Compact Dual-Band Filter in SIW Technology for a L-band Receiver

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Abstract— This paper presents the design of a dual band filter for the integration of a RF receiver front-end in the L band. The synthesis from the imposed filtering specifications led us to choose the SIW technology that ensures a good trade-off between electrical performances and space requirements.

Keywords— SIW, filter synthesis, RF front-end, co-design

I. INTRODUCTION

Advanced wireless RF front-ends are required to afford higher performances in always smaller footprints. The receive filter, presented in this paper, answers severe specifications, allowing to handle both GPS and Galileo signals with strong rejections to insure the immunity of the equipment. The specifications for such a dual-band filter are post noted in Table 1 and Figure 2. The trade-off between dimensions and quality factor is then going to lead the choice of the integration technology.

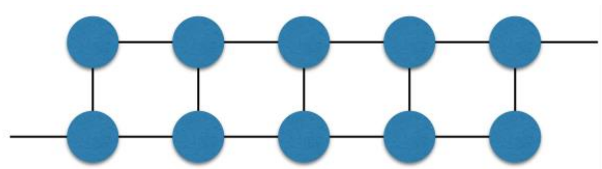
II. SYNTHESIS OF THE FILTERING FUNCTION

From specifications given in Table 1, one can note that high rejection levels (50 dB) are required in the vicinity of the passbands. As a consequence, a large number of resonators are necessary and their quality factors have to be sufficient in order to provide expected performance, leading to a complex and possibly cumbersome structure, while the specified footprint is 60 x 60 mm^2.

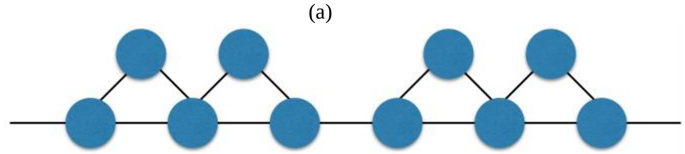
	Fmin	Fmax	Spec (dB)
[S21]	0.800	1.145	-50
[S21]	1.145	1.162	-15
[S11]	1.2126	1.30375	-13
[S21]	1.344	1.370	-5
[S21]	1.370	1.495	-50
[S21]	1.495	1.505	-5
[S11]	1.55042	1.60042	-13
[S21]	1.625	2	-50

Table 1. Filtering specifications

The dual-band filtering function is optimized regarding specified constraints, using the algorithm proposed in [1]. Thus, a 10-pole asymmetric transfer function with 4 transmission zeroes is found for fitting with the specifications. This transfer function is consistent with an implentation using an extended box topology or using triplets. The two topologies are presented in Figure 1.



(a)



(b)

Figure 1.Topologies allowing to implement a 10-pole 4-zero transfer function: (a) extended box topology (b) triplets topology

The transfer function is then drawn according to various finite values of quality factors. The insertion losses found for different quality factors are recorded in Table 2. As presented in Figure 2, in order to reach losses lower than 3 dB in every passband, a quality factor of 300 is necessary. Such a quality factor involves using non planar technologies; however, in order to fit with the footprint specification, a compact resonator based on SIW (substrate integrated waveguide) technology has been utilized.

	Insertion losses / dB	
Q_0	First passband	Second passband
100	5.0	7.0
300	1.7	2.5

Table 2. Insertion losses according to the quality factor.

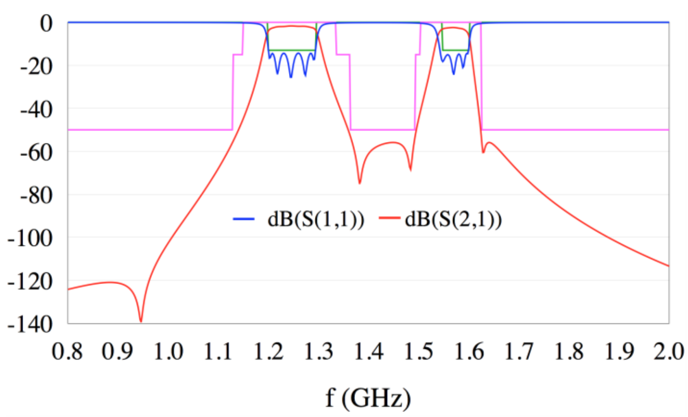


Figure 2. Ideal S Parameters of the filter for a quality factor (Q0) of 300.

III. MANUFACTURING TECHNOLOGY

In terms of quality factor, SIW technology is a solution, which is situated basically between planar and waveguide technologies [2], leading to Q values of some hundreds as expected in this application.

The filter has to be integrated within a receiver front-end, behind a patch antenna [4], whose footprint is 57 x 57 mm2. In order to fit with this specified surface, we decided to stack the resonators on two levels. For implementing 5 resonators on each level, the maximum size of a single resonator was estimated to 20 x 20 mm^2.

The selected substrate is a semi-organic from Rogers (RT / Duroid 6010) with relative permittivity ε_r = 10.2 (10.7 for simulation) and loss tangent tanδ = 2.10^{-3}. We selected this substrate because of the high relative permittivity, which allow reducing the resonator size. Substrate with lower loss tangent may be found, but the permittivity would be reduced.

In order to realize a resonator working in the L-band with a maximum size of 20 x 20 mm^2 using the previous substrate, a capacitive effect is required. The capacitive effect is provided by a post placed in the middle of the SIW cavity. The capacitive post will allow reducing the size of the resonator, but the quality factor will be reduced also. A precise dimensioning is performed applying electromagnetic analyses.

The design of the resonator is performed considering 3 stacked layers for each resonator level: two 2.54-mm layers and a 0.635-mm layer. The basic resonator, whose dimensions are presented in Figure 3, provides a quality factor of about 325 at 1.4 GHz, as specified in this study.

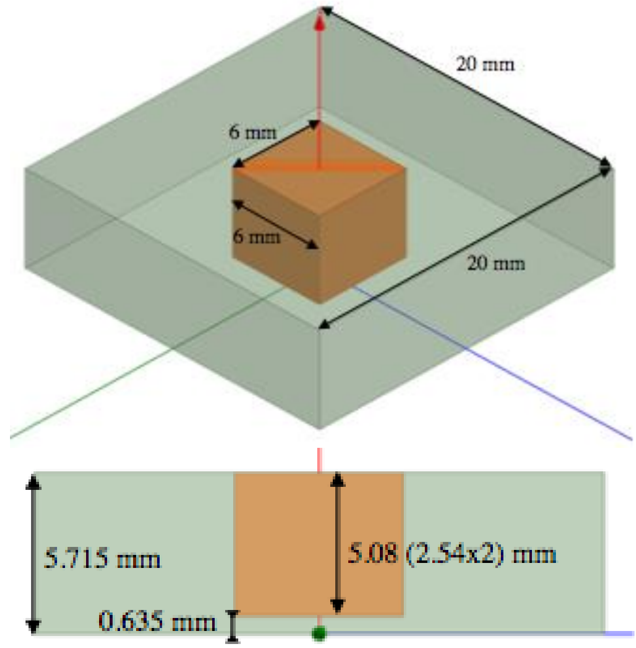


Figure 3. SIW resonator

IV. FILTER DESIGN

A. Coupling Matrix Synthesis

The filter is designed using coupled SIW resonators loaded by capacitive posts. The extended box topology is preferred, allowing a natural distribution of the resonators between the two levels.

With the synthesized transfer function, 64 solutions, i.e. coupling matrices, can be found for realizing the extended box network [5]. Among the 64 solutions, one has to be selected following several criterions:

1. A maximum number of positive couplings; later couplings being easier to implement with the SIW technology,
2. Relatively weak negative couplings, preferably for couplings between resonators placed on different layers (vertical couplings in Figure 4).
3. Horizontal couplings preferably identical on upper and lower levels, so that resonators can be aligned on the two levels in order to simplify their vertical couplings.
4. Some negligible couplings in order to simplify the whole design.

Among all (64) available solutions, the solution presented in Figure 4 was retained. Only the condition on weak negative couplings is not completely performed.

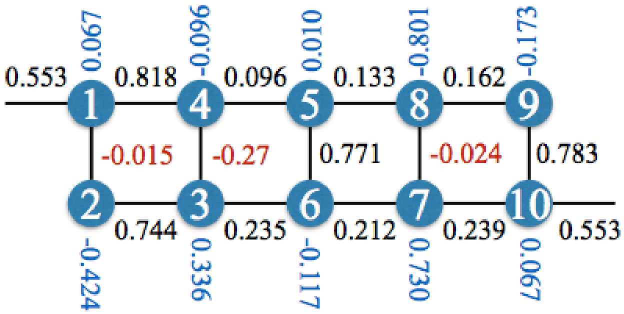


Figure 4. Coupling diagram

B. *Coupling Elements*

Before optimizing the whole structure, coupling elements between individual resonators have to be dimensioned. Considering two resonators coupled by any coupling element, two modes (even and odd modes) established in the structure. Depending on the nature of the coupling (electric or magnetic coupling), the sign is considered as positive or negative. For implementing quasi-elliptic functions, it is necessary to handle both positive and negative couplings. In the frame of this study, we selected three coupling elements described in Figure 5. These elements realize respectively:

- A positive coupling between resonators placed on the same level, realized by proximity (mainly magnetic coupling)
- A positive coupling for resonators stacked on different levels using lateral openings (magnetic coupling).
- A negative coupling for stacked resonators using apertures placed below the post (electric coupling).

C. *Final Design*

The structure is then dimensioned with an electromagnetic model defined as presented in Figure 6. The structure is excited by short-circuited coplanar waveguide (CPW) lines. The filter is then constructed by arranging positive and negative couplings between resonators, as defined in the synthesized coupling matrix. The initial dimensions are given by dimensioning of individual coupling elements, and the dimensions of the final structure are optimized by identifying the coupling matrix [5] after each electromagnetic simulation.

The filter dimensions are 20 x 93 x 11.52 mm^3. The structure has been dimensioned with aligned resonators and coupling elements; however, in order to fit with the footprint specifications, the filter may be folded in order to form a U-shaped structure.

The optimized model complies with the specifications as shown in Figure 7. As expected, the effective quality factor is found between 250 and 300. Moreover, one can note the presence of an additional transmission zero, which does not degrade the performance.

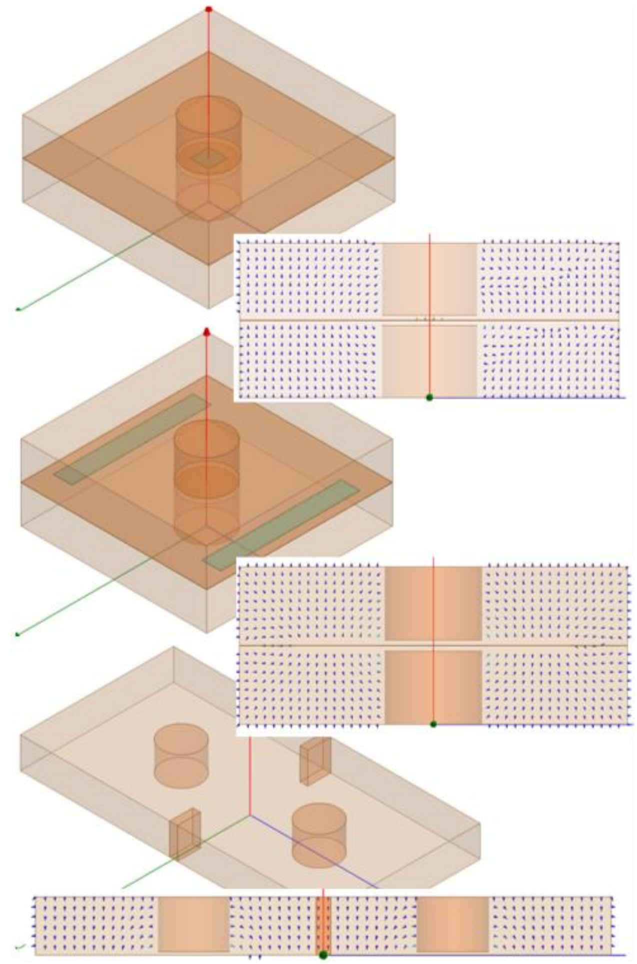
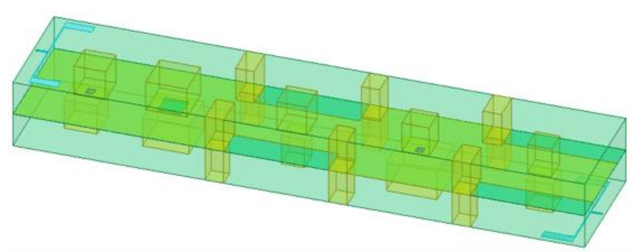
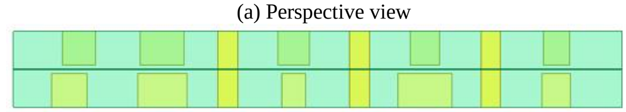


Figure 5. Resonators organization and real electric field display in the structure



(a) Perspective view



(b) Sectional view

Figure 6. Filter model (HFSS)

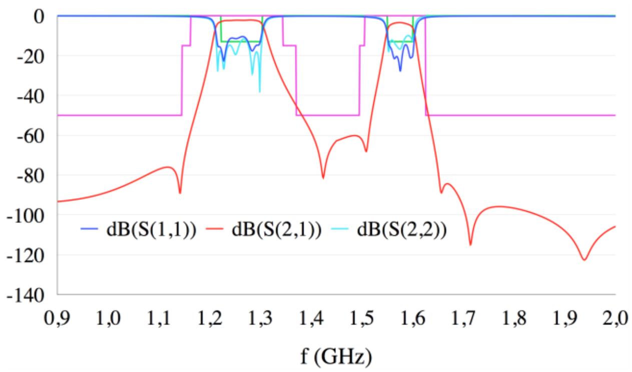


Figure 7. Simulated S-parameters (HFSS)

The simulation results shown the feasibility of such a compact filter, but a more advanced design is ongoing, where capacitive posts are modeled more precisely using metalized vias and where prepreg layers are considered between stacked dielectric layers.

V. Conclusion

This paper presents the design of a dual-band filter intended for a L band receiver. The SIW technology is chosen to optimize the compromise between compactness and electrical performances. A first design allowed to demonstrate the filter feasibility. An optimization of the design taking into account manufacturing constraints is currently ongoing.

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