A New Coupling Structure for Dual Mode Dielectric Resonators

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***Abstract*—A novel method for realizing coupling between two orthogonal HEM_{11} resonant modes in dielectric ring resonators is described. The coupling is obtained by means of a metallic strip located on the inner or on the outer boundary of the dielectric ring; a strong coupling is obtained, even with small width of the strip, in particular when the strip is on the inner boundary. The dual-mode resonator is then suitable for filtering applications, with normalized bandwidth requirements exceeding 1% (as in base station units for mobile communications), allowing a relevant reduction of the overall volume, at the expense of a small reduction of the unloaded Q. The novel coupling mechanism and the Q degradation produced have been studied both numerically (by using finite elements simulations) and experimentally (measurements from a prototype two-resonators filter are reported).**

***Index Terms*—Dielectric resonators, filters.**

I. Introduction

DIELECTRIC resonators using two orthogonal HEM_{11} modes are widely employed in dual-mode filters [1]–[3]; various mechanisms realize the coupling between the degenerate modes: metallic screws at 45° with respect to the two polarizations axis [1]; dielectric-slotted resonators [4]; and conductor-loaded resonators [5]. In the last years, dielectric dual-mode resonators are becoming an attractive alternative to coaxial resonators in the mobile communications filter units (an example has been recently presented in [5]). The main advantage in their use is the relevant reduction of the overall volume of the filter unit without an appreciable increase of the insertion losses. Two aspects must be considered, however, when looking for a coupling structure in dual-mode dielectric resonators, suitable for the above application: 1) the unloaded Q degradation due to the coupling mechanism; and 2) the wide bandwidth required, which calls for relevant coupling coefficients between the two orthogonal modes. These aspects may not be independent of each others: in fact, some coupling structures (as the metallic screws) strongly decrease the unloaded Q when large values of the coupling coefficient are required [4].

In this letter, we propose a simple structure for realizing the coupling, which is constituted by a metallic strip deposited on the outer or inner boundary of a dielectric ring resonator, parallel to the ring axis and with the same height; this structure allows to obtain coupling coefficients even larger than 10^{-2}, with a relatively small degradation of the unloaded Q.

II. The Dielectric Resonator and the Dual Mode Coupling Structure

The resonator considered here is constituted by a dielectric ring inserted inside a metallic enclosure with a circular or square cross section (relevant dimensions are shown in Fig. 1 in the case of square cross section); the metallic strip (width W_s, thickness t_s), deposited on the inner or outer boundary, realizes the coupling mechanism. The dielectric ring is dimensioned in order to excite the HEM_{11} mode, in absence of the strip, at the operating frequency (criteria for a suitable choice of the various geometrical parameters may be found in [2]). The presence of the metallic strip produces a splitting of the resonance frequency of the HEM_{11} mode; introducing two probes directed at 45° with respect to the axis of the strip (Fig. 1), the two degenerated modes may be excited. In order to verify this coupling mechanism, the structure in Fig. 1 has been designed at 2.15 GHz and simulated using a finite-elements program (HFSS from Hewlett-Packard). Table I reports the geometric dimensions of the structure, while Fig. 2 shows the results obtained (attenuation and return loss). Note that the input-output probes have not been optimized for the specific bandwidth determined by the metal strip, so a small return loss at center frequency is obtained; the two relatively distant peaks of the return loss identify, however, the presence of a strong coupling between the two degenerate modes.

A. Dependence of k on the Metal Strip Dimensions

The dependence of the coupling coefficient k on the metal strip width has been studied, using finite differences simulations. In particular, k has been determined from the resonance frequencies f_e and f_o obtained by placing a perfect magnetic wall (f_e) or a perfect electric wall (f_o) along the longitudinal symmetry plane of the strip; k is then obtained from the well-known formula [3]

$$k = \frac{f_o^2 - f_e^2}{f_o^2 + f_e^2}.$$

Fig. 3 shows the values of k computed for the test resonator specified in Table I, with both inner and outer placement of the metal strip, as function of the strip width. Note the relevant value of k, especially when the strip is placed on the inner ring boundary.

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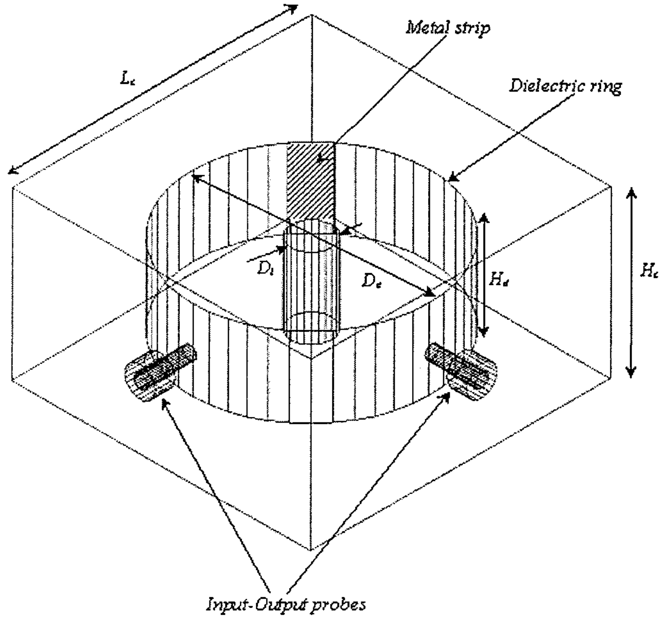

Fig. 1. Dual mode dielectric ring resonator with the new coupling structure (in alternative, metal strip can be placed on the inner ring boundary).

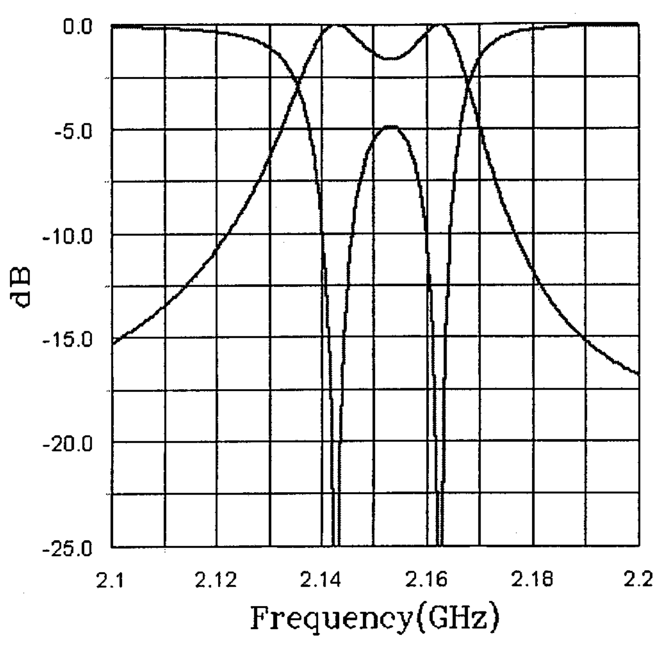

Fig. 2. Simulations results (attenuation and return loss) obtained from HFSS for the test resonator.

B. Unloaded Q Degradation due to the Coupling Metal Strip

The presence of the metal strip produces an increase of the overall losses in the dual-mode resonator, which decreases the unloaded Q of the HEM_{11} mode. In order to investigate this effect, the unloaded Q of the two modes parallel and orthogonal to the strip axis has been computed for two values of the strip width (using lossy materials in HFSS simulations); Table II reports the results obtained, together with the unloaded Q of HEM_{11} without the metal strip (loss parameters used in the simulations are also indicated).

TABLE I
PARAMETERS OF THE TEST DUAL MODE RESONATOR

Cavity height (H_c)	25 mm
Cavity side (L_c)	45 mm
Ring inner diameter (D_i)	6 mm
Ring outer diameter (D_e)	35 mm
Ring height (H_d)	12 mm
Metal strip width	5 mm
Metal strip thickness	100 μ
Ring relative dielectric constant	45

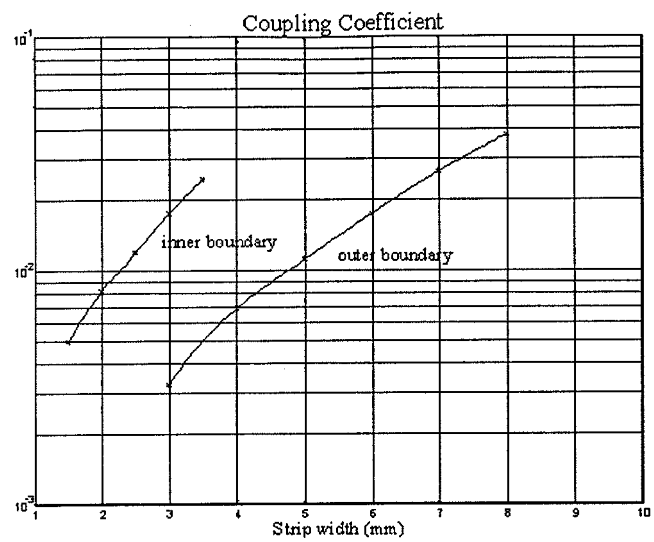

Fig. 3. Coupling coefficient for the test dual-mode resonators as function of the width of the metal strip.

TABLE II
COMPUTED UNLOADED Q FOR THE TWO ORTHOGONAL MODES WITH RESPECT TO THE STRIP AXIS). LOSS PARAMETERS: METAL CONDUCTIVITY $\sigma = 5.8 \cdot 10^7$, DIELECTRIC LOSS TANGENT $\tan\delta = 5\ 10^{-5}$

Mode	*Strip width (mm)*	*Unloaded Q*
HEM_{11}	0	14875
Normal	5	11738
Normal	8	9567
Parallel	5	14417
Parallel	8	14000

As expected, the Q_0 of the mode with the polarization axis parallel to the axis of the strip is practically unaffected by the strip; even if a certain Q_0 degradation is produced on the other mode, it should be considered that the actual unloaded Q of the equivalent coupled resonators is inside the values obtained

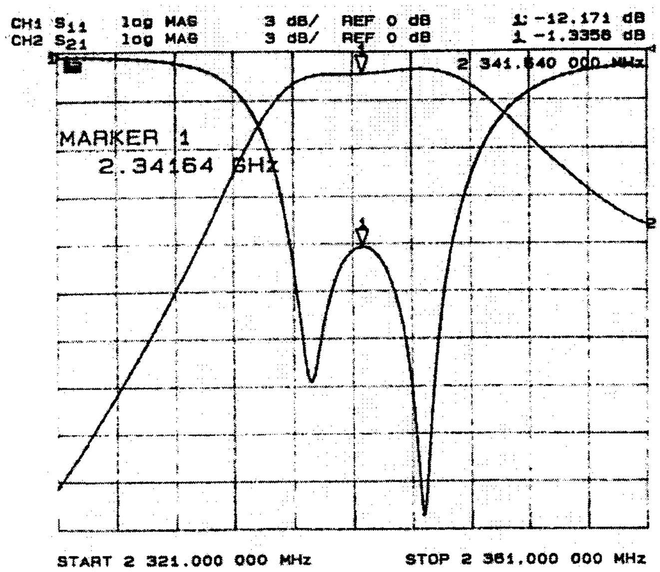

Fig. 4. Measured response of the experimental dual-mode dielectric resonator with metal strip coupling.

for the two modes. In conclusion, the expected Q_0 degradation, even with a very strong coupling coefficient ($4 \cdot 10^{-2}$), should be less than 30%.

III. Experimental Verification

A preliminary experimental verification has been performed on a dual mode dielectric resonator, coupled with a metal strip. The dielectric ring and the cavity (circular shape, diameter D_c) have the following parameters: $D_i = 10$ mm, $D_e = 32$ mm, $H_d = 20.54$ mm, $D_c = 62.5$ mm, $H_c = 41$ mm, $\varepsilon_r = 35.5$; the metal strip has a with of 5 mm and has been attached to the ring with a suitable adhesive. The input–output coupling probes have been dimensioned for a matching of about 12 dB at the center frequency (2.34 GHz). The measured response, reported in Fig. 4, shows a coupling bandwidth of about 10 MHz; the relatively large insertion losses are due to the metal cavity, which is made of aluminum without silver plating.

IV. Conclusion

In this letter, a novel mechanism for coupling two orthogonal HEM_{11} modes in a dual-mode dielectric ring resonator has been presented; it is constituted by a metal strip deposited on the inner or on the outer boundary of the ring. The coupling coefficient obtainable with this structure has been computed on a test resonator and has been reported as function of the width of the metal strip; moreover it has been shown that the unloaded Q degradation do to the metal strip is less than 30% with respect that of the uncoupled HEM_{11} mode. The large values of k realizable with relatively narrow strips allow to use this coupling structure in base stations filtering units for mobile communications.

References

[1] S. J. Fiedziusko, "Dual-mode dielectric resonator loaded cavity filters," *IEEE Trans. Microwave Theory Tech.*, vol. MTT-30, pp. 1311–1316, Sept. 1982.

[2] K. A. Zaki, C. Chen, and A. E. Atia, "Canonical and longitudinal dual-mode dielectric resonator filters without iris," *IEEE Trans. Microwave Theory Tech.*, vol. MTT-35, pp. 1130–1135, Dec. 1987.

[3] Y. Kobayashi and K. Kubo, "Canonical bandpass filters using dual-mode dielectric resonators," in *IEEE MTT-S 1987 Int. Microwave Symp. Dig.*, June 1987, pp. 137–140.

[4] D. Baillargeat, S. Verdyme, and P. Guillon, "Slotted dielectric resonators for rigorous design of a four-poles dual mode filter," *IEEE Microwave Guided Wave Lett.*, vol. 4, pp. 332–334, Oct. 1994.

[5] I. C. Hunter, J. D. Rhodes, and V. Dassonville, "Dual-mode filters with conductor-loaded dielectric resonators," *IEEE Trans. Microwave Theory Tech.*, vol. 47, pp. 2304–2311, Dec. 1999.