DIRECT COUPLING CONFIGURATION BETWEEN $TE_{01\delta}$ DIELECTRIC RESONATOR MODES APPLICATION TO THE DESIGN OF AN ELLIPTIC MICROWAVE FILTER

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ABSTRACT

A technic to realize direct coupling between Dielectric Resonators (DRs) acting on their dipolar mode is presented. This new geometric configuration eliminates the need of transmission lines, metallic screws or iris generaly employed in microwave filters to obtain negative coupling coefficients. An experimental 4 poles elliptic filter has been constructed to verify the theory.

I - INTRODUCTION

A large majority of microwave filters are at present time realized with low loss temperature stable empty metallic cavities. However, dielectric material characteristics development and satellite communications requirements have orientate users to DRs technics. Miniaturization of these components, their reasonable price combine to their high performances garantee their integration in several applications.

To increase performances of microwave filters, a large number of DRs are coupled. Several configurations are possible depending on the type of the mode which is considered in the DR.

On the $TE_{01\delta}$ mode, DRs can be coupled in a direct way when they are placed side by side or superimposed. But to achieve some response functions, as elliptic ones where a negative coupling is required, or to reduce the distance between DRs, iris or quater wavelength transmission lines are used [1].

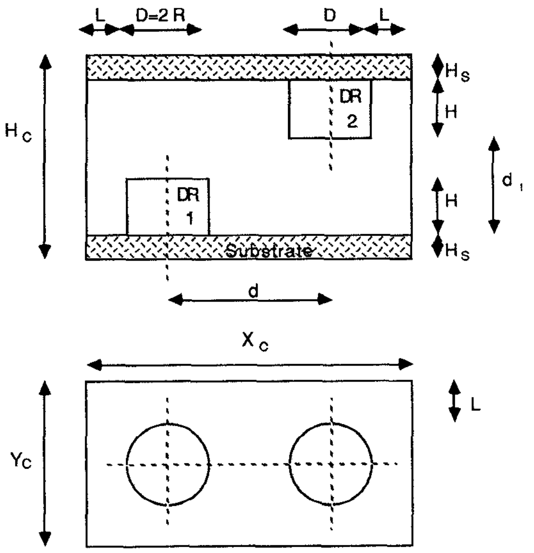
Another solution consists to use the HEM DR mode [2]. In this case, an adjustement screw allows to couple the two orthogonal polarisations of this mode, two adjacent DRs can be coupled directly or by means of an iris.

Those added metallic components -irises, screws, transmission lines- may generate spurious modes, increase losses in the structure, as conduction currents appear on the perturbations, and increase the cost of the product, as a high degree of precision is required on dimensions to obtain the desired exacting filter response.

We propose a new configuration using staggered DRs modes in which no annex components will be required to carry out filter response functions. In addition, this configuration will be interesting when mass and volume devices are critical. A 4 poles elliptic filter realization is presented.

II - ANALYSIS

The geometry of the structure under consideration is given in fig. 1. The cylindrical DRs of radius R and height H are placed on microstripline substrates of thickness H_S in a parallelepipedic metallic enclosure of basis dimensions X_c x Y_c and lenght H_c. The walls of the structure are at a distance L from the DRs ends. The DRs and substrates permittivities are respectively ε_r and ε_s. The distance separing the two staggered DRs axis is d, the distance between lower faces of the DRs is called d_i. We can note that this configuration garantees the same losses for the two DRs.



Staggered DRs shielded in a parallelepipedic enclosure
- Figure 1 -

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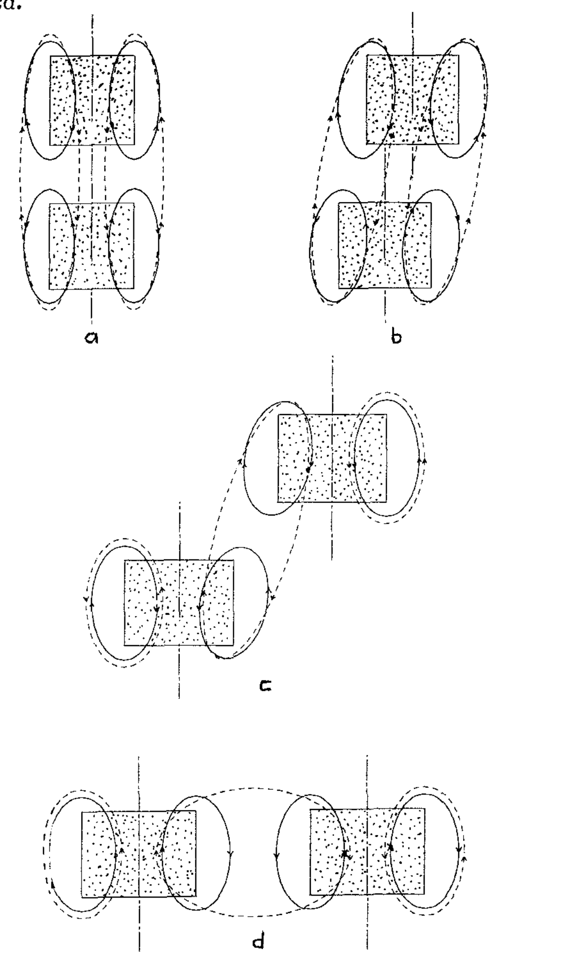
The coupling between two such DRs excited in the $TE_{01\delta}$ mode satisfies [3-4] :

$$k_0 = \frac{f^2_{oe} - f^2_{om}}{f^2_{oe} + f^2_{om}}$$

where f_{oe} and f_{om} are respectively the resonant frequencies of the even and the odd modes. These frequencies are solutions of the free oscillations wave equation which is solved by means of the three dimensional finite element method (F.E.M.) [5].

When $d_i=0$, $d> D$, DRs are adjacent, the coupling is then of "radial" type. When $d_i > H$, $d=0$, DRs are superimposed, the coupling is called of "axial" type. The electromagnetic configuration of the even and the odd modes which participate to those two coupling types are different as shown in figures 2a and 2d.

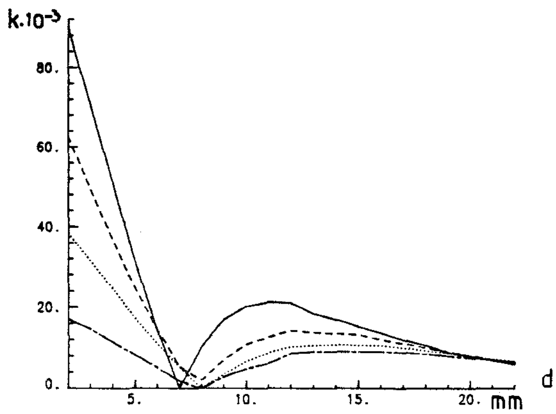


Direct coupling between two DRs
Different configurations
a-axial coupling b-staggered axial coupling
c-staggered radial coupling d-radial coupling
—— Magnetic field lines of the even mode
----- Magnetic field lines of the odd mode
- Figure 2 -

k_0 will be modified as a function of the position of the two DRs. In fig. 3, we show the measured coupling coefficient variation as a function of a distance d, for different values d_i. We now consider two superimposed DRs. If one moves radially (fig. 2b), axial coupling will decrease rapidly until critical coupling is achieved. Then radial coupling appears (fig. 2c), which encreases until it reaches critical coupling, and then decreases when the distance d between the two DRs increases futher.

Note that :

- the coupling coefficient k_0 cancels for $d \# D/2$ when $d_i \# H$. This configuration then yields small coupling coefficients for a small distance between DRs. This phenomenon can be exploited to reduce size and weight of DRs structures
- a small displacement around critical coupling allows significant variations in the coupling coefficients, so a small perturbation will be enough to adjust this coefficient over a large range, which can be use to make easier the DRs systems ruling
- this configuration is also efficient in realising negative coupling between DRs. As shown in figures 2b and 2c, for a same excitation on the upper DR, the magnetic field lines of even and odd modes imposed on the lower DR are opposed for axial and radial coupling. So by combining these two types of coupling in a same structure, negative direct coupling will be generated.



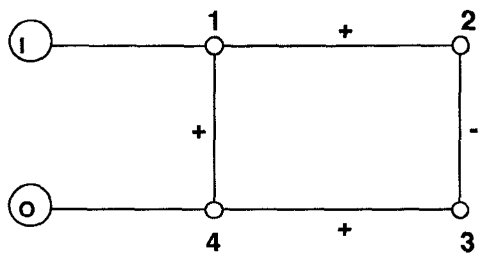
Coupling coefficient as a function of the distance between two DRs
DRs : H=6 mm, D=12 mm, $\varepsilon_r=36$
Substrates : $H_s=1,5$ mm, $\varepsilon_s=2,2$ Cavity : L=6 mm
—·- d_i = 15 mm ---- d_i = 12 mm
······ d_i = 10 mm —— d_i = 8 mm
- Figure 3 -

III - EXPERIMENTAL REALIZATION

To verify the theoretic assumptions, an experimental 4 poles elliptic prototype has been designed and constructed. Parameters of the filter are given in table 1. A scheme representation of the coupling matrix coefficients is generaly given as shown in fig. 4. The coupling between DRs 2 and 3 has to be negative, the other couplings are positive.

Center frequency	3,815 GHz
Band width	40 MHz
Normalized input and output impedance	1,353
center frequency - transmission losses - reflection losses	1 dB 26,5dB
Normalized coupling matrix	$\begin{bmatrix} 0 & 0,987 & 0 & 0,336 \\ 0,987 & 0 & -0,901 & 0 \\ 0 & -0,901 & 0 & 0,987 \\ 0,336 & 0 & 0,987 & 0 \end{bmatrix}$

- Table 1 -



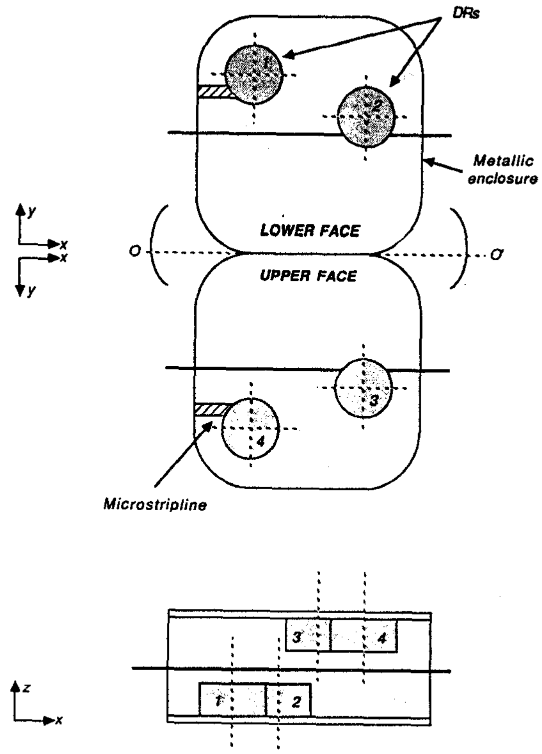
Scheme representation of the coupling matrix coefficients
*- **Figure 4** -*

These theoretic considerations have conduct us to realize the geometric configuration shown in fig. 5. The enclosure is opened around the OO' axis. DRs 1 and 2 set on the lower substrate, DRs 3 and 4 on the upper one. Curved microstriplines permit to couple DRs 1 (I) and 4 (O).

Couplings are direct and :

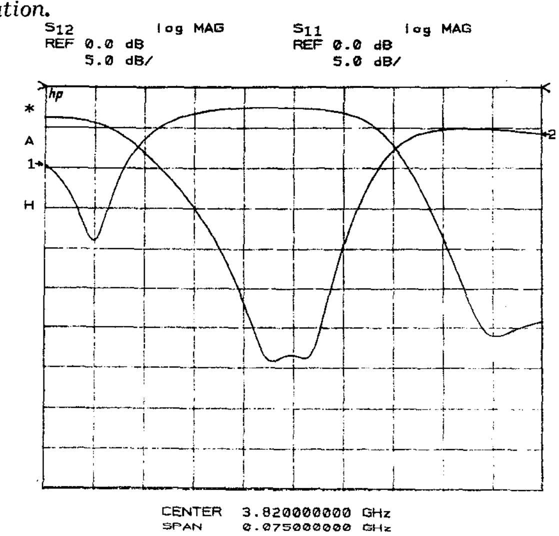
- *-adjacent positive between DRs 1-2 and 3-4 ("radial couplings")*
- *-staggered positive between DRs 1-4 ("radial coupling")*
- *-staggered negative between DRs 2-3 ("axial coupling")*

Dielectric rods have been inserted under DRs to limit the influence of the upper microstriplines armatures on 1 and 4 DRs frequencies and to decrease the losses on the metallic upper and lower planes. Metallic screws have been added to adjust coupling coefficients values and DRs frequencies.



Geometric configuration of the 4 poles elliptic filter
*- **Figure 5** -*

Fig. 6 shows the response of the experimental filter. The bandpass filter is about 38 MHz. Center frequency bandpass transmission losses (0,87 dB) and reflection losses (26,5 dB) are conformable to the theoretic requirements. These results can therefore open the door for using this new geometric configuration.



Measured insertion and return loss responses
*- **Figure 6** -*

A spurious mode appears at the bottom of the band, which can be due to a resonance of the enclosure, an upper mode of the microstripline, or spurious couplings between DRs 1-3 and 2-4. It can also indicate that this 4 poles prototype is not adequately tuned. Development of three dimensional F.E.M. analysis may forecast those spurious responses when we'll be able to take into account the entire experimental structure.

Nevertheless, this imperfect realization has allowed to validate the obtainement of an elliptic function response at the acces of a direct coupling device.

IV - CONCLUSION

A new configuration has been presented to carry out response functions. As it uses direct coupling between DRs, coupling irises, transmission lines or screws between DRs are unnecessary. This configuration also allows us to adjust the coupling coefficients over a large range using a small perturbation, and to reduce structure dimensions and weight.

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