Regulations Solution of Planar Superconductive Resonators used in the IMUX Filters of a Communications Satellite Payload in Band C.

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***Abstract*--** **The use of high critical temperature superconductive materials in the systems of satellite communication allows simultaneously to reduce the mass and the volume of devices and to reach performances of very high qualities. However, not controllable parameters in the manufacturing processes (indistinctness of the engraving, the non-uniformity of the thickness of the substratum, the …) do not allow to obtain a precision on the central frequency, where from the necessity of finding solutions to adjust the resonant frequencies without degrading the quality factor and without the use of the external systems of regulation which increase the weight and the congestion**

***Index Term*--** **Planar resonators, IMUX filters, satellite, Payload, regulations**

I. INTRODUCTION

The explosion of mobile communications led to impose more and more severe criteria on all the electronics functions in particular on those who assure signals filtering. Indeed, they have to satisfy in a number of strong constraints both at the electric level (bandwidth, selectivity, insertion losses, time distribution of group...etc) and at the level of cost and congestion. The very severe specifications of these filters thus require to envisage, to be able to exploit them, a regulation after manufacturing.

The research works presented in this article, are particularly interested in filters microwaves used in IMUX of a communications satellite payload. These filters are at present realized with a volume technology, what increases the weight and the dimensions, and consequently the launch price of a satellite.

The employment of high critical temperature superconductive materials [1] to realize banks of filters for the future systems integrating a very important number of channels, allows, simultaneously to reduce the weight and the congestion of devices and to reach very high performances. Furthermore, this technology could solve the problems of central frequency gap of filters due to the manufacturing hazards (indistinctness of the engraving, not uniformity of the substratum thickness).

The purpose of our researches is to propose a method which allow to adjust the central frequencies of superconductive filters without use of external regulation systems which can affect the echo's frequencies of the other resonators and the other couplings also in particular when they are placed near the circuit. They lead especially additional losses in the circuit and increase in a general way the size of cases, so limiting the mechanical integration.

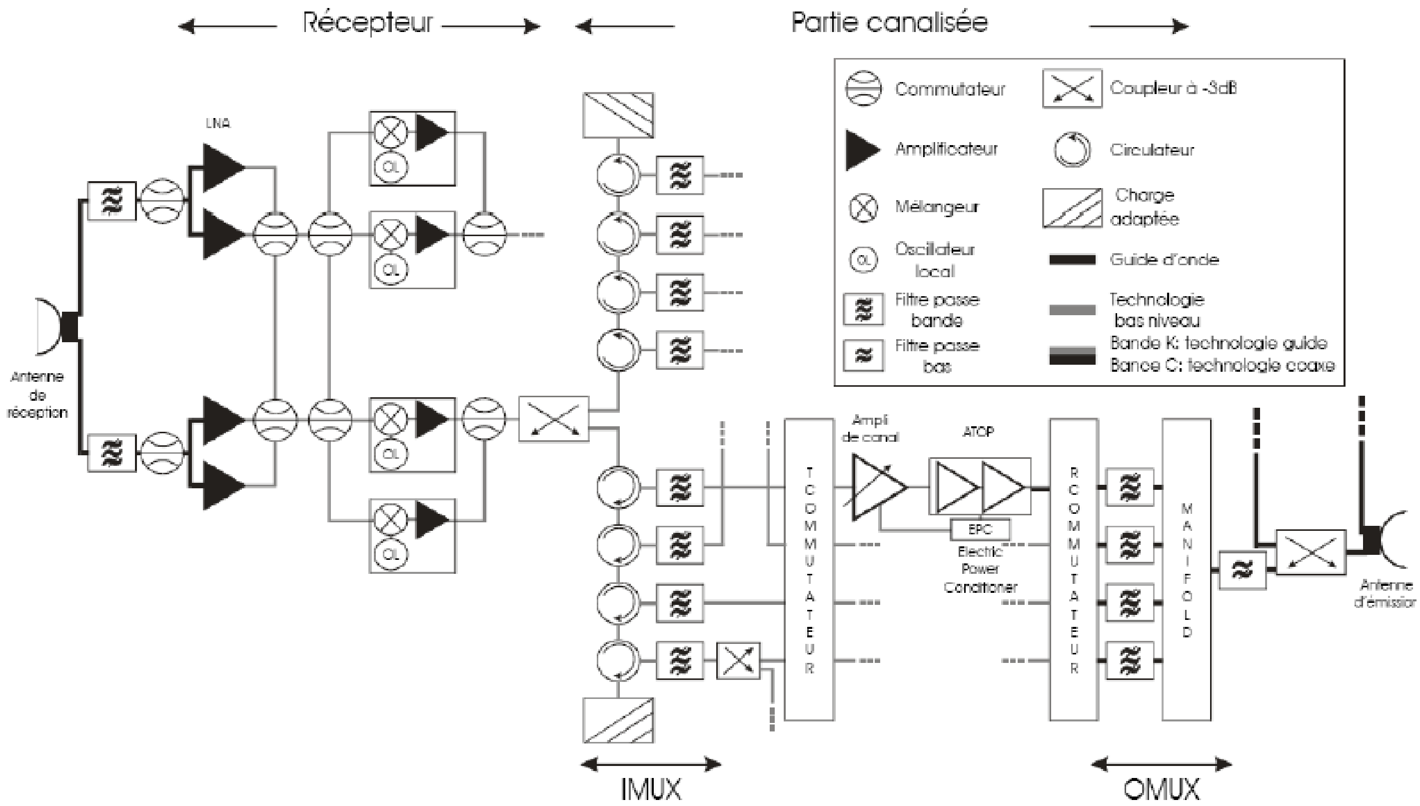
The simulations of resonators are made by using the ADS Momentum software which is a tool of electromagnetic simulation 2,5D adapted to planar structures.

II. MATERIALS AND METHODS

1) Microwaves filters used in the communications satellite payload

In the communications satellite payload, there are four types of filters.

The following figure (FIGURE 1) allows understanding better their role and their impact in such a system.



Their description is the following one:
Filter of reception: it is a wide filter bandages (Δf ~ 2 GHz), situated just after the receiving antenna, it selects all the signals to be treated. it thus eliminates the parasites frequencies and the noise off band. This filter has to have very low insertion losses not to degrade the noise factor of the receiver. The power throw-in at this level of the chain is very low [3].

IMUX filter: these filters are placed at the entrance of the different channels. They allow you to share the useful band into several channels or sub-bands whose width depends on the application (27, 36, 72 MHz, etc) .These filters must be highly selective and have a very small band to maximize the number of channels on the useful bandwidth.

An isolation of 50 dB between channels is generally required to avoid overlaps. In addition, the ripple in the band must be very low to avoid a parasitic amplitude modulation [4], [5], [6].

The power received by these filters is still low despite the amplification made by LNA placed upstream [7].

OMUX Filter: These filters are at the end of various channels canals, after the power amplifiers, so as to eliminate the frequencies parasites created by the latter. These filters are in very narrow band, with a good selectivity and a most constant possible time distribution group in the band. Their losses are very low not to decrease the strong powers which they are intended to handle [8], [9].

Broadcast filter: it is band-pass filter situated just before the transmitting antenna; it has for role to eliminate the harmonious and especially to limit the parasites in the band of reception to avoid the interferences [10], [11].

2) The technologies used to realize microwave filters

a. The volume filters

It is filters which allow to support strong powers and to have a very high quality factor (Q0 15000 - 25000 to 10 GHz), narrow bandwidth, and high selectivity … They are reasons why they are at present used in communications satellites in spite of the inconveniences which they present at the level of dimensions and weight.The volume filters are realized from generally cylindrical, rectangular metallic resonant cavities, or are built from guides of waves [12].

b. Planar filters

In the applications where the transport of signals of strong powers is not an essential parameter, the use of planar technologies is a solution to remedy the problems of dimensions and weight of the volume structures. planar filters are very interesting on these two points, but they are it also on the costs of realization which are more low, their good reproducibility and their opportunities of interconnection with the other circuits in particular the active circuits under forms of MMIC (Monolithic Microwave Integrated Circuit) [13].

Among the planar technologies, we can distinguish the microstrip technologies, coplanar, multilayer, each of them having her appropriate geometrical and electric specificities.

The major inconvenience of planar filters is their low quality factor quality. To improve this parameter, the supraconductrive technology is interesting because it allows making decrease the metallic losses. Furthermore, filters superconductive planar filters present a very high quality factors, which can reach 107 at 10 GHz and at T=77 K. Consequently, they could replace the volume filters used in IMUX in the payloads of satellites. Indeed, the powers received by these are very low and can be supported by a planar technology.

The use of high critical temperature superconductive materials allows, simultaneously to reduce the mass and the volume of devices while keeping excellent electric characteristics. However the first experimental results showed the appearance of a frequency gap with regard to the fixed template. It was shown that this variation is bound to the fact, that the substratum thickness used during the manufacturing is not perfectly identical to that fixed in the simulations during the conception [14]. To mitigate this problem, we are going to propose an adjustment

method of the central frequency of the resonators which allows to free itself from of external regulations systems.

c. Modification of resonators topologies

It is not possible to obtain planar superconductive filters at the end of the manufacturing process with frequencies identical to the compulsory templates. A regulation is inescapable when we wish to optimize their electric performances. The most common solution is the use of reticule adjusting screws inserted into cases [15]. This technique is mastered well this day but it limits the possibilities of industrialization because it is expensive at time. On the other hand, it increases in a significant way the insertion losses of the filter and the cases size so limiting their mechanical integration. Furthermore, the more the required performances are severe and the more the regulation is delicate.

The objective is to be able to adjust finely the answers of the superconductive filters without increasing its losses to satisfy the specifications.

The modification of the resonators and filters topologies [16] answers these requirements. Indeed, this method allows to change their frequency behavior and to envisage with confidence a regulation to obtain the wished results without introducing too many losses.

III. RESULTS AND DISCUSSIONS

Studies carried out on a linear monomode structure resonator of the IMUX filter, in the shape of open cross [14] (FIGURE 2), the length of which is equal more or less to the half-wavelength of working wave on a substratum of lanthanate of alumina ($LaAlO_3$) with a thickness of 500 µm, and a relative permittivity εr = 23,6 and a losses tangent $\tan\delta$ = 1*10-5 at 77 K and 4 GHz [17] showed that the not controllable parameters in the manufacturing processes (indistinctness of the engraving, the not uniformity of the thickness of the substratum) cause a gap of the centrale frequency and influence the quality factor (TABLE I)

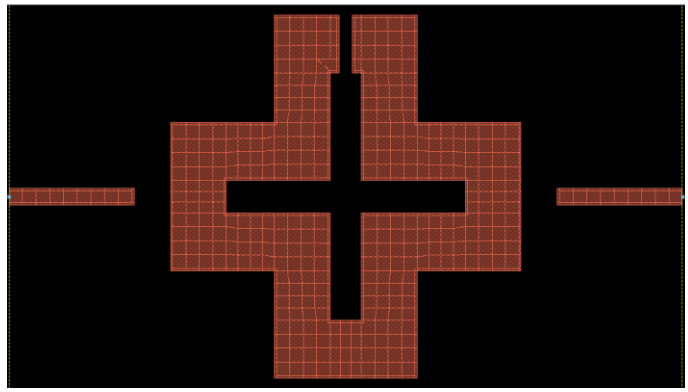


Fig. 2. Resonator in cross studied [14].

We simulated the structure presented in the figure (Fig.2) with the electromagnetic software 2,5 D Momentum, while emphasizing the relation between the variations of the substratum height Tsub , the echo's frequency F0, and the quality factor Q0.

We found the following results (TABLE I):

TABLE I

variations of F_0 and Q_0 for a resonator in open cross.

T_{sub}(µm)	F_0(GHz)	Q_0
486	3.99514	15930
495	4,00517	18723
496	4.00684	19040
497	4.00757	20982
506	4.01106	21019

These studies showed that one increasing the thickness of the substratum Tsub, we cause a gap to the right of echo's frequency, and an increase of the quality factor, and one decreasing Tsub, we cause a gap to the left of the echo's frequency, and a decrease of the quality factor.

To remedy the problem of the frequency gap due to the not uniformity of substratum thickness we are going to modify the topology of this resonator to have the minimum possible of variations in frequency.

By placing holes on the branch of the cross containing the opening, we were able to obtain a positive gap of the resonant frequency without degrading the quality factor (FIGURE 3).

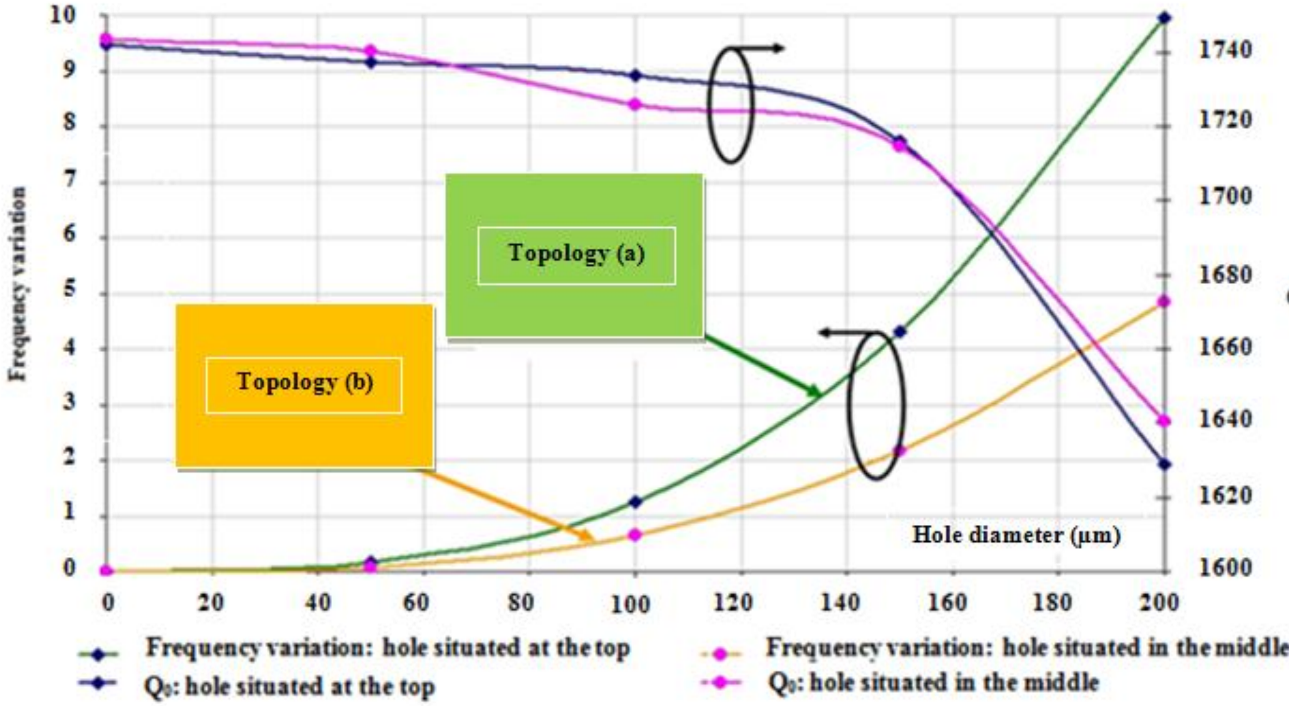


Fig. 3. variations of the frequency and the quality factor according to thewhole diameter in two different cases.

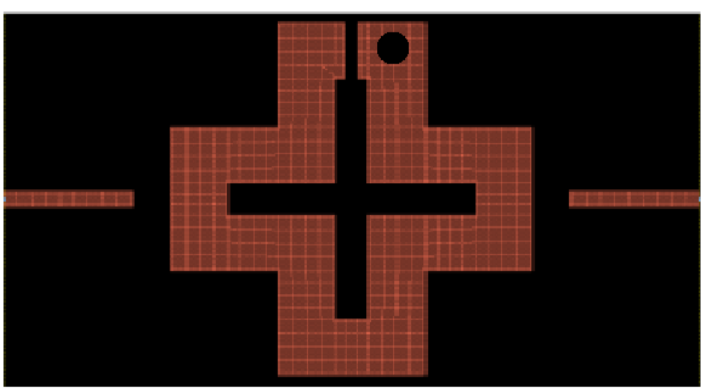


Fig. 4. Topology (a)

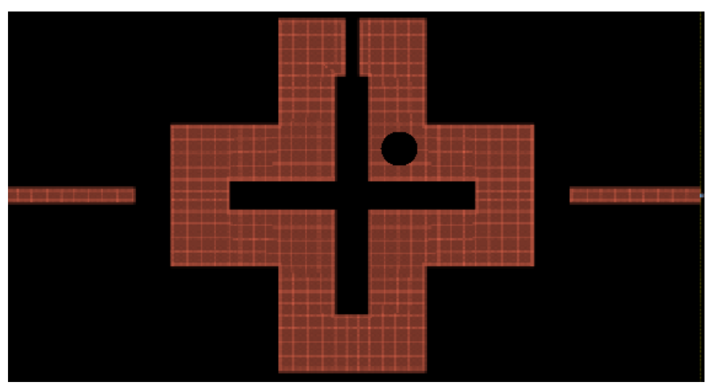


Fig. 5. Topology (b)

ndeed, the placed hole decreases the surface of the resonator in a capacitive zone, what is translated by a decrease of the capacity value and thus an increase of the resonator frequency [16].

We thus saw a process to increase the echo's frequency of a resonator. With this method, we obtain significant gaps which can be used to make vary the filter frequency. But it is also necessary to be able to compensate for the negative gaps in frequency. It is thus necessary to be interested in the negative variation of frequency.

To be able to obtain negative gaps in frequency, the hole is placed in a region where the current density is raised (FIGURE 4). This disturbance extends the way browsed by the current what is translated by an increase of the self value and thus a decrease of the echo's frequency of the resonator.

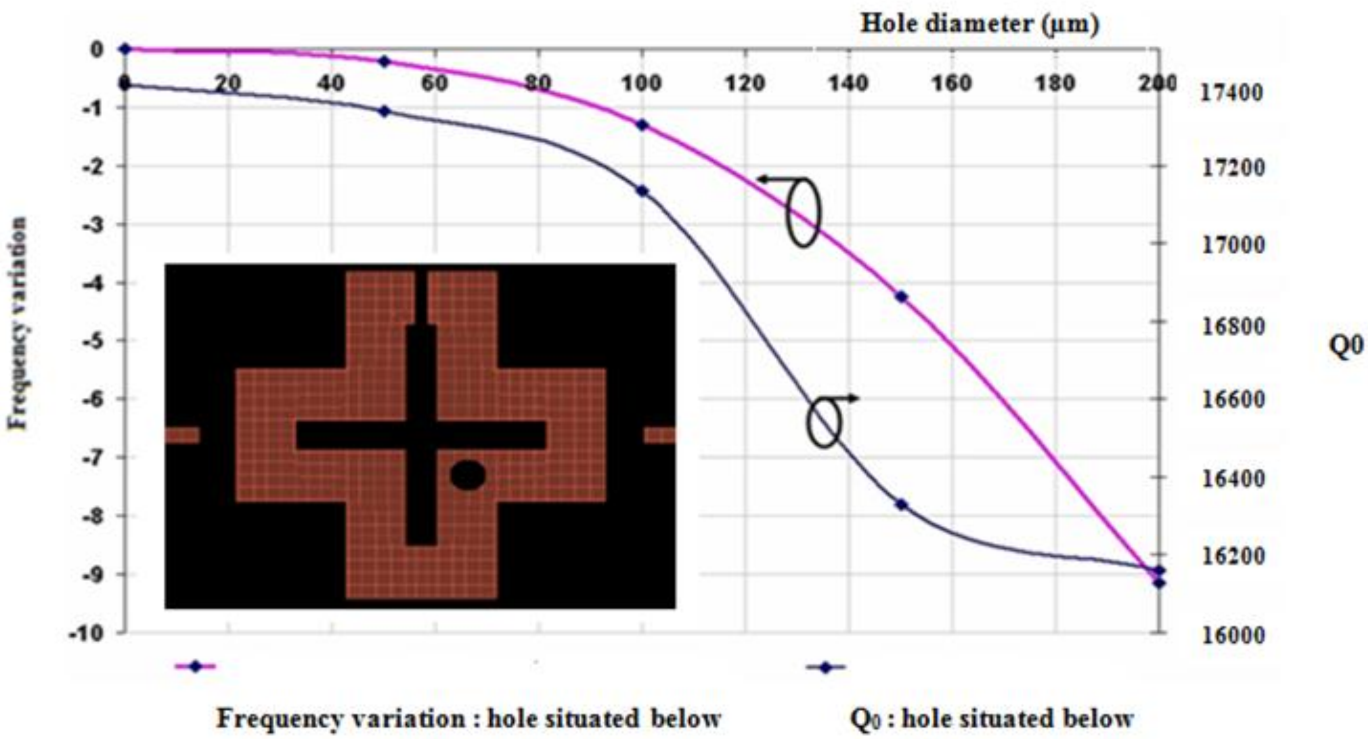


Fig. 6. variations of the frequency and the quality factor according to the hole diameter in the case of hole situated in the lower branch

We showed in simulation that topology modification of planar superconductive resonators allows to adjust the echo's frequency as well in a be positive way as negative, without degrading too much the insertion losses of the filter.

IV. CONCLUSION

The planar superconductive technology allows to reduce the mass and the volume of devices and keeping excellent electric characteristics.

The modification of the topology of planar superconductive resonators dedicated for the realization of microwaves filters used in the communications satellites payload present the advantage to be little sensitive to the variations of substratum height caused by manufacturing hazards , and allow to avoid regulation systems which increase the dimensions and the weight of filters [18].

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