar structures" that will be more reasonable and will expand the understanding of the possibility of using planar DRs with WG mods in different wavelength ranges.

Disk DRs whose height is less than the critical values $H < H_{cr}$ ($H_{cr} = \lambda_d/2$) necessary for the excitation of the WG modes in open dielectric disks is considered here. In this case, for foreign literature the use of the term "ultra-planar dielectric resonators" would be most appropriate. This problem is interesting both from a scientific and applied point of view, since it allows expanding the possibilities of using DR with WG modes, for example, in microelectronics.

Indeed, the WG modes in open dielectric disks with such height value are not excited due to high radiation losses from flat bases [6–8]. To solve this problem, conductive mirrors adjacent to the flat bases of the disk are proposed. In this case, the field is limited by conducting surfaces in the axial direction, and the

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