A NEW FINITE ELEMENT METHOD FORMULATION APPLIED TO D.R. MICROWAVE FILTER DESIGN

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ABSTRACT

A new 3D finite element formulation using NEDELEC polynomials [1] has been developped to compute electromagnetic and electrical parameters of microwave devices ; to prove the advantages of this new formulation which does not generate any non physical responses, we have applied it to evaluate resonant frequencies f_0, unloaded Q_0 dielectric resonator (D.R.) used in the design of L band microwave filters.

INTRODUCTION

In mobile communications systems acting in L frequency band, high power band pass filter are required.

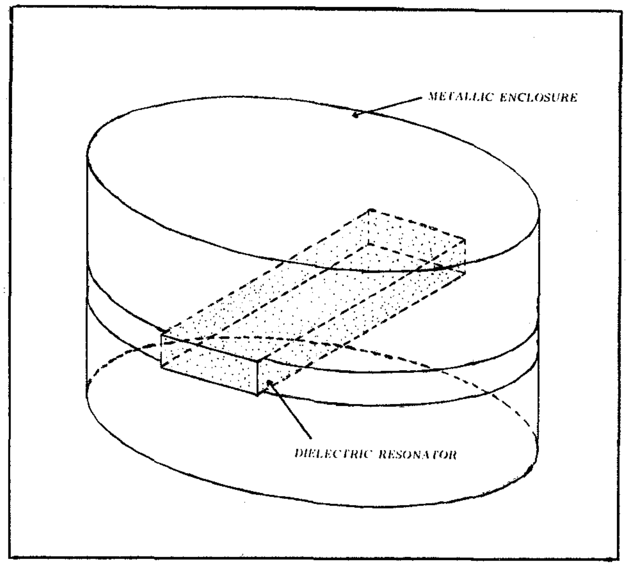
Some solutions have been already proposed to realize such type of filters ; in particular quarter $TE_{01\delta}$ D.R. modes [2] or TM_{010} cylindrical D.R. modes [3].

We propose here to use shorted circuit rectangular D.R. excited on their TM_{110} modes and inserted into cylindrical metallic enclosures (figure 1) so that the axis of the D.R. and that of the metallic waveguide were perpendicular.

This type of structure which uses rectangular resonators permits to obtain :

- a better unloaded Q_0 factor than quarter D.R.
- a higher inter-stage coupling coefficients for a reduced distance between adjacent D.R.
- a good dissipation of temperature

The electromagnetic (f_0 and Q_0) and electrical (coupling coefficients) parameters of such a structure have been computed by using the 3D finite element method (F.E.M.) in which first order NEDELEC polynomials have been introduced.



- Figure 1 -
Configuration of short circuited D.R.

MIXED ELEMENTS

The exact evaluation of resonant frequencies of a shielded dielectric resonator cannot be done by a straight forward analytic method, but only by a numerical solution implemented on a computer usually a large mainframe computer.

Numerical computations of E.M. field by F.E.M. may require to solve equation (1) in which the second term vanishes for free source systems.

$$\iiint_V \frac{1}{p} \{\vec{\nabla} x \vec{\psi}\}\{\vec{\nabla} x \vec{\varphi}\}\, dV - K^2{}_0\, q \iiint_V \vec{\psi}.\vec{\varphi} = 0 \qquad (1)$$

$$K^2{}_0 = \omega^2\, \varepsilon_0\, \mu_0$$

where V : volume of the structure
ω : pulsation

For magnetic $\vec{H}$ field formulation

$\vec{\psi} = \vec{H}$

$\vec{\phi}$: *test function normal to magnetic surfaces*

$p = \varepsilon_r \rightarrow$ *permittivity*

$q = \mu_r \rightarrow$ *permeability*

For electric $\vec{E}$ field formulation

$\vec{\psi} = \vec{E}$

$\vec{\phi}$: *test function normal to electric surfaces*

$p = \mu_r$ *and* $q = \varepsilon_r$

The F.E.M. requires the use of Lagrange polynomials, but in this case the F.E.M. solution contains many non physical spurious modes, since the divergence equations (div$\vec{H}$ in H formulation, div$\vec{E}$ in E formulation) are not satisfied.

The numerical computation of equation (1) by the finite element method may require new types of elements whose degrees of freedom are not field values at mesh nodes, but other field related quantities like e.g. circulation along edges at the mesh. These special elements, as described by NEDELEC [1], are called "mixed" elements. Using these new elements, the F.E.M. solutions are interently free of non physical modes.

In table 1 we give the frequencies obtained between 1.6 and 1.7 GHz using both E and H formulation. With Lagrange formulation we note the presence of many spurious modes. These one's can be distinguished from the real modes of the structure by using two means : one of which consists to introduce the penalty factor A=divH, the other to draw the E.M. field lines of each mode.

	2nd order Lagrange 1479 modes 4437 degrees of freedom	1rst order mixed elements 2242 modes=degrees of freedom	
Formulation	H	H	E
Spurious modes GHz	1.6588	-	-
Mode TM_{110} GHz	1.6993	1.4661	1.5670

- Table 1 -

The advantages of this new formulation over the old one which used Lagrange polynomials are:

-the suppression of spurious modes

-the reduction of computing time

-the use of H formulation or E formulation

-the knowledge of the electric field from the E formulation

ELECTROMAGNETIC PARAMETERS

We first evaluate resonant frequency, Q_0 factors and electric and magnetic field of parallelepipedic D.R. acting on their TM_{110} mode. The following dimensions have been choosen for this calculation :

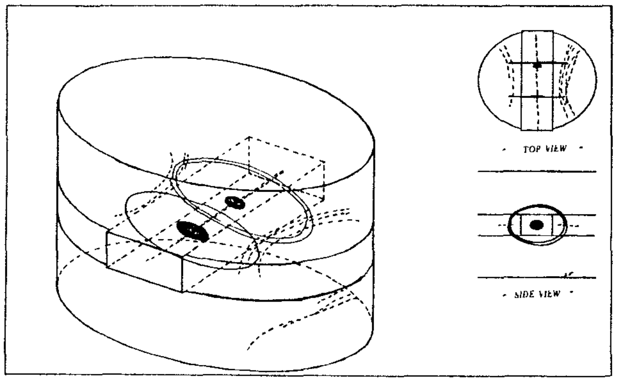
D.R.=(10.5x10.5x45)mm

Diameter of cavity=44 mm

Height of cavity=75 mm

Calculated (F.E.M.) and measured frequencies are respectively 1.527 GHz and 1.5 GHz. For a conductivity σ=1.57 10^7 mho/m, Q_0 value is 5930.

As an example of the results obtained with 3D F.E.M. we present in figure 2, the electric and magnetic field of TM_{110} rectangular D.R. mode.



- Figure 2 -

TM_{110} Rectangular D.R. mode

—— magnetic field lines

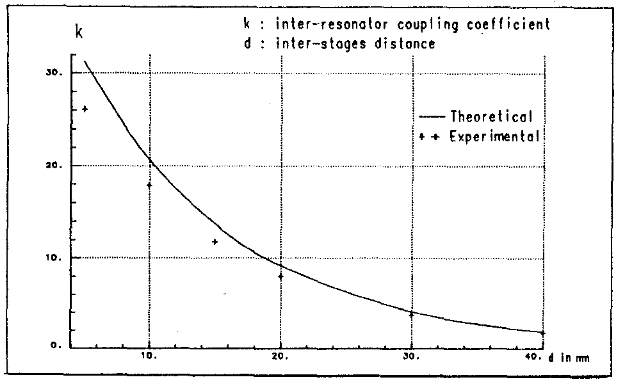
- - - electric field lines

ELECTRICAL PARAMETERS

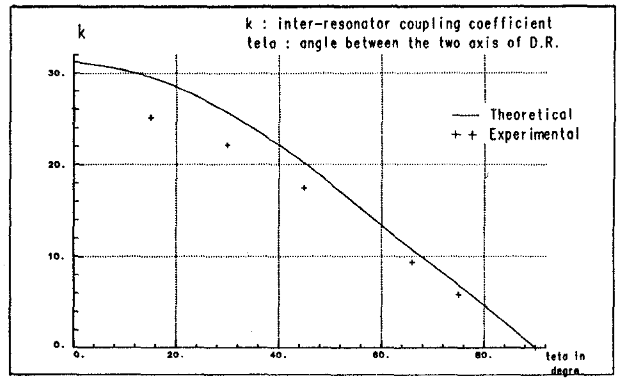
The theoretical and experimental coupling coefficients between two D.R. as a function of the interstages distance are shown in figure 3. Using the symmetry of the structure the coupling coefficient k [4] is accurately calculated from the following relation (1) :

$$k = \frac{f_e^2 - f_m^2}{f_e^2 + f_m^2} \qquad (2)$$

in which f_e and f_m are the resonant frequencies corresponding respectively to even and odd modes.

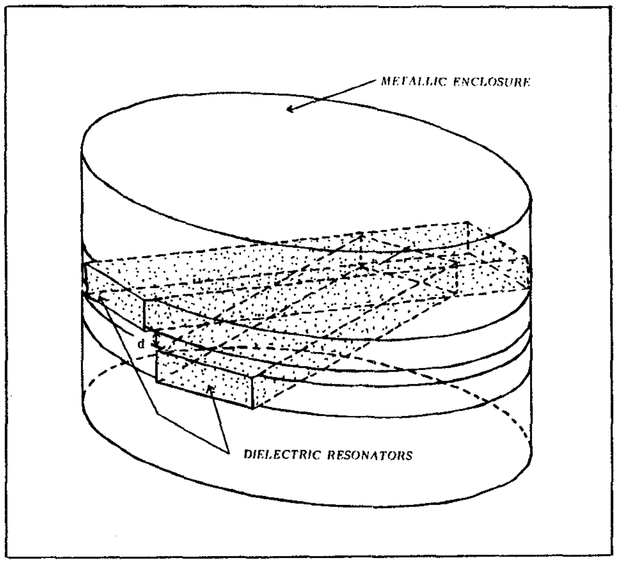


*- **Figure** 3 -*
Inter-resonator coupling



*- **Figure** 5 -*
Inter-resonator coupling

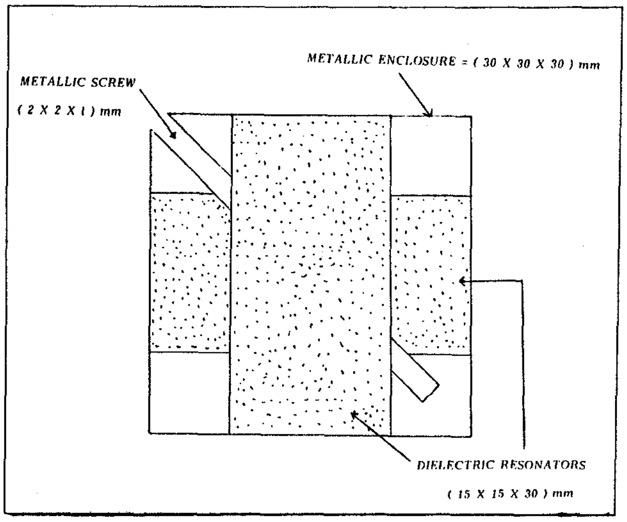
This configuration in which D.R. and waveguide axis are perpendicular permits also to obtain the coupling coefficient variation as a function as the angle θ between two D.R. (figure 4). With such a configuration we can have a small coupling coefficient value for a small distance between two D.R. according to angle θ .



*- **Figure** 4 -*
Coupled resonators in circular waveguide

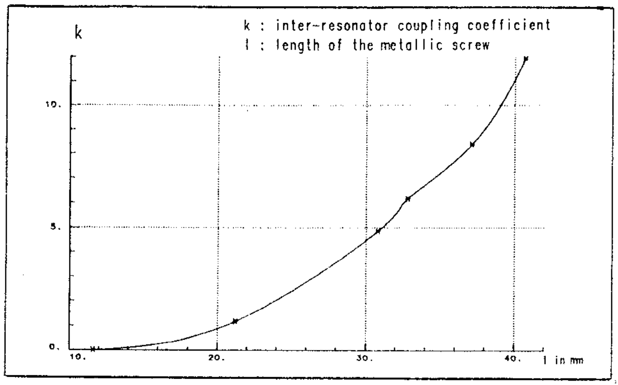
In figure 5, we give comparison between calculated and measured coupling coefficients versus the angle θ for an inter-stage d distance equal 5 mm. Let be noted that in this case, we cannot use the symmetry of the structure for the coupling coefficient computation and so it is necessary to take into account the whole structure.

When θ =90°, the coupling coefficient is equal to zero. However, two orthogonal D.R. can be coupled by using a metallic tuning screw (figure 6) which destroys the orthogonality between the two TM_{110} modes excited in each resonator.



*- **Figure** 6 -*
Structure with its metallic screw configuration of the right angle

We can note also that this configuration permits to obtain negative coupling coefficient value, result which is useful to realize elliptic band-pass filters [5], [6] (figure 7).



- Figure 7 -
Coupling with a metallic screw

CONCLUSION

In this paper, we have applied a new 3D finite element formulation to compute electromagnetic and electrical parameters of microwave D.R. devices.

The comparison carried out between theoretical and experimental results shows the use fullness of this formulation.

More accurate results should be obtained by using second degree NEDELEC polynomials.

These results should lead to realization of compact high power band-pass elliptic filter which using TM_{110} parallelepipedic D.R. modes, have low loss and less spurious characteristics.

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