Dual-mode filters for cellular base stations using metallized dielectric resonators

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***Abstract* — A novel configuration for dual-mode filters employing dielectric ring resonators is presented. The coupling between two orthogonal polarized modes (HEM_{11}) within each dielectric ring is realized through a rectangular metallic strip deposited on the boundary of the ring (inner or outer). The coupling coefficient so obtained is large enough to allow the realization of high selectivity filters for cellular radio base stations. A 4 resonators test filter has been designed and realized using the novel resonators: the performances obtained are reported in the paper.**

I. Introduction

The use of dual-mode resonators is very attractive in filters for cellular-radio base stations, allowing a relevant reduction of the overall volume of the filter unit. Actually, several problems have limited their practical use: first, the coupling coefficients required for this class of filters are much larger than those typically realizable with classical dual-mode dielectric resonators. Moreover, the Q_0 degradation of two strong-coupled HEM_{11} modes could become too large for the considered application (losses unacceptable).

In this paper we show the realization of a dual-mode filter employing dielectric ring resonators, operating on HEM_{11} mode, which use a new mechanism for realizing coupling between two orthogonal polarizations [1]. The coupling structure is realized by means of a rectangular metal strip located on the inner or outer surface of the dielectric ring; as it will be shown, a strong coupling can be so obtained, even with a small width of the strip (in particular when the strip is on the inner boundary); moreover, the maximum Q_0 degradation due the strip is less than 20% even when a large coupling is realized.

II. Metallized dielectric resonator

It is well known that in dual-mode resonators the structure employed for producing the coupling between the two orthogonal polarizations of the resonant mode plays a fundamental role in determining the performances of the resonator; in case of dielectric resonator, the use of metallic screws for coupling the two polarizations give poor results both for what concerns the level of the obtainable coupling and for the degradation produced on the unloaded Q_0. Some other coupling mechanisms have been proposed in the literature [2, 3], but also these structures suffer either for high losses or for an insufficient coupling level.

We have then developed a new coupling structure for dielectric resonators [1], which allows a good compromise between the above requirements. The basic resonator (fig. 1) is constituted, as usual, by a dielectric ring (inner and outer diameters d_i, d_o, height h), resonating on the first hybrid mode (HEM_{11}); the coupling between the two orthogonal polarizations is obtained through a metallic strip deposited on the outer (or inner) boundary of ring (fig.1). In order to study the coupling realizable with the new structure, the resonator has been inserted into a rectangular cavity, as depicted in fig. 2. The geometrical dimensions of the cavity and the ring have been determined [4] by imposing at 2.15 GHz the resonance frequency f_0 of HEM_{11} (without the strip); then, using a finite-difference program (HFSS from Hewlett-Packard), the coupling coefficient k has been determined for various widths w of a metal strip deposited on the outer boundary.

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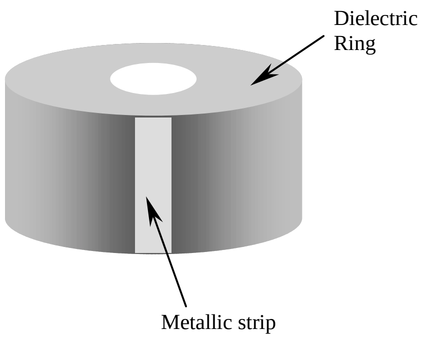

Fig. 1. Ring dielectric resonator operating on HEM_{11}; the metallic strip (which could be deposited as well on the inner boundary) determines the coupling between two orthogonal polarized HEM_{11} modes.

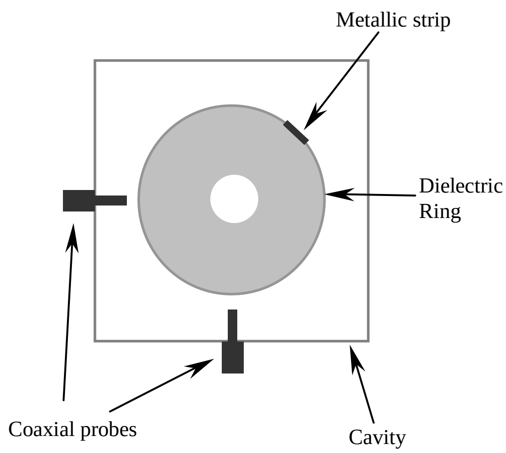

Fig. 2. The test cavity used to evaluate the coupling coefficient and the unloaded Q of the two coupled HEM_{11} modes.

In fig. 3 the dependence of the coupling coefficient *k* on the width *w* determined from simulations is reported in graphical form, for a dielectric resonator having ε_r=45, d_i=6mm, d_o=35mm, *h*=12mm (the dimensions of the cavity are indicated in fig. 3 caption). Note that even with a relatively narrow strip (5 mm), a coupling coefficient larger than 10^{-2} can be achieved.

In addition to the coupling coefficient, also the unloaded Q_0 for the considered resonator has been computed (including both dielectric losses due to a $\tan\delta=5 \cdot 10^{-5}$ and metal losses do to a conductivity $\sigma=5.8 \cdot 10^{7}$); the presence of a metal strip with width equal to 5 mm produces, in the worst case (mode with polarization axis parallel to the strip in the horizontal plane), a Q0 of 11000. Considering that the value of Q_0 without the metal strip is about 14000, the Q_0 degradation produced by the strip is about 20%.

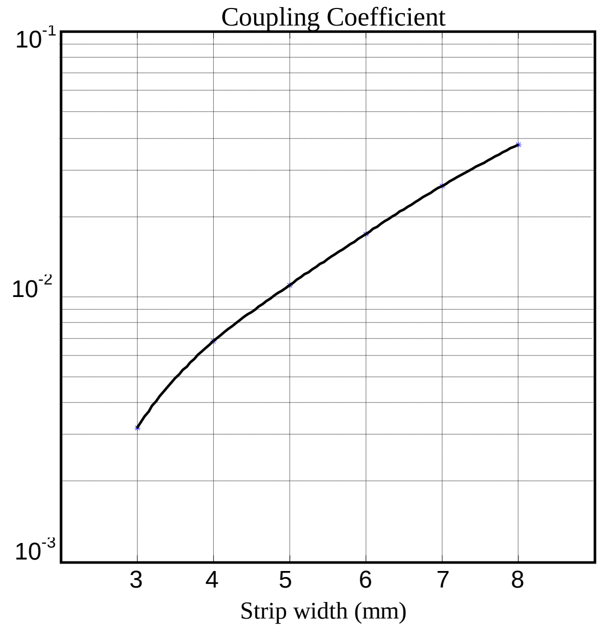

Fig. 3. Coupling coefficient *k vs.* strip width *w*. The test cavity has the side equal to 45 mm and the height equal to 25 mm

For what concerns the spurious responses, the first higher order mode excited in the dielectric resonator loaded with the metal strip is the TM_{01}, which is about 120 MHz higher than HEM_{11}; it has been found that this mode can be further separated by extending the metal strip in the top and bottom faces of the ring, for a length about equal to the width of the strip (fig 4). In this way, TM_{01} is pushed at about 250 MHz from HEM_{11}, which remains practically unaffected.

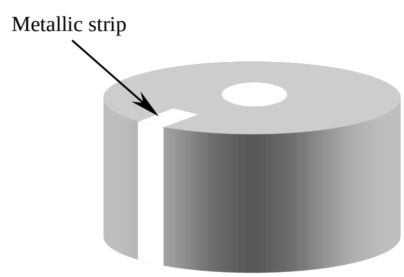

Fig. 4. The dielectric resonator with the modified metal strip for increasing the separation of the first higher order mode (TM_{01})

III. TEST FILTER DESIGN

Using the dual-mode dielectric resonator presented in the previous section, a test filter has been designed and fabricated to verify the practical behavior of the novel resonator when used in a filtering structure. The filter operates at 2.157 GHz with a bandwidth of 12 MHz, and employs two equal dielectric resonators, with a metallic strip 4mm wide for coupling the two orthogonal HEM_{11} modes (the total number of equivalent resonators is then equal to 4). In fig. 5 a scheme explains how the couplings are realized between the various resonant modes (each mode is represented by the E-field polarization axis). Note that the coupling between resonators 2 and 3 is realized through a vertical window loaded with a metallic stub (this allows to uncouple resonators 1 and 4) [2].

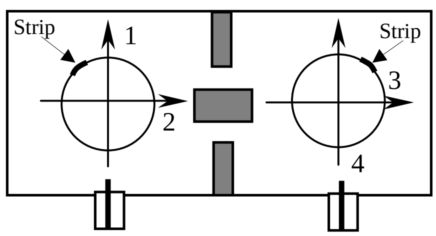

Fig. 5. Schematics representations of the couplings in the test filter (top view).

The theoretical values of the coupling coefficients has been determined in order to obtain en equiripple bandwidth with 26 dB of return loss (Chebycheff response); these values are: k_{12}= k_{23}=0.006, k_{23}=0.0045. Note that, from the graph in fig. 3, a strip width of 4 mm is sufficient to realize the k_{12} value.

The input and output coupling structures are realized with capacitive probes (with an inductive post as a matching element [2]); the required valued of external Q is 125.

For fabricating the test filter, silver-plated aluminum was used for the cavities, while the metallized strip on the dielectric resonators was made with a silver deposition 10µ thick; four metallic screws were used for tuning purposes.

The measured response is shown in fig. 6, while a photo of the realized prototype is reported in fig. 7. Note that the measured losses at the center of the pass band are 0.5 dB; this value corresponds to an unloaded Q of the equivalent resonators of about 7000 (the worsening with respect to the computed value is due to the additional elements present in the cavities, such as the tuning screws, the coupling metal stub and the input and output probes).

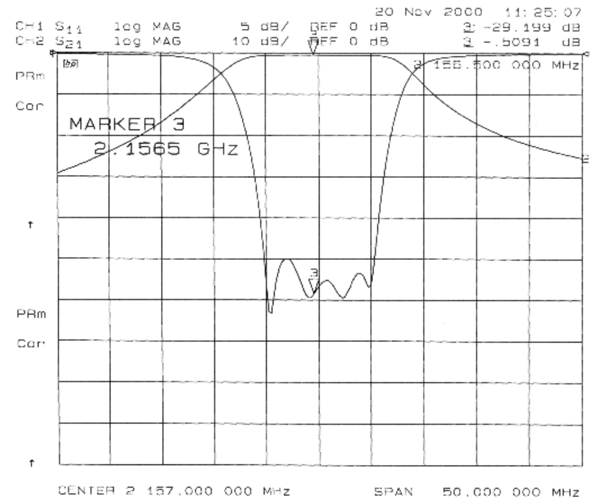

Fig. 6. Measured response of the test filter.

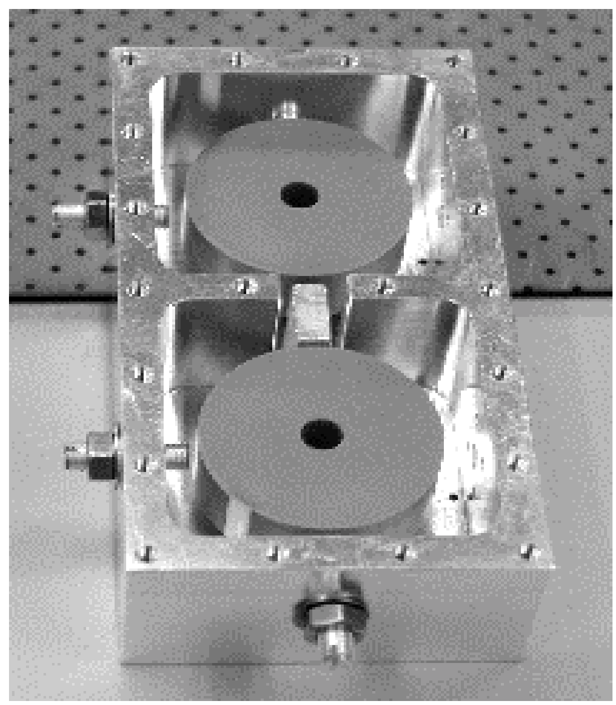

Fig. 7. Photo of the test filter (the input-output coupling probes are not reported).

IV. CONCLUSION

A novel coupling structure for dual-mode dielectric resonators has been introduced; it allows realizing large coupling factors, with relatively small degradation of the unloaded Q of the resonators. A dual-mode test filter has been designed and fabricated for investigating the performances of the novel structure; the results obtained indicate the possibility to employ this kind of dual mode filter for substituting the usual coupled-cavity filters in cellular base station unites (with a relevant reduction of the overall volume at about the same level of losses).

Further investigations are currently under development for increasing the spurious-free resonance bandwidth, which is, at present, of about 250 MHz.

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