DIELECTRIC RESONATORS BAND PASS FILTER WITH HIGH ATTENUATION RATE.

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SUMMARY

A bandpass filter with high attenuation cut off has been realized by cascading a bandpass filter containing 4 dielectric resonators and a two dielectric resonators bandstop filter.

The filter response has a higher cut off attenuation rate (26 db/10 MHz) compared to the original bandpass filter (14 db/10 MHz).

The attenuation characteristics and return loss response show that the bandpass and the center frequency remain inchanged at 40 MHz and 4.015GHz respectively. The insertion losses are low (1db)

INTRODUCTION

Waveguide or cavity resonators give the best unloaded Q's and hence will result in filters with minimum insertion loss for a given fractional bandwidth. However they have the disadvantage of being relatively bulky and of being useful over only a limited frequency range because of the possibility of higher order modes.

The availability of dielectric resonators with small tan δ and good temperature characteritics {1} enable microwave filters to be designed with dielectric resonators. This paper presents a new dielectric resonator type filter named : bandpass filter high attenuation cut off rate.

. Bandpass filter

A typical bandpass filter to be designed is comprised of a rectangular waveguide below cut off containing dielectric resonators. The structure is then connected at both ends to two rectangular propagating waveguides as shown in figure 1.

When the propagating waveguides are excited by the $TE_{1,0}$ mode and if the dielectric resonators are oriented along the x direction, the $TE_{0,\gamma,\delta}$ mode of the dielectric resonator will be excited.

. The external quality factor Q_e of the dielectric resonator in the evanescent waveguide has been analysed. Q_e is given by equation 1 .

$$Q_e = \frac{\lambda_o^2 L\, D^2 a\, a'^2 b\, Z\, \gamma'_1 \{\frac{L}{2}(1+\frac{\sin\beta_x L/2}{\beta_x L/2})\}\, J_1(p_{01})}{512\, \Pi\Phi^2\, I^2\, (1+\rho_1)^2\, Z'\varepsilon_r e^{-2\gamma'_1 l}}$$

$$\Phi = \frac{2\, a'\, a^2}{\Pi(a^2-a'^2)} \sin\frac{\Pi d}{a} \qquad (1)$$

$$I = \sum_{n=1,3..odd} \frac{2(\gamma'_1)^n}{n\,!}\left(\frac{D}{2}\right)^{n+2} \frac{1}{p_{01}^2} J_1(p_{01})\{\frac{\Pi}{4}\, 1+\prod_{k=2}^{n+1}(\frac{2k-1}{2k})\}\}$$

$$-\{\frac{1}{(\frac{\Pi}{a'})^2-\beta_x^2}\{(\frac{\Pi}{a'}-\beta_x)\sin(\frac{\Pi L}{2a'}+\beta_x\frac{L}{2})+(\frac{\Pi}{a'}+\beta_x)\sin(\frac{\Pi L}{2a'}-\beta_x\frac{L}{2})\}\}$$

ρ_1 : reflection coefficient at $z'=0$ looking toward $z' < 0$.

Z, Z': wave impedance respectively of the propagating and cut off waveguides

γ'_1 : attenuation constant

β'_x : propagation constant in dielectric resonator

$J_1(p_{01})$: trigonometric Bessel function of 1st kind.

Theoretical and experimental Q_e variations as a function of the distance between center of the resonator from the sectional phase S_o located at $z'=0$ are given in figure 2.

- The method used to calculate the direct coupling k between two dielectric resonators in a cut off waveguide is based on the theory of perturbation {2} . k is given by (2). We note that this k value depends on the reflection coefficient at the discontinuity

$$k = \frac{4\gamma'_1 Z' b'\, e^{-\gamma'_1 ss}}{\omega(1-e^{-2\gamma'_1 d})(1-\rho_1)\{(\varepsilon_r Z'^2+\mu)+\eta^2/4\}} \qquad (2)$$

η : free wave impedance
d : length of the waveguide
ss : inter resonators spacing.

The inter resonators coupling coefficient k vs ss distance between the resonators is given in figure 3.

A 4 resonators Tchebyscheff filter has been designed and realized with the specifications given in table 1.

Curves 4 show the frequency response characteristics of the bandpass filter.

Table I : Theoretical and experimental results of a 4-resonator Bandpass Filter.

	THEORETICAL	PRACTICAL
Centre Frequency	4 GHz	4, 0135 GHz
Bandpass	40 MHz	39 MHz
Ripple Factor	0,2 dB	0,3 dB
Insertion Loss	0,618	0,75 dB
V.S.W.R.	1,1	1, 18

2. Bandstop filter

A bandstop filter can be realized by placing the dielectric resonators in a propagating waveguide. The resonators are placed in such a way that they rest isolated in their own metal enclosure but are coupled to the main waveguide through aperture on the waveguide walls (figure 5).

The H_x coupling configuration is chosen because the orientation of the dielectric resonator is symmetrical with respect to the electric field.

Fig. 6 gives the measured values of the external Q factor as a function of the distances d and t respectively. It can be observed that for a fixed position of the resonator (t), Q_e remains practically constant for $d \geqslant 3$ mm.

A bandstop filter is to be designed to satisfy the specifications given in table 2.

Fig. 7 shows the attenuation characteristics of the two resonators bandstop filter constructed.

Table II : Theoretical and Experimental values of a 2-resonator Bandstop Filter.

	DESIRED SPECIFICATIONS	EXPERIMENTAL
CENTRE FREQUENCY	3,88 GHz	3,875 GHz
BANDSTOP	20 MHz	19,5 GHz
INSERTION LOSS	0,3 dB	0,33 dB
V.S.W.R.	1,1	1,22

3. Bandpass filter with high attenuation cut off

An interesting feature occurs when the bandpass filter is cascaded at its ends by two bandstop filters. Their presence behave essentially as introducing two poles of finite attenuation to the bandpass filter response in the stop band.

The resonators were tuned such that their resonant frequencies fall summetrically outside the bandpass limits until a minimum attenuation of about 30 MHz is obtained in the stop band.

The filter response is shown in fig.8. The measured pole frequencies of 4.056 and 3.978 GHz with the minimum attenuation of 32 db seems to agree quite well with the calculated values.

It can be now observed on the same figure that the new filter response seems to have a higher cut off attenuation rate (26 db/10 MHz) compared to the original bandpass filter (14 db/10 MHz). The center frequency and the bandpass remain unchanged at 4.015 GHz and 40 MHz respectively. However with the introduction of the bandstops, the insertion loss in the pass-band increases (0.75 db to 1 db).

References

{1} R.K. PLOURDE - O'BRYAN - THOMSON
A new BAO TiO_2 compound with temperature stable high permittivity and low microwave loss.
Journal of the American Ceramic Society.
Vol. 57 P. 450 October 1974.

{2} C.C. JOHNSON
Field and wave electrodynamics
NEW-YORK Mac-Graw-Hill 1965.

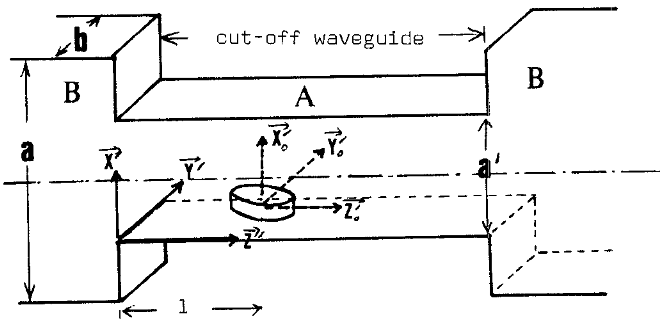

Fig.1 : Dielectric resonator in a cut-off waveguide.

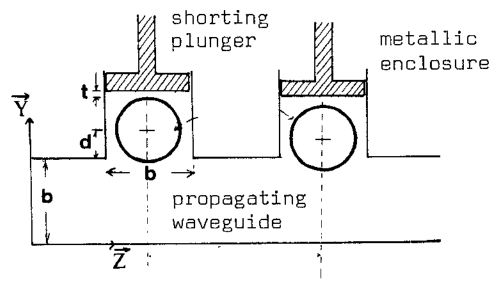

Fig.5 : 2-resonator bandstop filter.

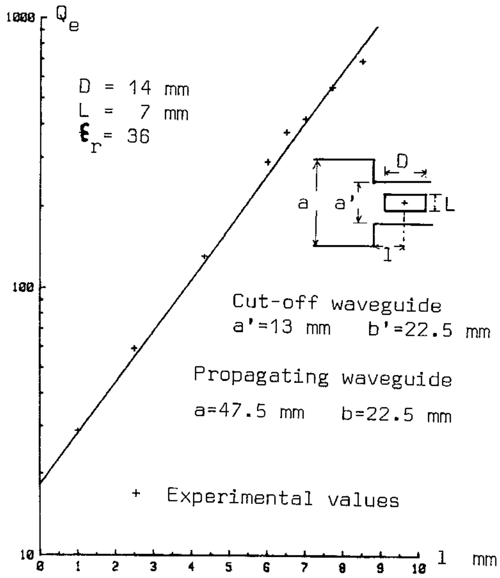

Fig.2 : External Q-factor Q_e vs distance l.

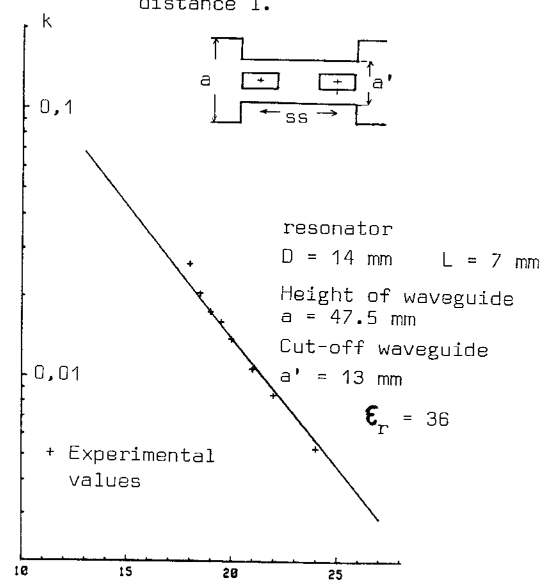

Fig.3 : Inter-resonator coupling coefficient k vs ss mm

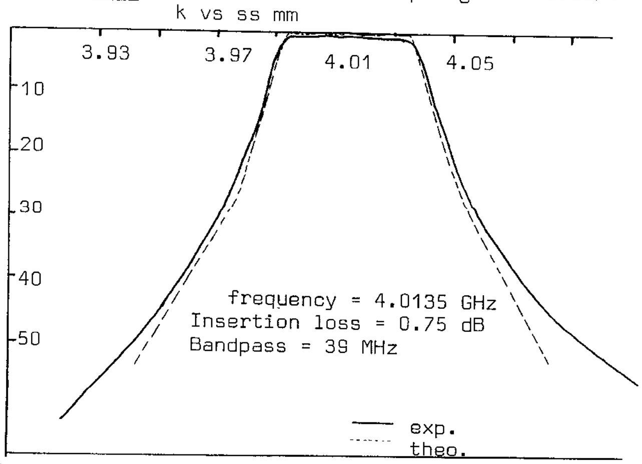

Fig.4 : theoretical and experimental values of bandpass response.

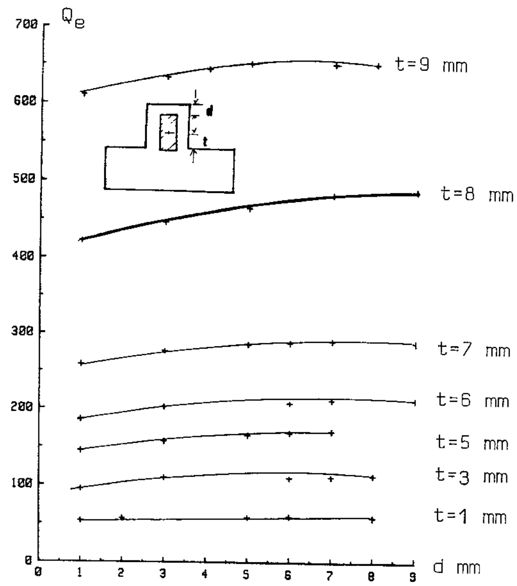

Fig.6 : External Q-factor Q_e vs d mm.

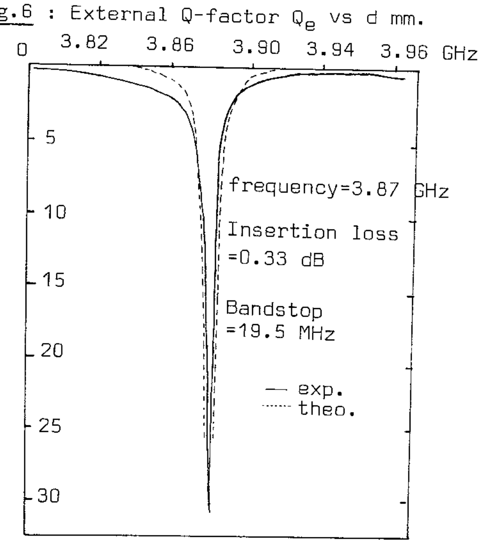

Fig.7 : 2-resonator Butterworth Bandstop Filter

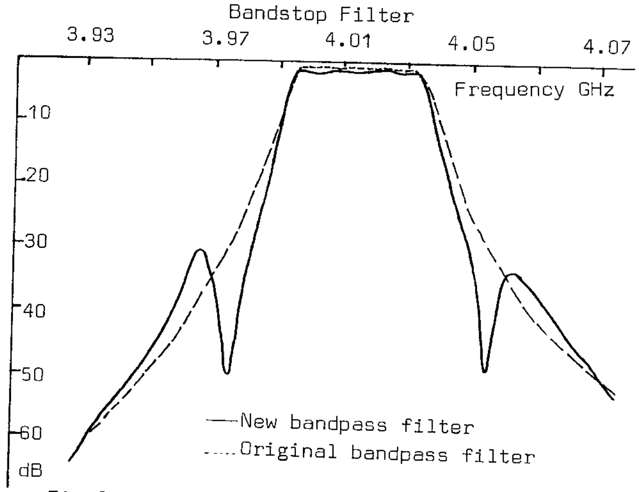

Fig.8 High attenuation bandpass filter.