Accessing to UMTS Filtering Specifications Using New Microstrip Miniaturized Loop-Filters

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Abstract — **A new topology for the design of microstrip loop-filters is proposed in this paper. This new geometry is used in a coupled-loop-resonator filter in order to improve the out of band rejection (by introducing an additional transmission zero), as well as insertion loss (thanks to a significant circuit size reduction). The design methodology of these filters is first described and then experimental performances are discussed. Finally, a high performance duplexer, specified for UMTS frequencies and requirements (i.e. in the 1.9 - 2.17 GHz frequency band), is presented. Measured insertion loss is lower than 2.5 dB and an isolation level greater than 40 dB is achieved between Tx/Rx channels, thanks to the multiple out of band transmission zeros introduced in the filter synthesis.**

I. Introduction

The new commercial applications of the mobile RF networks have contributed to the development of small size, lightweight, high performance and low cost components. These requirements concern every function of the on-board electronic equipments and specifically filters. Therefore, new filters' topologies, such as SAW filters and ceramic block filters, have been extensively studied. These low cost filters are mainly used in mobile terminals. However, despite their good performances, many difficulties remain: among them, reliability and interconnections when implementing these components in a complete integrated RF front end.

Therefore, planar filters, which are easy to produce and to integrate with other printed RF functions, are still very attractive. For these reasons, significant studies have been realized in order to improve electrical performances and size of microstrip filters. Different topologies such as slow-wave-resonator filters [1], loop-filters [2] or compact hairpin resonator filters [3] have been proposed

In this paper, an original double-coupled-loop-resonator filter is proposed. This solution allows maximizing the out of band rejection, while providing a significant size reduction. The design methodology is detailed and experimental results for two filters are given in order to validate the used resonator geometry. Finally, a duplexer, designed for the UMTS frequency band (1.9-2.17 GHz), is presented.

II. Filters Specifications for 3G Mobile Applications

Drastic performances and restrictions are required for filters integrated in 3G mobile communication systems, such as UMTS. Insertion loss must be as low as possible, which leads to maximize the Q factor for the resonant structures. In addition, the size restriction is also important for both mobile terminals and base stations. Moreover, the operating relative bandwidths are very narrow and do not exceed 3% (e.g. UMTS Tx channel: 1.92-1.98 GHz — UMTS Rx channel: 2.11-2.17 GHz). Mainly because of the intrinsic conductive and radiating loss, such low bandwidths generally contribute to increase the filter insertion loss when planar technology is used. Furthermore, it is necessary to optimize the out of band rejection in order to implement efficient duplexers with high Rx/Tx isolation, especially in the Rx frequency band. Finally, the filters have to be low cost and easily reproducible.

III. Design Methodology for Improving Microstrip Loop-Filters Performances

A. Previous works

We have recently proposed several microstrip loop-filters [2] [4], with improved performances in terms of losses, size reduction and rejection level. Single or double resonator configurations were used in order to achieve convenient filtering responses. In this case, intra- and inter- loop-resonator couplings were used so as to create electrical multi-paths inside the filter structure, which led to transmission zeros at the desired frequencies.

Recently [5], these filters were implemented in a Rx/Tx duplexer for UMTS terminals and good performances were achieved in accordance with UMTS specifications. However, compact and extremely fine interdigited

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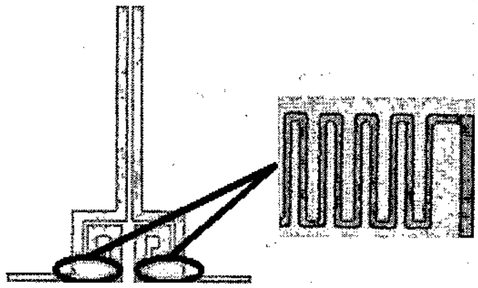
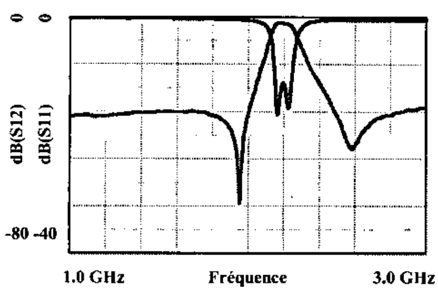
sections were used to tune the coupling level between the feeding lines and the loop resonator (Figure 1).



a) Photography of a double-loop filter



b) Measurements of the filter

Figure 1. Double-loop filter with interdigited coupling areas.

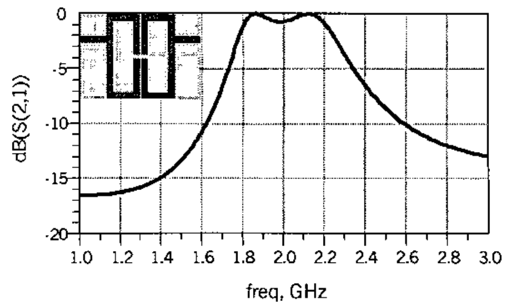
This configuration led to major difficulties when implementing and optimizing such filters and duplexers.

As a solution, we propose new resonators with simplified structures without any interdigited areas. Thus, 2nd order filters, with up to three transmission zeros, can be successfully synthesized with such resonators and without any technological limitation.

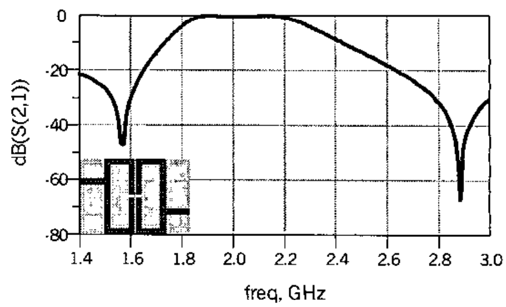
B. New filter design

Both for a given filter order and for a fixed insertion loss value, improvement of the out of band filter rejection or of the Rx/Tx duplexer isolation can be achieved by introducing transmission zeros.

In this purpose, the filter topology used in this work is based on two half-wavelength coupled resonators. The position of the feeding points has been chosen in order to obtain "in-phase" or "out-of-phase" input/output access. Such feeding conditions have great incidence on the filter's electrical response. As shown in Figure 2, the first structure (with "out of phase" input/output access) has no transmission zero. In contrast, the second configuration (with "in phase" input/output access) introduces two transmission zeros on each side of the operating frequency band. The location of such infinite-rejected frequencies directly depends on the lengths of the two complementary sections of the loop resonator. These sections are defined from the open-circuit ends of the resonator to the position of the feeding point **[6]**.



a) "Out of phase" input/output access.



b) "In phase" input/output access.

Figure 2. Filter's feeding geometries.

Filter miniaturization enhancement can be obtained by compacting the loop topology, as shown in Figure 3. Moreover, multiple coupling effects are created within the resonator by introducing new electrical paths in the structure. As presented in Figure 3, a second transmission zero can be introduced above the operating frequency band. This transmission zero frequency is related to the position of the inter-resonator coupling zones and to the selected coupling level.

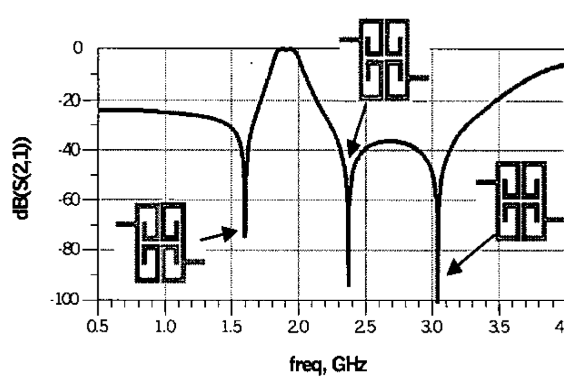


Figure 3. Transmission zero frequencies and related lengths.

This coupling area position can easily be adjusted with respect to the total resonator length for maintaining the center resonant frequency. Furthermore, the two upper transmission zeros can be brought closer to each other, maximizing the out of band rejection above the operating band (Figure 4).

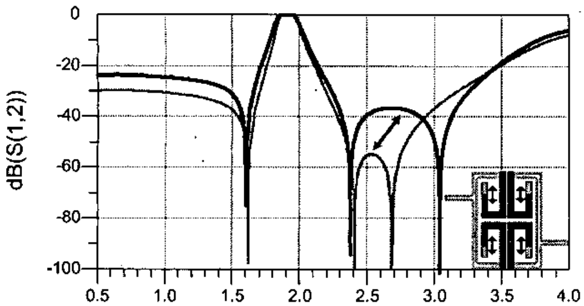


Figure 4. Transmission zero tuning.

Additionally, the upper transmission zeros are also highly dependant on the coupling effects between the two arms within each resonator. Figure 5 shows the filter responses with and without taking into account these coupling phenomena. Consequently, this inner coupling constitutes a second free parameter, which enables adjusting the out of band rejection.

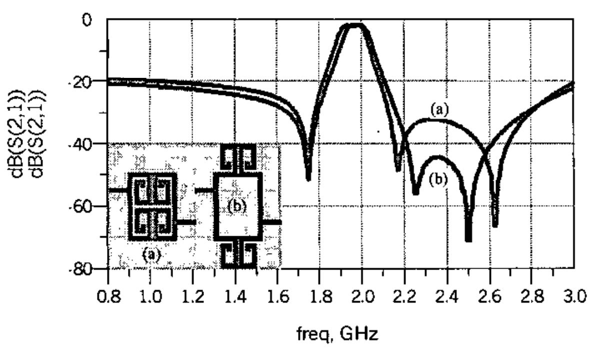


Figure 5. Intra-resonator-coupling effect on the transmission zero frequencies.

Finally, a filter fulfilling required specifications can easily be implemented, while following these some very simple design rules.

IV. EXPERIMENTAL RESULTS

First, a circuit simulator (ADS software from Agilent) has been used in order to both analyse the filter response and define the different lengths of the resonator arms. Very good agreement has later been obtained with the use of an EM simulator (ADS-Momentum from Agilent).

Then, two filters for Tx and Rx bands (Figures 6 and 7), were synthesised on an Al_2O_3 substrate (ε_r = 9.9, tan $\delta = 10^{-3}$, h=635μm). The out of band rejection and the Rx/Tx isolation have been optimized in the Rx band.

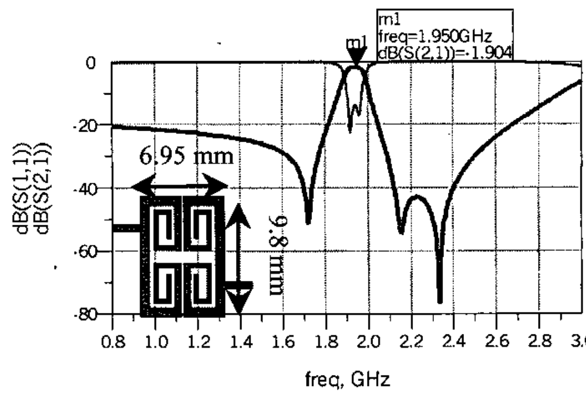


Figure 6. Tx filter's layout and measurements

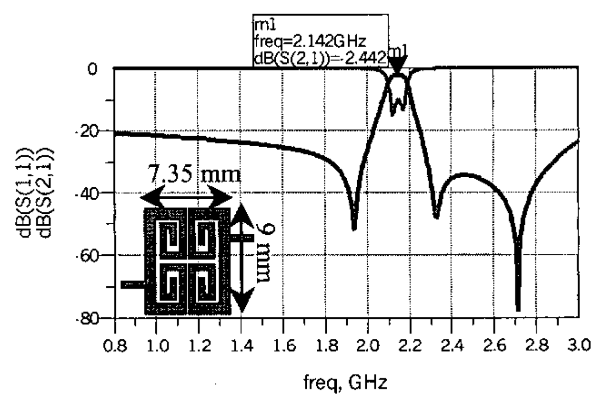


Figure 7. Rx filter's layout and measurements

Measured insertion loss is in the order of 2dB and 2.4dB, with a return loss of −13dB and −12dB, for Tx and Rx bands respectively. The Tx filter rejection level is greater than 40 dB in the 2.1-2.4 GHz frequency range (which includes the Rx band), while a transmission zero is positioned at 1.95 GHz (i.e. in the Tx band) for the Rx filter. Both filters are quite small and their dimensions are lower than 7.5*10 mm². It is to be noted that identical results were also obtained using Teflon substrate (Ro 6010: ε_r = 10.2, tan $\delta = 10^{-3}$, h=635μm)

Finally, a duplexer combining the two filters was built (Figure 8), and very good performances were achieved. In this case, insertion loss was lower than 2.5dB for both Rx and Tx bands.

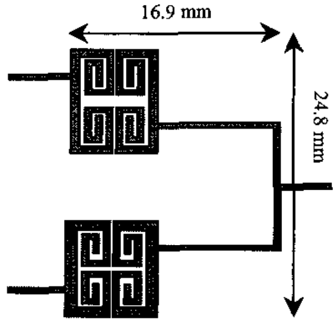
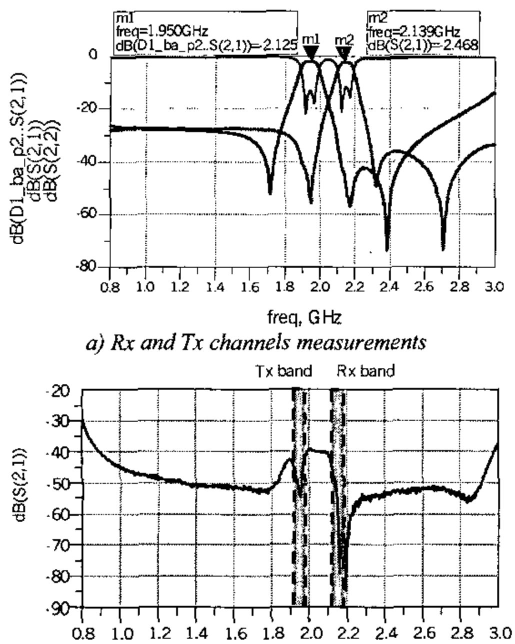


Figure 8. Duplexer layout

The dimensions of the presented duplexer are not optimized, and its compactness could be greatly improved by using meander transmission lines instead of straight lines, for example.



a) Rx and Tx channels measurements

b) Rx/Tx isolation

Figure 9. Duplexer measurements.

The measured VSWR is 1.6 (Tx) and 1.7 (Rx), and the Rx/Tx isolation is about -42dB and -50dB for the Tx and Rx bands respectively. The presented results are in accordance with UMTS specifications.

V. CONCLUSION

A new topology of loop-filter resonators is presented. The proposed design provides significant improvement of filter compactness and of electrical performance level. Indeed, a third transmission zero can easily be introduced in the filter response, which optimizes the out of band rejection. Filters and duplexers in the UMTS bands have been synthesized according to the proposed design. In addition, experimental results have been presented, showing very good performances in terms of insertion loss, return loss and mainly rejection level. Finally, the simplicity of the design used avoids technological difficulty and allows easy reproduction.

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REFERENCES

[1] J.-S. Hong, M.J. Lancaster : "Theory and experiment of novel microstrip slow-wave open-loop resonator filters", IEEE Transaction on Microwave Theory and Techniques, Vol. 45, n°12, dec. 1997, p. 2358 -2365

[2] Y. Toutain, J. Ph. Coupez, C. Person : "Microstrip miniaturized loop-filters with high out-of-band rejection for future 3G mobile terminals", IEEE IMS 2001, Phoenix, May 20-25th 2001, p1589-92

[3] M. Sagawa, K. Takahashi, M. Makimoto : " Miniaturized hairpin resonator filters and their application to receiver front-end MIC's", IEEE Transaction on Microwave Theory and Techniques, Vol. 37, n°12, dec. 1989, p. 1991-1997

[4] Y. Toutain, J. Ph. Coupez, C. Person, M. Ney : "Miniaturized loop–filter with high out of band rejection for future UMTS mobile terminals", 30th European Microwave Conference, Paris, 2000, p. 324-327.

[5] Y. Toutain, J. Ph. Coupez, C. Person : "Design and implementation of a compact microstrip Tx/Rx diplexer for UMTS equipments", 14th International Conference on Microwaves, Radar and Wireless Communications, MIKON-2002, Vol.1, pp 187 - 190.

[6] S.-Y. Lee, C.-M. Tsai: "New cross-coupled filter design using improved hairpin resonators", IEEE Transaction on Microwave Theory and Techniques, Vol. 48, n°12, dec. 2000, p. 2482 -2490