A HIGH Q FACTOR MICROWAVE CAVITY

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ABSTRACT

A solution is proposed, using interfaces between low and high permittivity dielectric media to reduce considerably losses in classical metallic cavities, and so to obtain high performances microwave filters.

An experimental confirmation of theoretical results is demonstrated by using two dielectric plates to increase the unloaded quality factor of a traditionnal metallic circular cavity excited on the TE_{011} and TE_{111} modes.

INTRODUCTION

Narrow band-pass filters, or high power one's, need the development of high unloaded quality factor resonators. Empty metallic cavities, or cavities loaded with dielectric resonators (DR) are commonly used. However, above 20 GHz, DR become too small and empty metallic cavities may need a significant increase of their unloaded quality factor.

In this paper, we try to demonstrate that using dielectric interfaces instead of metallic one's allows to decrease significantly losses, always with keeping dimensions nearest classical devices one's.

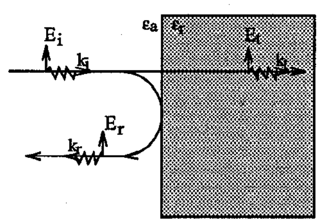
THEORETICAL ANALYSIS

a) - Principle

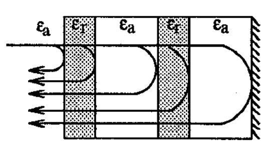
In this paper, our aim is to decrease metallic losses of resonant cavities at microwave frequencies. We will show that with introducing dielectric plates, we can increase the unloaded quality factor of a metallic empty cavity. We may reach this aim by two ways. Consider an incident electromagnetic plane wave falling on a dielectric interface between two different dielectric constant (ε_a and ε_r) media (figure 1). When ε_r is larger than ε_a, the amplitude of the reflection coefficient ρ tends toward -1 [1], which is a metallic short circuit condition. The other way to obtain -1 reflection coefficient is tuned to account in a well-known device at optical frequencies. The Mirror Bragg Reflectors (M.B.R.), which include an infinity of juxtaposed λ/4 dielectric plates (figure 2).

For practical reasons, it is convenient to use a finite sommation of dielectric interfaces, closed by a metal ending (figure 3). It will decrease the metallic losses of the device because of a lower incident wave amplitude on the terminal metallic plate.

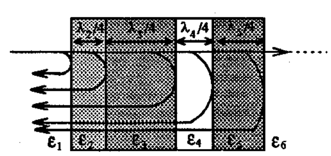
- figure 1 -



reflection and transmission of a normal incident plane wave



Multilayered structure
- figure 3 -



Mirrored Bragg Reflectors
- figure 2 -

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b) - Choice of a dielectric media

We may choose dielectric media by two ways :

1) - $\varepsilon_r/\varepsilon_a$ ratio tends toward infinity : the stored energy in ε_r medium is very low, and so the ε_r material could support some losses. This high $\varepsilon_r/\varepsilon_a$ ratio allows to use the two structures previously introduce.

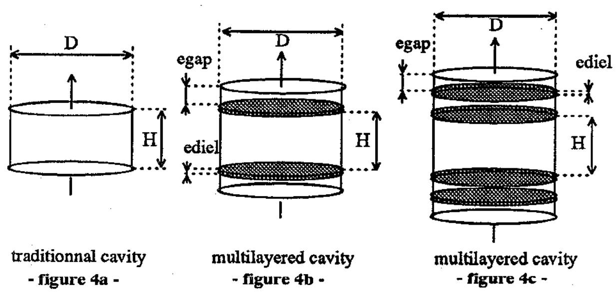
2) - $\varepsilon_r/\varepsilon_a$ ratio is low : the stored energy can't be neglected and the material has to be loss less. In this case, we may only use the multilayered structure, we will choose this second solution for our application [2] [3].

c) - Field appearance

- Mode TE_{011} :

We are first interested on the TE_{011} mode. Four dielectric media (figure 4c) are placed to "protect" upper and lower faces of the conventionnal metallic cavity (figure 4a). Because we want to compare the two structures, we have interest on H_z field appearance of this mode (figure 5a, figure 5c).

We should notice that the H_z field appearance is the same for these two cases if we look for this field component in the empty part of height H between the dielectric interfaces (figure 4c).

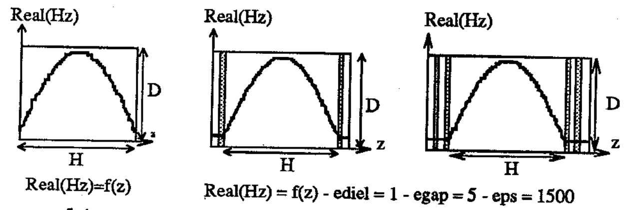


- figure 4a - - figure 4b - - figure 4c -

- Mode TE_{111} :

We put only one dielectric plate on bothsides of the traditionnal cavity (figure 4b). Then we perform the previous study concerning the H_z field on the TE_{111} mode, one hand on the dielectric loaded cavity (figure 5b) and in the other hand the traditionnal empty cavity (figure 5a).

The presence of the dielectric plates doesn't modify the field distribution of the TE_{111} mode. So we could keep traditionnal nomenclature for cavities to descript multilayered cavity modes.

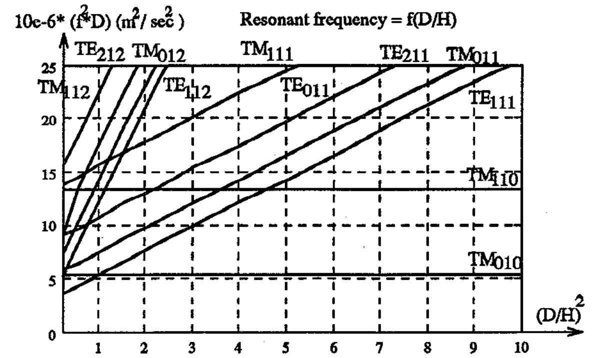


- figure 5 -

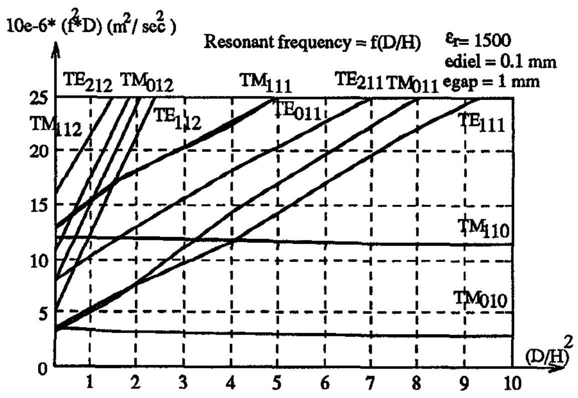
d) - Modes map

In order to observ the multilayered cavity behaviour, we have simulated the evolution of resonant frequencies of several modes, as a function of D/H ratio, for a traditionnal cavity (6a) and a multilayered one (6b).

Notice that empty cavity modes map is globaly conserved. We may then use multilayered cavities for complex applications as multi-mode resonant cavity filters for example.



- figure 6a -



- figure 6b/ -

e) - Q_0 optimization

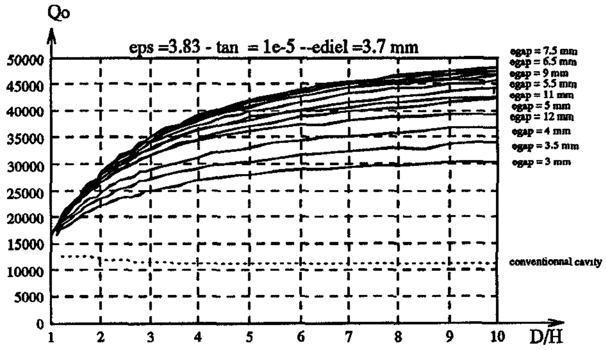
A dielectric medium (ε_r=3,83, $\tan\delta=10^{-5}$) has been arbitrarly choosen. We have tried then to optimize the unloaded quality factor (Q_0) of the structures 4a, 4b and 4c. Therefore we have plotted the evolution of Q_0 as a function of D/H ratio and for different air gap dimensions of the multilayered cavity.

- Mode TE_{011} :

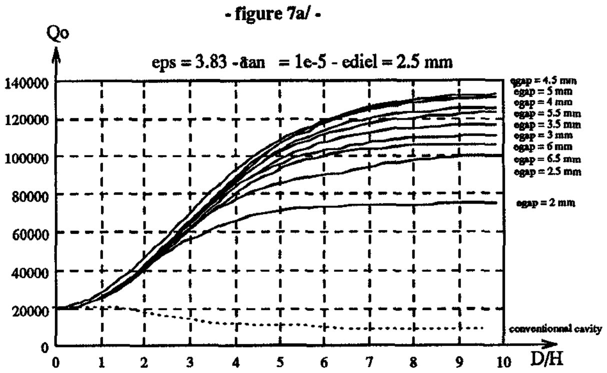
The figure 7b shows that we obtain a 10 factor between classical and multilayered structures Q_0.

- Mode TE_{111} :

The figure 7a shows that we obtain a 5 factor between classical and multilayered structures Q_0. We also notice a maximum efficiency of our device for high D/H ratio and so a higher rate of "protected" metallic surfaces.



- figure 7a/ -



- figure 7b/ -

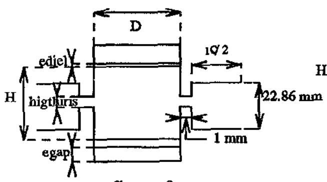
f) - Excitation of TE_{111} mode

Let us consider that the cavity is on it optimum dimensions. Then we study the behaviour of the cavity with or without dielectric plates when the structure is excited on one of the two polarisations of the TE_{111} mode by rectangular metallic waveguides through rectangular iris (figures 8a-8b).

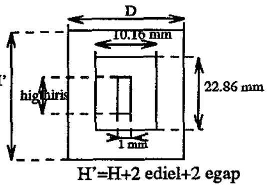
These computations are performed using the forced oscillations finite element method [4].

The figure 9 shows the evolution of $|S_{21}|$ as the function of the frequency of the traditionnal cavity and of the multilayered cavity.

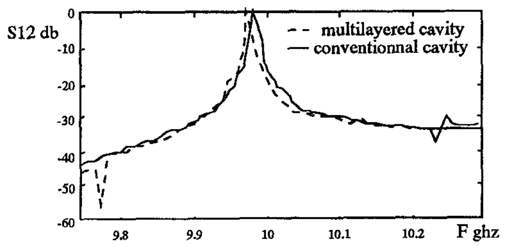
We can conclude that the isolation of the TE_{111} mode of the multilayered cavity can be compared to the empty cavity one.



-figure 8a-



-figure 8b/-



-figure 9-

EXPERIMENTAL RESULTS

We have measured the two structures using only one dielectric layer. The dielectric constant (ε_r) is nearest 36 and its frequency-quality factor product (fQ) is around 40 000. Results are given in table 1. Notice that we obtain a gain of 70 % between Q_0 devices, by the fact of using high D/H ratio.

	4a structure		4b structure	
	simulated	measured	simulated	measured
f (Ghz)	13.25	13.20	13.25	13.22
Q	15010	15120	26000	26200

- table 1 -

CONCLUSION

The introduction of dielectric interfaces in substitution for metallic ones has shown it efficiency. The resonant energy is keeping in the air and an increase of Q_0 nearest 70 % has been measured. Theoretical investigations show that the device can be optimized including more than two dielectric media in the cavity, measurements are in process. So, by using properties of this structure, we could consider that high Q factor cavities may be used to built multimode high performance multilayered cavities to replace favorably traditionnal one's.

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