Dual-Mode Filters with Grooved Dielectric Resonators for Cellular-Radio Base Stations

L. Accatino , G. Bertin, M. Mongiardo* and G. Resnati**

Telecom Italia Lab (formerly CSELT) V. Reiss Romoli, 274 - 10148 Torino, Italy
* Dipartimento di Elettronica, Università di Perugia,I-06100 Perugia, Italy
** FOREM,S.r.l. Via Archimede 22, 20041 Agrate Brianza (Mi), Italy.

Abstract— **Dual-mode filters for cellular-radio base-stations require resonators with high unloaded Q-factor, wide spurious-free operating window and possibility of high coupling values either to input or between resonators. These features are obtained by employing a new cavity resonator loaded by a grooved ceramic disk. The groove, which may increase up to a full air gap, allows the insertion of probes and tuning/coupling screws where the field is stronger.**
Experimental results of an eight-pole transmit filter show the suitability of the proposed resonator for realizing cellular-radio base stations filters.

I. Introduction

Next generation mobile services will require a large number of cellular-radio base stations with filters specifically developed for UMTS and IMT-2000 applications. Such filters should present favourable characteristics in terms of low losses, appropriate frequency response, miniaturization and low cost.

In order to reduce dimensions two techniques, initially developed for satellite applications, are currently adopted: the multiple reuse of the same cavity and the insertion of a low-loss high-permittivity ceramic block within the cavity body [1], [2], [3].

These techniques have been used in [4] to realize an asymmetric dual-mode filter with conductor-loaded dielectric resonators for the 900 MHz GSM band. The basic dual-mode cavity there presented makes use of a metal plate placed on top of a ceramic resonator which enlarges the operating bandwidth, but reduces the achievable unloaded Q. More recently, a dual-mode filter employing dielectric ring resonators with metallic strips has been presented in [5]. In both cases, the conductor losses on the metallic strips deteriotate the cavity Q; in addition, such strips or plates once realized are not suitable for tuning.

A different approach has been proposed in [6] where, instead of placing metallic parts on the dielectric, the resonator shape has been changed in order to achieve quasi-dual-mode resonances while also reducing dimensions. Unfortunately, apart for manufacturing difficulties, the proposed configurations present a lower Q with respect to that achieved by traditional dielectric resonators.

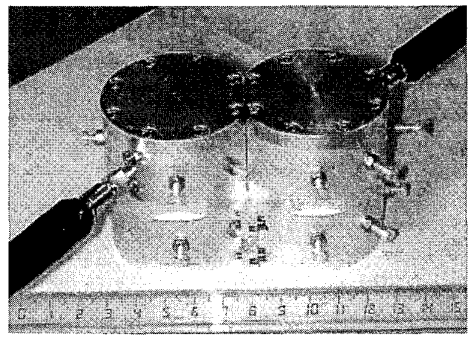

Fig. 1. Photo of the 8-poles filter

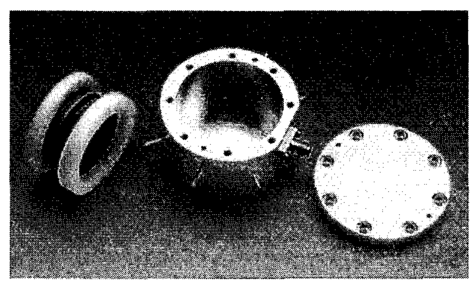

Fig. 2. Single cavity photograph: note the supporting washers (white) and the grooved (darker region) ceramic resonators.

In the present paper a low-loss eight-pole filter has been designed for a UMTS-Tx channel application, see Fig. 1; it makes use of a cavity, shown in Fig. 2, where a grooved dielectric resonator has been suspended by means of low-permittivity supports [7].

Next section illustrates the cavity arrangement and its advantages; section III considers the dual mode excitation and the the intercavity coupling; finally, section IV shows the realized filter with symmetrically or asymmetrically placed transmission zeros.

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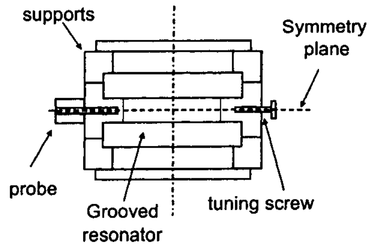

Fig. 3. Side view of the cavity with the grooved dielectric resonator. Note that the groove presence enables the penetration of probes or screws into areas of high field concentration.

II. The grooved ceramic resonator

A. Cavity structure

A sketch of the proposed cavity[1] resonator is reported in Fig. 3. The groove in the ceramic body, that may increase up to a full air gap, enables the penetration of probes or screws into areas where the fields are stronger: this results in a much higher coupling or tuning action with respect to the standard uniform cylindrical shape. Such high values of coupling are typically required in filters used in cellular-radio base stations, where the ratio between useful bandwidths and center frequencies produce relatively large fractional bandwidths, as compared to satellite applications.

The high permittivity resonator is kept in place by using two low-permittivity washer-shaped supports. This prevent the resonator to contact the conductors; consequently a high value of Q has been obtained, with measured results in the range of 9000-9500.

B. Cavity resonances

The cavity supports hybrid HE_{mn} resonant modes and TE_{0n}, TM_{0n} modes when the angular index m is zero. As the structure is symmetric with respect to the longitudinal axis, all modes display an electric or magnetic wall at symmetry plane and will be denoted respectively as E or H type. The modal spectrum depends on the size and shape of the cavity elements. The resonant mode used for the filter is the dual degenerate $HE_{11}H$ resonance. The improvement in the spurious-free performance is achieved in two ways: by using simmetries and by optimizing dimensions.

Symmetry is advantageously considered for preventing the excitation of all modes showing an E-plane symmetry. This is done by placing the input probe and coupling/tuning elements on the symmetry plane

[1]patent pending

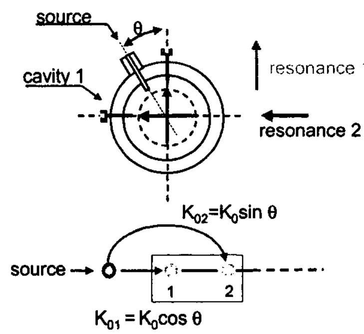

Fig. 4. Realization of the dual mode resonances in the input cavity. Mode resonaces are determined by the tuning screw positions.

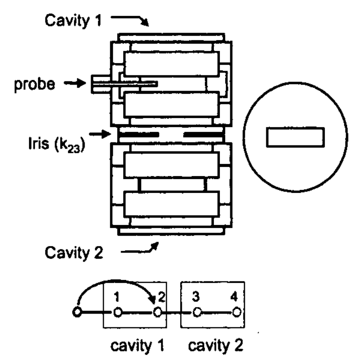

Fig. 5. Intercavity coupling realized by means of a rectangular iris.

(shown in Fig. 3). Moreover, TE_{0n} modes are not excited if probes and screws are placed radially.

Optimization of cavity dimensions and shape is performed by using an accurate full-wave modal routine, based on the approach introduced in [9]. The present analysis method takes into account also the grooved dielectric resonator geometry, the washer supports with indentations and the metal housing.

III. Coupling and Tuning

A. Dual mode excitation

In order to realize the dual mode excitation in the input cavity, the input probe is placed at a rotated position with respect to reference mode orientation which is determined by the tuning screw position, as illustrated in Fig. 4. This provides the simultaneous coupling of source node to both resonant modes into the cavity. Coupling between modes, k_{12} in the above fig-

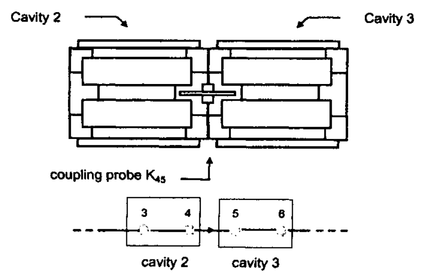

Fig. 6. Intercavity coupling realized by means of an intercavity probe.

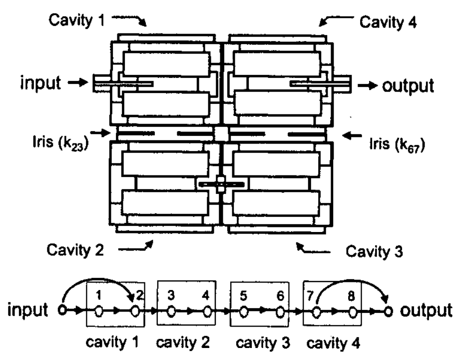

Fig. 7. Eight-pole dual-mode filter structure arrangement (side view). Cavity 1 is connected to cavity 2 by an iris discontinuity; a similar coupling is also used between cavity 3 and 4. The coupling between cavity 2 and 3 is obtained by means of an intercavity probe, visible in the lower part of the figure.

ure, is obtained as usually, i.e. by screws placed at 45 degrees w.r.t. to tuning screws. A similar mechanism holds for dual mode generation in the output cavity. Dual mode excitations in other cavities (not the input/output ones), is also achieved by placing screws at 45 degrees w.r.t. to tuning screws.

B. Intercavity coupling

Cavities are coupled to each other in two ways: when placed one on the top of the other a rectangular iris is used for coupling; when placed side-by-side an intercavity probe is considered.

Fig. 5 illustrates the case for the rectangular iris coupling; the shape, dimensions and position of the rectangular iris are such that only the second resonant mode is coupled to the lower cavity. Iris geometry has been determined in order to achieve the sought values of coupling by the full-wave model previously described.

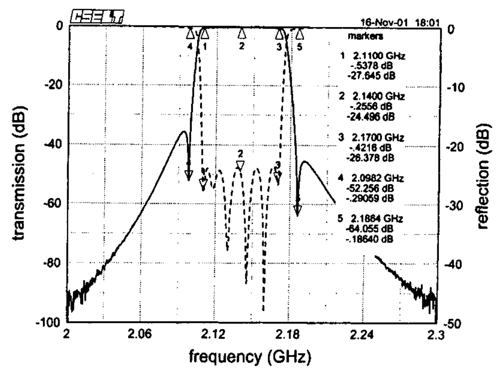

Fig. 8. Measured response of the eight-pole filter.

Fig. 6 reports the intercavity coupling as realized by a probe extending inside the dielectric groove. The correct coupling value is achieved experimentally.

IV. Filter Prototype

An eight-pole dual-mode filter[2] has been designed with a center frequency of 2.14 GHz (UMTS transmit frequency) and a bandwidth of 60 MHz. In order to fulfill the filter specifications transmission zeros have been asymmetrically placed on the passband sides at -1.3 and 1.4 (normalized lowpass units). Fig. 7 reports the filter structure and also the routing diagram which shows that the transmission zeros are obtained by using the "trisection" concept [8], with the first trisection placed at the input node and the second at the output node.

The cavity arrangement achieves a high degree of compactness. Moreover, by using different coupling means (either irises or probes) in the inner main path (see Fig. 7) the propagation of unwanted modes inside the filter structure is inhibited. In fact, any $TE_{01}H$ mode that may accidentally be excited, owing to manufacturing inaccuracies, is not coupled to the next cavity neither by an end iris, nor by a central probe. Similarly, the second HE_{11} resonance $HE_{11}E$, which is inevitably coupled by an iris, is not coupled by the central intercavity probe, placed where the (electric) field of the $HE_{11}E$ mode is zero.

A prototype filter, with cavities of 27.5 mm height and 42 mm diameter has been manufactured. The ceramic material has a relative permittivity ϵ_r=34-35 and loss tangent of $5.3 * 10^{-5}$; the supporting washers are made of teflon, owing to its low permittivity and low loss. The unloaded cavity exibits a resonant frequency of 2.250 GHz with a Q_u of 9000 to 9500.

[2]patent pending

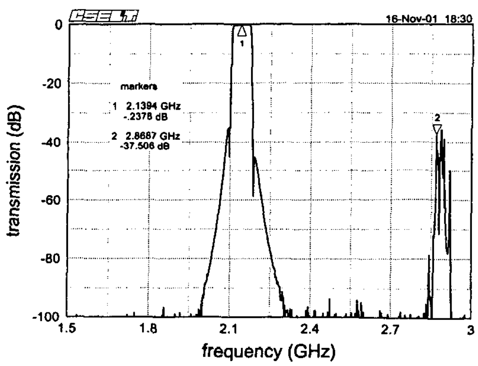

Fig. 9. Measured wideband response

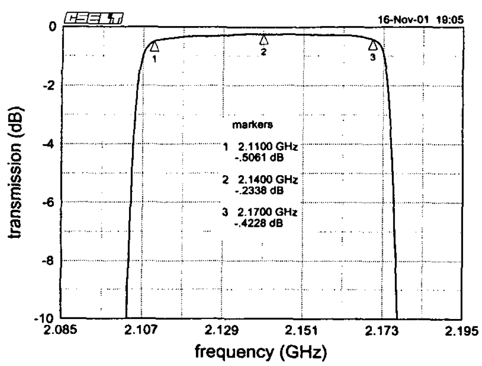

Fig. 10. Measured in-band response

The eight-pole structure under consideration has been tuned in two steps. In the first (main) step the filter is sectioned by short-circuiting the intercavity probe and tuning the resulting 4-pole structure by a computer-aided procedure [11]. The second (refining) step brings the filter to its final configuration directly working on the input return loss response of the whole filter. The filter measured performance is reported in Fig. 8, Fig. 9 and Fig. 10. Low insertion loss ($< 0.3dB$ at band center) and wide spurious-free window ($\sim 700Mhz$) are observed.

V. Conclusions

An eight-pole dual-mode filter with transmission zeros, suitable for UMTS or IMT-2000 cellular-radio base station filters, has been realized by using a novel cavity structure with a grooved dielectric resonator supported by low permittivity washers.

The proposed configuration exibits high values of coupling and unloaded Q and, by using a specifically developed full-wave simulator, may be optimized for obtaining a sufficiently wide operating frequency window.

Measured results confirm the structure usefulness for practical applications.

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