Microstrip miniaturized loop-filters with high out-of-band rejection for future 3G mobile terminals

Yann Toutain, Jean-Philippe Coupez (*), Christian Person

LEST - ENST Bretagne (*)/UBO - BP832 - 29285 BREST CEDEX - France
Tel: 33.2.29.00.13.19 - Fax: 33.2.29.00.13.43 - Email: Yann.Toutain@enst-bretagne.fr

***Abstract* - This paper deals about the implementation of miniaturized microstrip band-pass filters operating on a very narrow bandwidth. We propose an original synthesis for achieving high out-of-band rejection by means of a 2nd order resonant structure, for which transmission zeros are introduced through mutual coupling effects. Quite good performances are obtained regarding losses, size and spurious resonances for the proposed topology, which can be considered as a good solution for future mobile on-board equipments.**

I.-INTRODUCTION

With the emergence of new telecommunication services and architectures, specific and drastic requirements are involved today concerning on-board electronic equipments, especially about filters and multiplexers. The transmission losses within the operating Tx and Rx bandwidths, usually less than 3%, as well as the out-of-band responses and the isolation between channels, remain critical parameters for both base stations and mobile terminals.

Among the numerous available possible configurations, new generations of band-pass filters like SAW filters or coaxial ceramic modules, have been developed and extensively used, mainly for mobile devices, for size and cost motivations. Nevertheless, many difficulties are encountered when implementing such filters, considering either reliability or interconnection constraints with common electronic functions integrated in RF front ends. In this way, microstrip filters remain really attractive. Significant efforts have been done in order to improve the electrical performances and the dimensions of such elements. Then, alternative but efficient solutions can now be proposed for substituting the conventional hybrid configurations (SAW or ceramic filters mounted on PCB) used up to this time [1] [2] [3].

II.-DESIGN METHODOLOGY FOR IMPROVING MICROSTRIP FILTER PERFORMANCES

We have recently proposed [4] a new microstrip loop filter with improved performances in term of losses, size and rejection level. A single resonator was employed in order to minimize the dimensions and the insertion losses whereas particular implementation and design rules was proposed to achieve a convenient filtering response. An interdigitated area is used to tune the coupling level between the feeding lines and the loop resonator within a limited area. Despite transmission zero are usually introduced by mutual coupling effects between non-adjacent resonators, we rather operate with a single resonator structure for size and loss motivations. A transmission zero is first introduced by means of a capacitive coupling effect located at the feeding lines open-ends (fig.1). In comparison with the second network (path 2), which determines the resonant frequency of the filter, we can observe that the S21 phase parameter related to the path 1 is out of phase at high frequencies with respect to the path 2 reference phase value. This coupling provides a direct path (path 1) which stays in phase each apart the resonance frequency while the second path is out of phase each apart the resonance frequency. The zero appears by destructive combinations of this two paths at a particular frequency where the amplitude of each path are equal but out of phase.

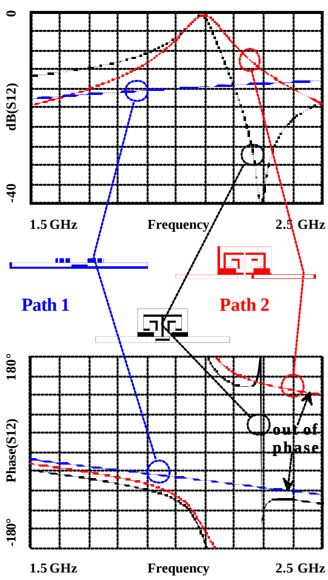

Fig. 1. Single resonator with a transmission zero : Principles

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The length of the resonator is used for defining the center operating frequency while the coupling between the feeding lines extremities contributes to the transmission zero location. The main effort for the designer lies in the definition of an appropriate decomposition of the resonator shape, regarding the required filtering response.

Quite a fair agreement is obtained between the HP-Momentum simulation and the experimental results as presented on the figure 2.

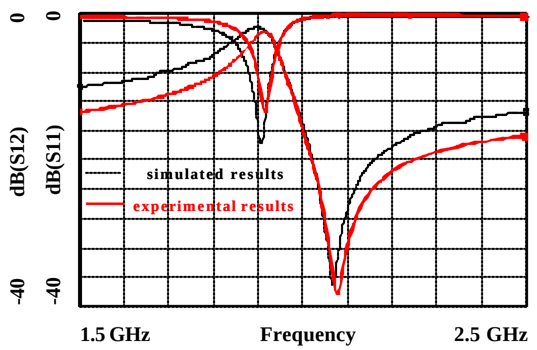


Fig. 2. Comparison between measured and simulation on a single resonator structure with multiple coupling

The complete structure, integrated on an appropriate substrate (εr=10.2, h=635 µm), is quite small (7 mm * 5 mm, see figure 3), with performances in accordance with new mobile system requirements.

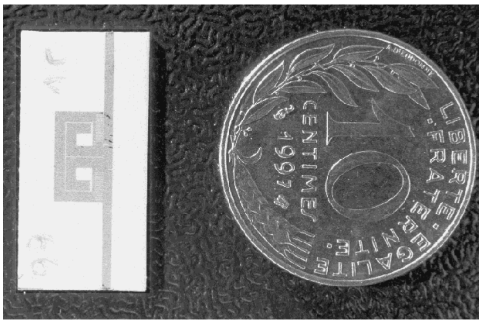


Fig. 3. Photography of the single resonator structure.

Nevertheless, only one transmission zero can be introduced with a single resonator structure. Moreover, this zero is necessarily located at a frequency higher than the center operating one because of in-phase and out of phase recombination constraints. The insertion of a transmission zero at a lower frequency requires at least a second order topology with multiple non-adjacent couplings.

III.- MINIATURIZED TWO RESONATORS STRUCTURE : COUPLING POSSIBILITIES

Various possibilities can be investigated for mutually coupling two resonators comparable to the previous one, then achieving improved filter performance. The figure 4 shows several coupling configurations between two loop-resonators. No transmission zero is observed with such 2-poles filters.

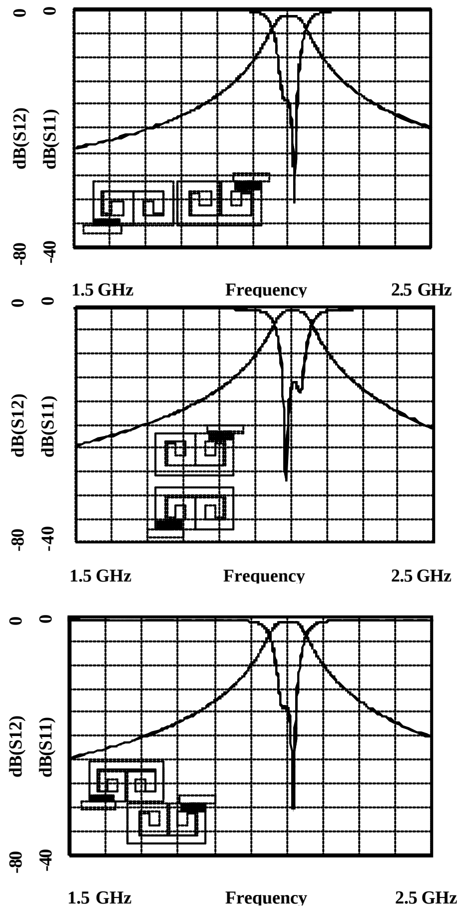


Fig. 4. No-transmission zero topologies by means of two unsymmetrical coupled resonators

Indeed, in relation with the non co-directive coupling effects existing between the two resonators, great difficulties are encountered for retrieving out-of-phase recombination between the different possible paths for the signal, and therefore the associated zero.

In the other hand, transmission zeros can be recovered when operating with symmetrically coupled configurations. The compartmental study reported on figure 5 clearly underlines the possibilities of generating a transmission zero, depending on the symmetry axis ensured with such co-directive coupled resonators.

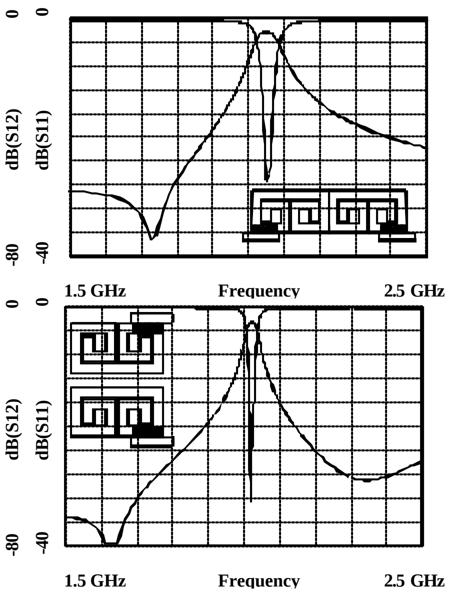
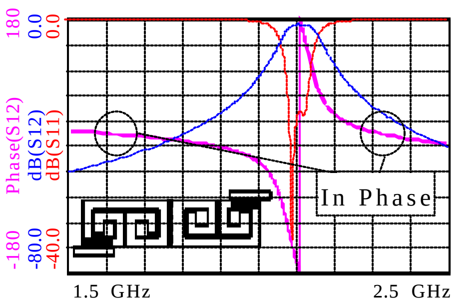


Fig. 5. Laterally coupled resonators – Symmetrical configurations for recovering transmission zero -

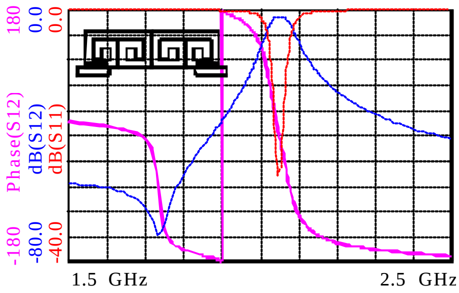
With symmetrical coupling architectures, (figure 5), the out-of-phase destructive conditions can be easily recovered each apart with respect to the operating bandwidth. The resonator shape can be adjusted so as to control the effective electrical length of one path with respect to the other. The main difficulty lies in keeping the fundamental resonance conditions at Fo, which may basically be affected by these coupling phenomena.

IV. COUPLING TWO RESONATORS FOR INTRODUCING A ZERO: PRINCIPLE

Through a two resonators structure without symmetry axis, the transmission phase remains identical each apart from the transmission frequency band (Figure 6-a). This is opposite to the single resonator behavior seen before where the phase keeps out of phase before and after this transmission band (Figure 1, path 2).



a) Unsymmetrical architecture



b) Symmetrical architecture

Fig. 6. S parameter responses and transmission phase variation of a "two resonators" structure.

The same approach as the one used for the single resonator structure – i.e. controlling the out-of band S21 phase parameter - can therefore be proposed for introducing a transmission zero in a 2nd order structure. To introduce a zero in such a structure (fig.6b), we have to generate a coupling path corresponding approximately to a half-wavelength long trajectory in order to create the out of phase signal compared with the reference phase presented in the figure 6a.

The structure presented on figure 7, is composed of two resonators coupled to their feeding lines by interdigitated coupling area. The presence of the symmetry axis, in association with an appropriate coupling technique, contributes to create the path with required 180° phase shift through the structure (represented in dotted line) with respect to the direct coupling path. It results in a transmission zero at lower frequencies.

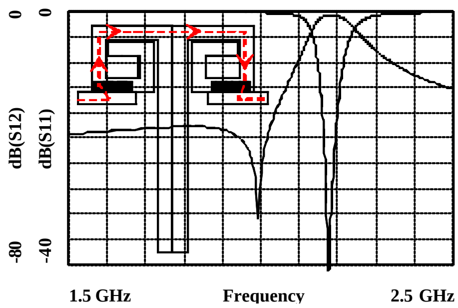


Fig. 7. Example of a two resonators structure with a transmission zero at low frequencies

V. INTRODUCING TWO ZEROS IN A TWO RESONATORS STRUCTURE

The same procedure can be applied for producing additional transmission zeros with this basic 2nd order structure. The control of a first zero is realized by means of a short coupling path, equivalent to an electrical length lower than half a wavelength at Fo (Path 1 on figure 8). The second path length (path 2 on figure 8) is extended through an additional long capacitive coupled lines section, then producing a zero at a lower frequency F_1. So, we obtain a zero on both sides of the operating bandwidth without degrading either the size or the in-band transmission losses.

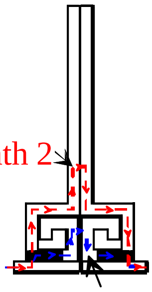


Fig. 8. Presentation of the two paths in the 2 resonators structure.

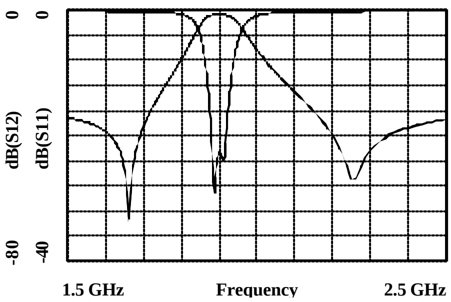


Fig. 9. Simulation response of the 2 zeros structure.

We realize a structure similar to the one presented on figure 8. The dimensions remain quite small despite the low operating frequency (17 mm * 8 mm, see the figure 10), in accordance with the original synthesis technique employed and an appropriate substrate choice (Rogers 6010, εr=10.2, h=635 µm, tgδ=0.001). 50 µm slots are considered in the interdigitated input-output coupling areas.

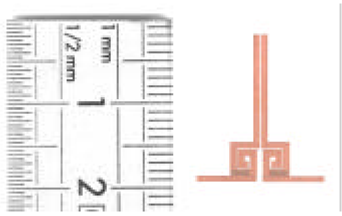


Fig. 10 Photography of the realized two resonators structure.

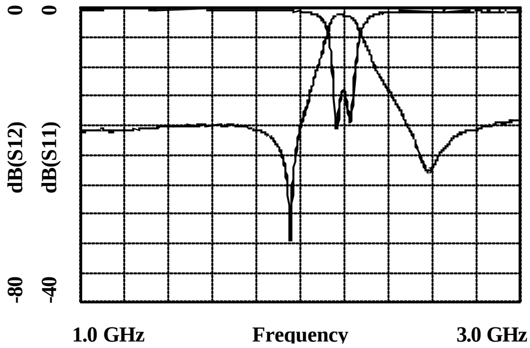


Fig.11. Measurements

Losses lower than 2.6 dB are obtained on a 30 MHz band centered at 2.18 GHz (RX band). A rejection level greater than 45 dB is achieved on a 30 MHz band centered at 1.955 GHz (TX band).

VI. CONCLUSIONS

A new topology of filter using miniaturized microstrip resonators is presented in this paper. A two resonators structure is proposed in order to generate transmission zeros located on a both sides of the transmission bandwidth. The global performances of such filter are therefore improved, despite the reduced number of resonators, in terms of rejection and insertion losses. This modified loop-filter is consequently really attractive for wireless applications, especially for the future third generation of mobile terminals.

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