Novel Compact Narrow-band Microstrip Dual-mode Resonator Filters for 3G Telecommunication Systems

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Abstract— **Novel compact microwave bandpass filter configurations based on the dual-mode microstrip square loop resonators are proposed. Two bandpass prototypes operating in the UMTS frequency range have been fabricated and measured: a 4-poles and a 5-poles dual-mode filters with a bandwidth of 3 %. These filters exhibit significant dimension reduction without any appreciable decrease of performance thus making themselves very attractive for nano- and pico-cellular base stations in 3G communication services.**

Index Terms: Bandpass filters, elliptic-function filtering, microstrip resonator, 3G communication systems

I. Introduction

THIRD generation cellular networks are characterized by a continuous cell reduction. Nowadays, for indoor applications, service providers are thinking in terms of "pico-cells" with typical radii within some tens of meters. This tendency on one hand increases the market volume of base stations, on the other hand yields power handling reduction with respect to 2nd generation cellular networks. Moreover, for urban and indoor applications particular attention must be payed to the environmental impact of the equipments, thus weight and size are becoming more and more stringent constraint for the realization of modern cellular telephony hardware.

Filtering at 3G operating frequencies is inherently a problem: waveguide and, more generally, 3D approaches, widely used in 2G base stations for their performance, are not affordable any further in nano- and pico-cellular networks; for these applications more compact solutions such as planar ones, not commonly used in 2G systems because of their relatively high losses, tuning difficulties and low power handling, are becoming even more attractive in 3G apparatuses. In this field of application microstrip dual-mode filtering [1],[2] is an interesting technique. Solutions appeared in the literatures [3],[4] demonstrated the validity of this approach and its appreciable superiority in comparison with conventional planar techniques (coupled lines, hairpin...).

This paper proposes a novel filter configuration based on dual-mode microstrip square loop resonators([5]) as an alternative to the proposal of Hong et al. [6]. In [6] dual-mode microstrip square loop resonators have been coupled in a face to face fashion to reduce the overall 2D extension of the filter at the price of a certain enlargement of the structure along the third dimension. In our paper size reduction has been pursued by developing a novel configuration consisting of dual-mode microstrip square loop resonators sharing the same ground plane one of the back of each other. The coupling between resonators on different metallization layers is obtained by means of via-throughs. Beyond the overall reduction obtained by stacking the resonators this configuration has also the advantage of an easy tunability. With respect to the face to face configuration, in fact, back to back one allows for the insertion of screws in the filter package that can be used to alter the microstrip behavior by proximity effect. A 4-poles elliptic dual-mode bandpass filter operating at 1.95 GHz with a bandwidth of 3 % has been designed and tested. To foster this approach improvement of the structure has been pursued by exploiting the presence of the coupling structure. A fifth resonator has been realized by using the interconnecting circuit. This allows filter order and selectivity to be increased without any price in terms of dimensions. Realization and testing have validated these concepts.

II. First filter configuration

In Fig. 1 the layout of a planar 4-poles elliptic dual-mode bandpass microstrip square loop resonator filter is depicted. A square loop consisting of four identical arms forms a basic resonator; a small patch discontinuity is attached to an inner corner of the loop to couple the pair of degenerate modes supported by the square ring cavity. Considering the equivalent circuit proposed in [7] the whole 4-poles filter consists of two dual-mode square loop resonators purposely coupled. The in-out coupling, the direct coupling and the cross-coupling between non-adjacent resonators are provided by proper interconnecting microstrips. The experimental S-parameters are shown in Fig. 2. The structure in Fig. 1 is considered as the starting point to design the new filter configurations. The basic idea is to fold this structure along the vertical symmetry plane till the ground planes on the back side of the substrate touch each other. At this point the structure becomes multi-layer: circuit level top, shared ground plane, circuit level bottom. To restore the coupling between rings proper interconnecting structures are developed. The cross-coupling has been recovered by simply inserting a via-through connecting the two microstrip terminations; the coupling between adjacent resonators, previously provided by the direct coupling of square ring branches is now obtained by coupling first each ring to a microstrip, then the terminations of the microstrips to each other with via-throughs (see fig. 4 for more details). This structure has been designed and optimized by using AWR Microwave Office CAD suite. In particular, special attention has been devoted to optimize the dimension of the interconnecting structures in such a way as to find the proper length of the lines accounting for the presence of the via through. Prototype has then been realized by etching microstrip circuit on a Taconic TLC 32-0300 CH/CH substrate. After the realization (fig. 4) testing and characterization have been done. Fig. 5 shows the frequency responses of the filter. Return loss better than -15 dB, insertion loss close to -4 dB, good selectivity and out of band rejection have been obtained.

III. Second filter configuration

As soon as the structure has been validated a simple yet effective improvement has been developed. The idea behind this improvement is the exploitation of interconnecting structures to provide an additional resonator. The circuit designed to couple former adjacent rings can be easily recognized as a potential multi-layer microstrip resonators. This sub-circuit, in fact, was purposely designed in the previous filter not to resonate in order to avoid possible uncertainties at that stage of the development. At this stage the cited interconnection has been instead optimized to provide the fifth resonator allowing filter order increase. In order to simplify the structure a five resonator filter without cross coupling has been conceived. Again the structure has been designed and optimized by using AWR software (fig. 6) than the prototype has been realized (fig. 7) and tested. Fig. 8) and 9) show the narrow- and broad-band frequency response respectively. As expected, improvement in selectivity and out of band rejection have been obtained at the expense of a slight increment of losses.

IV. Conclusion

Novel planar microwave filtering structures operating in the UMTS frequency range have been developed by stacking microstrip dual-mode resonators one on the back of each other. Coupling problems have been solved by developing proper sub-circuits that in a second stage of development have been used to increase the order and selectivity of the original configuration without further expense in terms of size. Realization and measurements have been provided. Significant dimension reduction without appreciable decrease of performance has been demonstrated.

V. Acknowledgments

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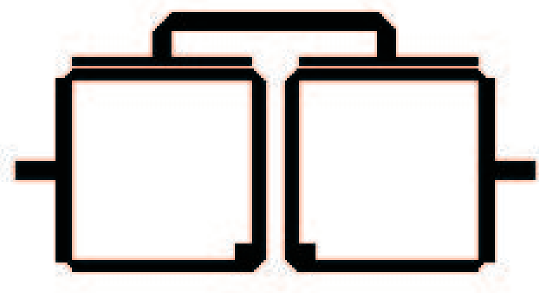

Fig. 1. Layout of the conventional configuration for a 4 -poles dual-mode elliptic bandpass filter.(substrate Taconic TLY 5A-0200)

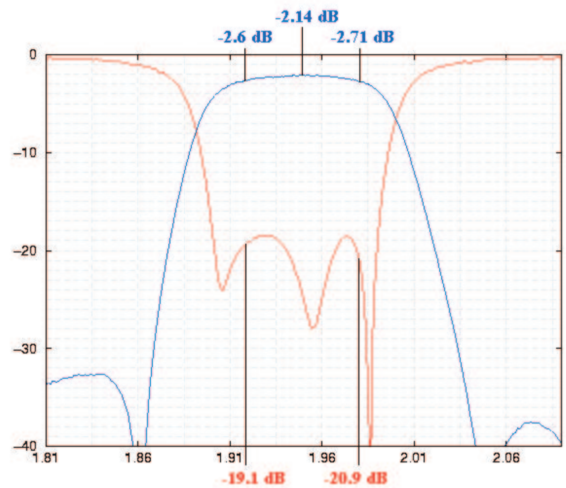

Fig. 2. Experimental S-parameter results of the structure of Fig 1

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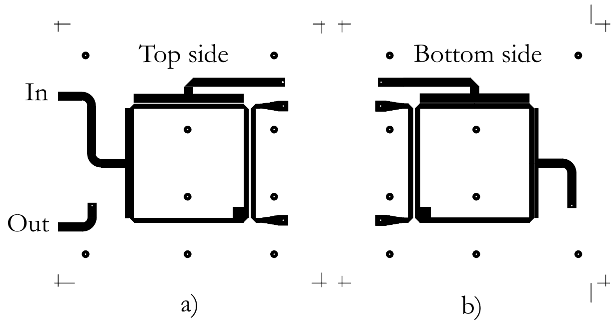

Fig. 3. Layout of the top side (a) and of the bottom side (b) of the new 4-poles dual-mode elliptic bandpass filter.

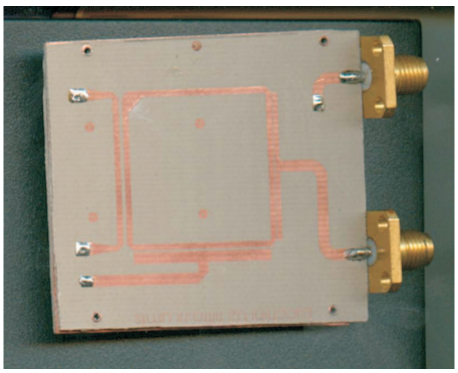

Fig. 4. Photo of the top view of the structure of Fig. 3. Substrate Taconic TLC 32-0300 CH/CH

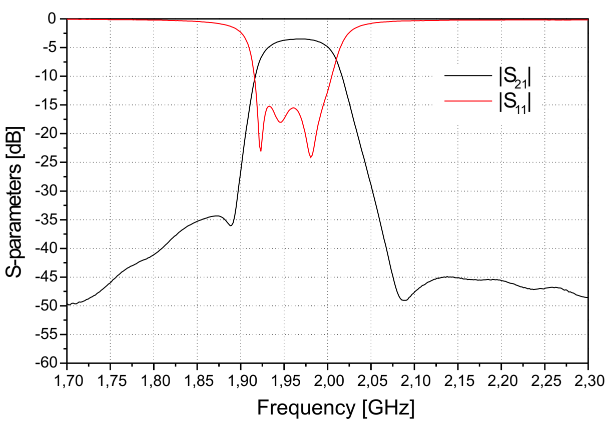

Fig. 5. Experimental results of structure of fig. 3 and 4

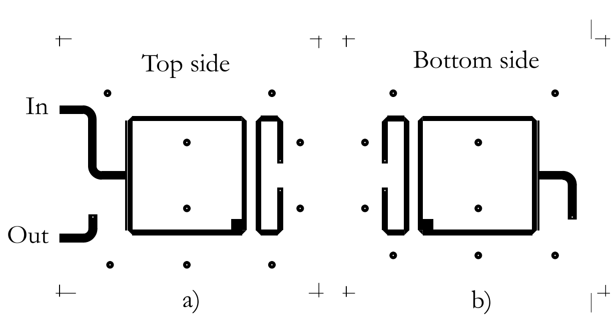

Fig. 6. Layout of the top side (a) and of the bottom side (b) of the new 5-poles dual-mode bandpass filter.

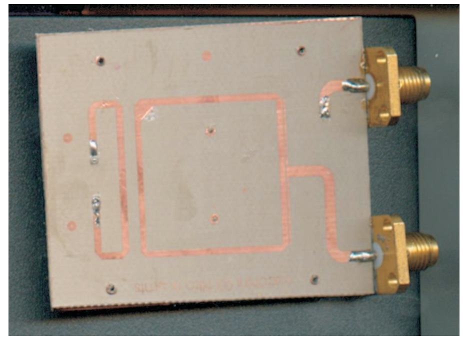

Fig. 7. Photo of the top view of the structure of fig. 6 and 7. Substrate Taconic TLC 32-0300 CH/CH

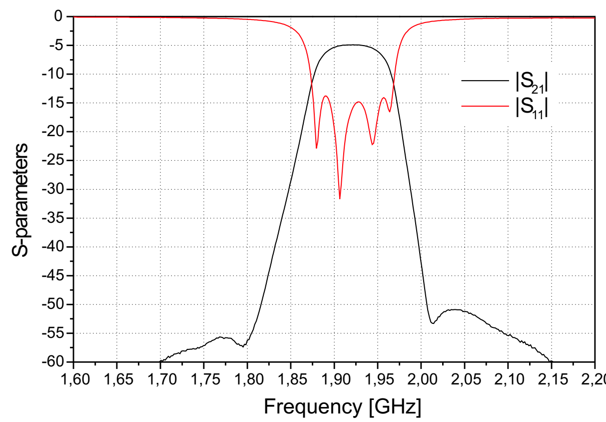

Fig. 8. Narrow band response of the filter of Fig.6

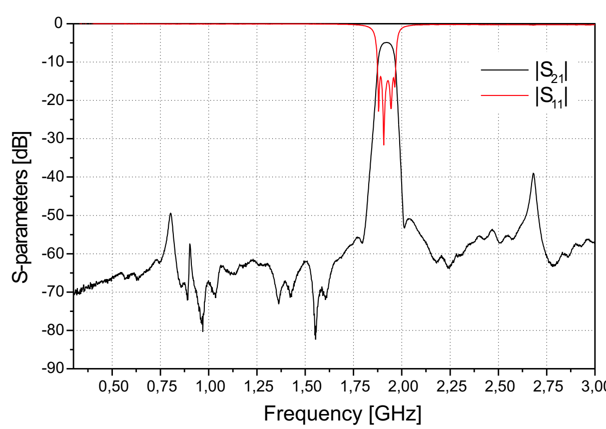

Fig. 9. Broadband response of the filter of Fig.6