A NEW DIELECTRIC LOADED CAVITY FOR HIGH POWER MICROWAVE FILTERING

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ABSTRACT

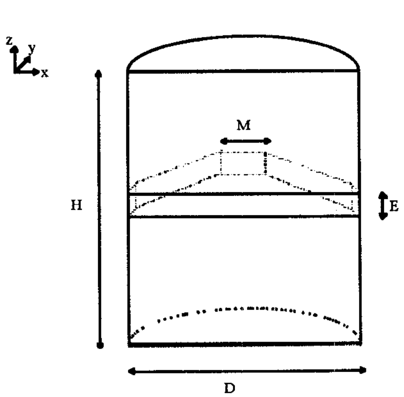
This paper is devoted to high electrical performances filter realization for space application. A new form of new dielectric plate resonator shielded in a metallic cavity is presented. It is suitable for high power applications and presents the advantage to be easily manufactured. The finite element method is applied to design the resonators. Experimental 4 poles quasi elliptic filters have been realized to prove the efficiency of our new technique.

INTRODUCTION

The space communications require high electrical performances and limited sizes filters. During the last years, dual mode dielectric resonators (DR) devices have been developped. These structures are compact and present a high unloaded quality factor Q_0 [1]. So the dissipated power in the filter is small, but the resulting thermal dissipation resultant remains critical for space applications.

A solution consists in positionning the high permittivity DR in contact with the metallic cavity. Nevertheless, the metallic losses of the device may then increase dramatically [2].

The topology we propose in this paper has been developped to provide a good compromise between the Q_0 level and the thermal dissipation.



- figure 1 : an half of the cylindrical structure -

Two structures composed of parallelepipedic dielectric plates inserted in cylindrical (figure 1) and parallelepipedic (figure 2) cavities have been examined in the first part. The three dimensional Finite Element Method (F.E.M.) [3] is applied to characterize the different resonant modes of these structures. The theoretical results are compared to experimental ones.

In a second part, one of the mode is chosen for its high Q_0; the dimensions and topology of the device are optimized to obtain a good frequency isolation of this mode. We have then compared the performances of our new structures to the performances of classical ones. In the last part, an experimental realization of a 8 pole filter is presented.

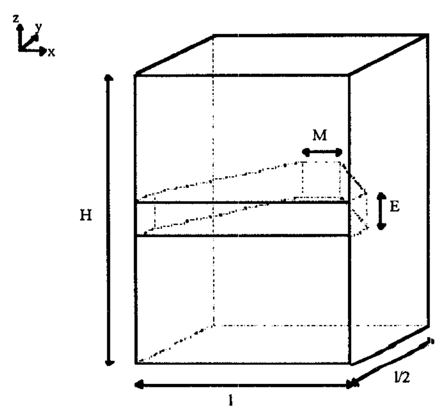
I - RESONATOR CHARACTERISTICS

The resonator is composed of a parallelepipedic dielectric plate (thickness E) shielded in a cylindrical metallic cavity (diameter D, height H) (figure 1) or in a parallelepipedic one (dimensions 1 x 1 x H) (figure 2). The corners of the dielectric plate have been cut to provide a good contact between the resonator and the cavity. In this paper, we name σ the conductivity of the metallic walls, ε_r the relative dielectric permittivity and $\tan\delta$ the dielectric loss tangent (in this part $\sigma = 5{,}6 \cdot 10^7\ S.m^{-1}$, $\varepsilon_r = 34$, $f(\tan\delta)^{-1} = 39\ 000$).

The F.E.M. has been applied to characterize the first resonant modes of these structures. For each mode, we have computed :

- the resonant frequency f_0
- the unloaded quality factor Q_0 given by :

$$\frac{1}{Q_0} = \frac{1}{Q_m} + \frac{1}{Q_d} \qquad [2]$$



- figure 2 : an half of the parallelepipedic structure -

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with :

◊ Q_m : the metallic quality factor

◊ Q_d : the dielectric quality factor

The electrical performances of the two cavity topologies are similar. So we present, in the first part, only the results relative to the cylindrical one.

At first, we have observed that all the first modes are transverse electric (TE) modes and two mode nomenclatures have been determined :

- In the first one, we have only considered the range n of the mode on the frequency axis. The modes are noticed TE_n .
- In the second one, we have determined three subscripts n,m,p related to the field variations in the axis directions. This solution can't be applied for one of the mode.

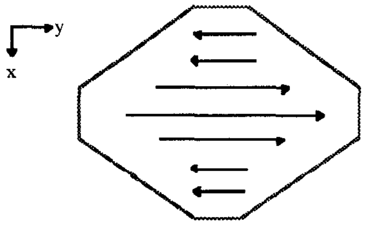
Theoretical results are given in the table I-1. Measurements have been performed to validate these computations.

For filtering applications, it's interesting to select the modes which present two polarisations at the same frequency, to reduce the device size. In the following parts, we will choose to develop computations and measurements on the TE_{101} and TE_{211} modes. Schematic representations of the electrical field lines of these modes are presented on figure 3 and figure 4. The TE_{211} seems to be very interesting because of its higher Q_0. But as the electromagnetic energy is confined in the dielectric resonator, this mode will be difficult to couple. So, for moderate bandwidth application, we will use the TE_{101} mode and for very narrow band filters application, we will select the TE_{211} mode.

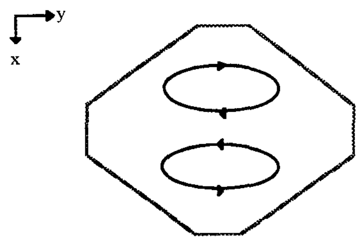
II - OPTIMIZATION OF THE TE_{211} MODE ISOLATION

In this part, a dielectric plate (E=4 mm, M=1,46 mm, ε_r=36, $f(\tan\delta)^{-1}$=40 000) is excited on the TE_{211} mode in a parallelepipedic cavity (H=20 mm, l=24,78 mm, $\sigma=1{,}5.10^7$ $S.m^{-1}$). The table II-1 shows that this mode is not correctly isolated particularly on the upper band of frequency as the TE_{221} mode may also be excited.

Our purpose is here to modify the dielectric plate resonator topology to increase the TE_{221} resonant mode frequency without modifying the electrical performances of the TE_{211} mode. Our solution is presented figure 5. Considering the electromagnetic field repartition of these two modes, two slots have been made along each resonator side. The performances of this resonator are presented in table II-2. We can notice that an isolation of 800 Mhz has been obtained. Moroever, the electrical performances of the TE_{211} mode stay unchanged.



- *figure 3* : electromagnetic field lines in the half-height section -



- *figure 4* : electromagnetic field lines in the half-height section -

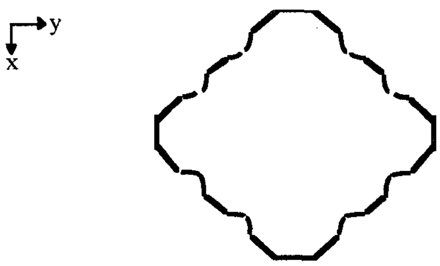
Mode	TE_1 TE_{101}	TE_2 TE_{111}	TE_3 TE ?	TE_4 TE_{211}	TE_5 TE_{221}
Polarization number	2	1	1	2	1
f (GHz) theory	2,113	2,575	2,66	3,335	3,5
f (GHz) measure	2,119	2,571	2,674	3,336	*
Q_d (theory)	20720	15310	15710	11840	11910
Q_m (theory)	11220	27460	9600	27290	147310
Q_0 (theory)	7280	9830	5960	8260	11020
Q_0 (measure)	7230	*	6070	9700	*

* : non coupled mode
E = 8 mm ; M = 2 mm ; H = 28 mm ; D = 34 mm

- Tableau I-1 -

Mode	f_0 (Ghz)	Q_d	Q_m	Q_0
TE_{111}	3,756	10 910	17 820	6 770
TE_{211}	4,83	8 500	21 280	6 070
TE_{221}	5,281	8 120	81 490	7 380

- Tableau II-1 -



- *figure 5* : a section of the new resonator -

Mode	f_0 (Ghz)	Q_d	Q_m	Q_0
TE_{111}	3,946	/	/	/
TE_{211}	5,204	7 930	31 930	6 350
TE_{221}	6,015	/	/	/

- Tableau II-2 -

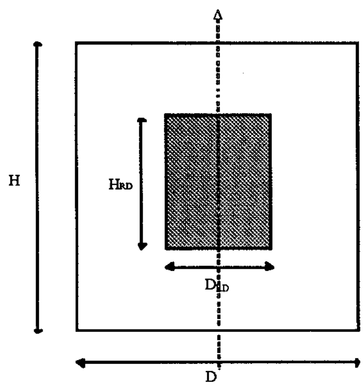
III - COMPARISON TO CLASSICAL STRUCTURES PERFORMANCES

To evaluate the electrical performances of our dielectric plate structure excited on the TE_{211} mode, we analyzed two classical ones :

- In the first one, the DR is excited on its first hybrid mode. It is centrered in a metallic cylindrical cavity (figure 6) [1]. The DR is not in contact with the metallic walls.
- The second is composed of a cylindrical dielectric waveguide excited on its first TM mode and short circuited in a metallic cavity (figure 7). The resonator is suitable for high power applications.

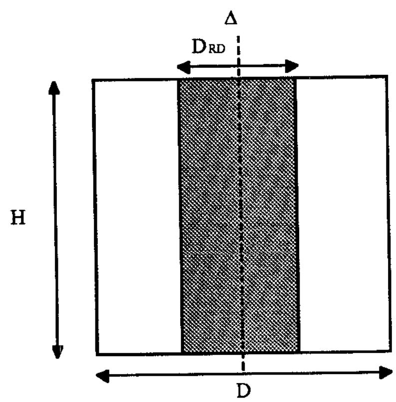
We optimize the dimensions of the three structures to obtain a same resonant frequency in the same cavity size (H=20 mm, D/2=13,98 mm). The Q factors are given in the table III-1.

We can notice that the classical dual mode DR (figure 6) presents a higher Q_0 factor than our new solution. But the metallic contacts with the dielectric plate which explain this difference, is fundamental for an efficient thermal dissipation. The Q_0 factor of the structure shown figure 7 is dramatically limited by the z axis metallic contacts.



Δ : rotation axis.

- figure 6 -



Δ : rotation axis.

- figure 7 -

	Q_d	Q_m	Q_0
Dielectric plate : 1	8 500	21 280	6 070
Cylindrical resonator without metallic contacts : 2	9 790	63 350	8 480
Cylindrical resonator with metallic contacts : 3	17 380	7 000	4 990

1 : E = 4 mm, M = 1,46 mm   2 : D_{RD} = 15,63 mm, H_{RD} = 5,21 mm   3 : D_{RD} = 3,4 mm

- Tableau III-1 -

IV - MULTIMODAL FILTERS REALIZATIONS

We have developed and measured a quasi-elliptic 8 pole filter using the dual mode dielectric plates resonators, excited on the TE_{101} mode.

The coupling matrix [1] of this filter is given in table IV-1. The group delay is corrected to be constant in the bandpass. Each of the 4 dielectric plates is shielded in a parallelepipedic metallic cavity. These cavity are coupled by cross or rectangular iron irises, in accordance with the coupling matrix requirements. One of the polarization of the first cavity, and the parallel one in the fourth cavity are coupled by two coaxial probes antennas placed near a dielectric plate corner, parallel to the dielectric plate. Three metallic screws [1] have been integrated in each cavity :

- One placed at π/4 from the probe axis to couple the two polarizations of the resonator mode.
- Two are placed in the polarizations axis to adjust the frequencies of the shielded resonators.

The reflexion and transmission responses of the filter are presented on figure 8a and 8b. The insertion losses at the resonant frequency are equal to 1,1 dB. The reflexion coefficient is less than -20 dB in the passband. The figure 9 presents the equalized delay group.

The dielectric plate resonator technique is then suitable for narrow bandwidth to moderate bandwidth filtering.

f_0 = 3,93 Ghz   Δf = 55 Mhz
$R_1 = R_2$ = 1,0783

kj	1	2	3	4	5	6	7	8
1	0	-0,82	0	-0,267	0	0	0	0
2		0	0,77	0	0	0	0	0
3			0	0,5	0	0	0	0
4				0	-0,559	0	0	0
5					0	0,56	0	0,264
6						0	0,427	0
7							0	0,821
8								0

- Table IV-1 -

CONCLUSION

The dielectric plate resonators adds the advantages of high electrical performances and of an efficient thermal dissipation, as the dielectric resonator is placed in contact with the metallic cavity. Moroever, the filter developed using this technology are not difficult to manufacture ; the geometry of the resonator is simple, no dielectric support is required.

So this solution is suitable for space applications, in particular for an integration in output multiplexers.

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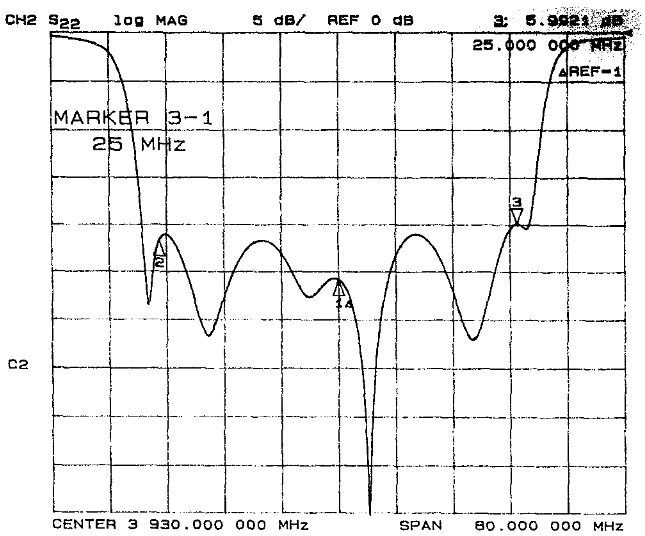
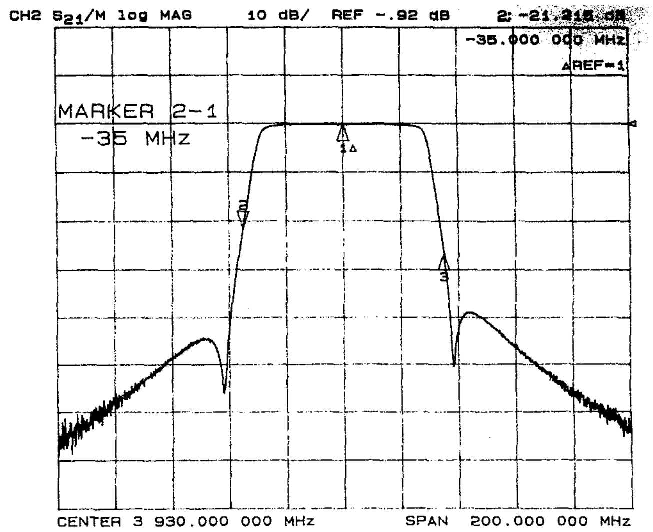
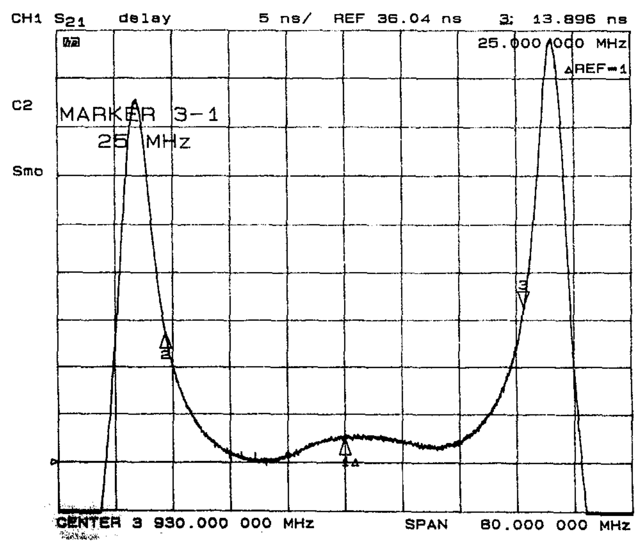


- *figure 8a* : reflexion coefficient of the filter -



- *figure 8b* : transmission coefficient of the filter -



- *figure 9* : group delay of the filter -