TEMPERATURE COMPENSATION OF RESONANT CAVITIES WITH A TEFLON POST

Javier Bará, Professor, Chair of Microwaves, Universidad Politécnica de Barcelona, E.T.S.I.Telecomunicación, Apdo. 30002, Barcelona-34 Spain.

ABSTRACT

The negative temperature coefficient of ε for teflon is used to compensate the frequency drift of a metal cavity due to thermal expansion. An experimental X-band transmission resonator was compensated in this way with a 10 mm teflon post. The results are considered of great interest for the compensation of waveguide millimiter wave oscillators.

INTRODUCTION

Teflon, as specified by the manufacturer /1/, has a negative temperature coefficient for ε of -224 ppm/ºC and a linear thermal expansion coefficient of 100 ppm/ºC. That the overall effect of a post in a region of maximum $\bar{E}$ in a resonant cavity is of opposite sign to that of the metal expansion can be seen as follows; for a thin post extending along the cavity unperturbed field, $\bar{E}_o$:

$$(f-f_o)/f=-(\varepsilon_r-1)\int_\tau|\bar{E}_o|^2\, dV/4U\simeq-2(\varepsilon_r-1)\tau/V \quad (1)$$

with τ=volume of teflon post, V=cavity volume.

From this expression we can obtain

$$\alpha(f)=-\alpha_r-(\tau/V)\left[\varepsilon_r\alpha(\varepsilon_r)+(\varepsilon_r-1)\left[\alpha(\tau)-\alpha(V)\right]\right]\simeq-\alpha_r+(\tau/V)\sigma \quad (2)$$

with $\alpha(x)=\partial x/\partial T/x$ in ppm/ºC, α_r=coefficient of linear thermal expansion of metal ($\sim$17 ppm/ºC for copper or brass).

For teflon ε_r=2.1, $\alpha(\varepsilon_r)$=-224 ppm/ºC. The value of $\alpha(\tau)$ is more problematic, since it will depend on the expansion conditions imposed on the post by its position in the cavity, but we may take $200\leq\alpha(\tau)\leq$ 300 ppm/ºC.

We therefore obtain for σ values ranging from 200 to 300 ppm/ºC which, with this approximations, would cancel $-\alpha_r$ =-17 ppm/ºC for $5.7\%\leq\tau/V\leq$ 8.5% . With this values, $12.5\%\leq(f-f_o)/f\leq18.9\%$.

POST IN A TE_{10n} RECTANGULAR RESONATOR

The approximate results obtained above for $(f-f_o)/f$ show that the variational expression (1) may not be accurate enough for design calculations. Unfortunately, the results given by Marcuvitz /2/ for a dielectric post in a rectangular guide prove to be, as shown in fig. 1, in worse accordance with experimental results than those obtained from (1) rewritten as

$$(f-f_o)/f= -2(\varepsilon_r-1)\gamma\tau/V, \quad \text{with } \gamma= \int_S \sin^2 \frac{\pi x}{a} \sin^2 \frac{n\pi x}{d} \frac{dS}{S} \tag{3}$$

that is, taking into account the field variation inside the post and approximating it by the empty guide field.

In view of this, and since no data on thick dielectric posts in a rectangular waveguide other than /2/ have been found, we proceeded from (3) taking for γ measured data.

MEASUREMENT OF γ

We used a $3\lambda_g/2$ section of X-band guide (WR-90) with ϕ=5 mm inductive irises. The length was taken large to avoid interaction beteween the thick posts and the irises. Fig. 1 shows the results obtained for $\Delta f=f_o-f$ (f_o=11638 Mhz). The post was prevented from getting loose in the cavity in the process of heating-cooling by means of a screw centered in the broad face of the guide. The results obtained for γ are plotted in fig. 2.

From (3) we can write ($x=\tau/V$):

$$\alpha(f)=-\alpha_r + R\frac{x}{1+2.2x} \qquad \text{with} \quad R=-2\left\{\varepsilon_r\alpha(\varepsilon_r)+(\varepsilon_r-1)\left[\alpha(\tau)-\alpha(V)+\alpha(\gamma)\right]\right\}$$

The experimental results obtained for $\alpha(f)$ for D=6,7,8,9 and 10 mm yielded R fairly constant and approximately equal to 320 ppm/ºC. The fluctuations on its values are attributed mainly to different mechanical instalations of the posts.

EXPERIMENTAL FILTER

An experimental transmission cavity was made in X-band guide as shown in fig. 3. The cavity is λ long to permit insertion of the teflon post in one of the $\bar{E}$ maxima and a tuning post in the other, since the specific application intended required to operate in the 10.7-11.7 Ghz band.

From the data above it is found that the condition $\alpha(f)=0$ is met for x=6.0%, which results in a post of D=9,4 mm.

The following results were obtained:

-With D=9.2 mm, $\alpha(f)$ varied between -2 and -6 ppm/ºC, depending on the position of the tuning post (10.7 f 11.7 Ghz)

-With D=10 mm, $\alpha(f)$ varied between +3 and -1 ppm/ºC, under the same conditions as above.

It should be noted that in this filter a) the presence of the tuning post and b) the reactive interaction between the post and the inductive wires, only 1 mm apart, introduce further deviations from the theoretical model.

DISCUSSION

A more accurate theoretical prediction of results requires, at least:

i) Good measurements of $\alpha(\varepsilon_r)$ and $\alpha(D)$ for teflon.
ii) A careful control of the mechanical instalation and the stresses of the post
iii) Accurate computation of the efects of a dielectric post in a rectangular waveguide.

These problems are at present under investigation.

REFERENCES

/1/.-"Design Data for Teflon", Du Pont de Nemours, brochure A-66426
/2/.-N. Marcuvitz, Ed.;"Waveguide Handbook", Boston Technical Publishers Inc., 1964, pp. 166-167.

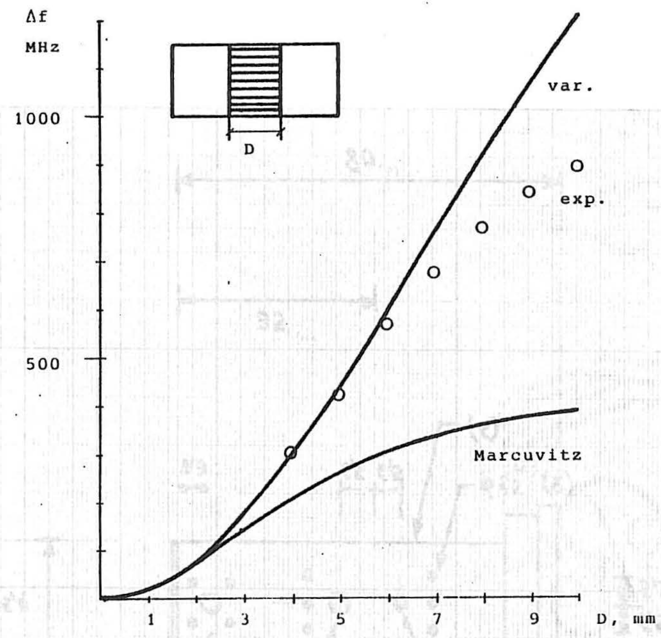


Fig. 1.- Frequency shift $f-f_o$ produced by insertion of teflon posts. Upper curve: Variational expression. Lower curve: Marcuvitz data. Circles: Experimental results.

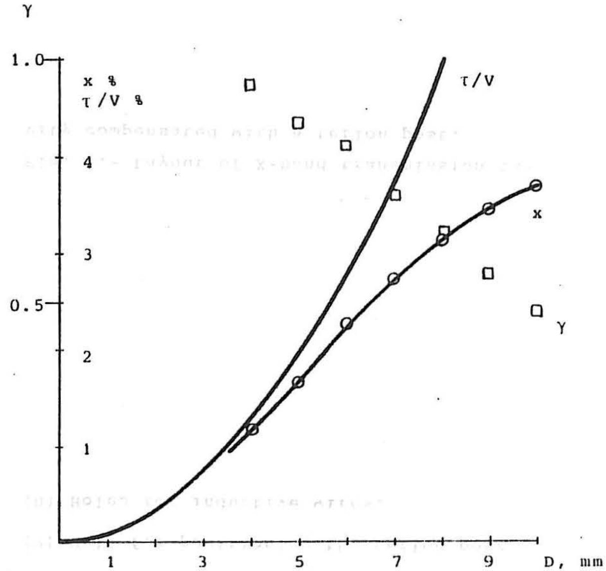
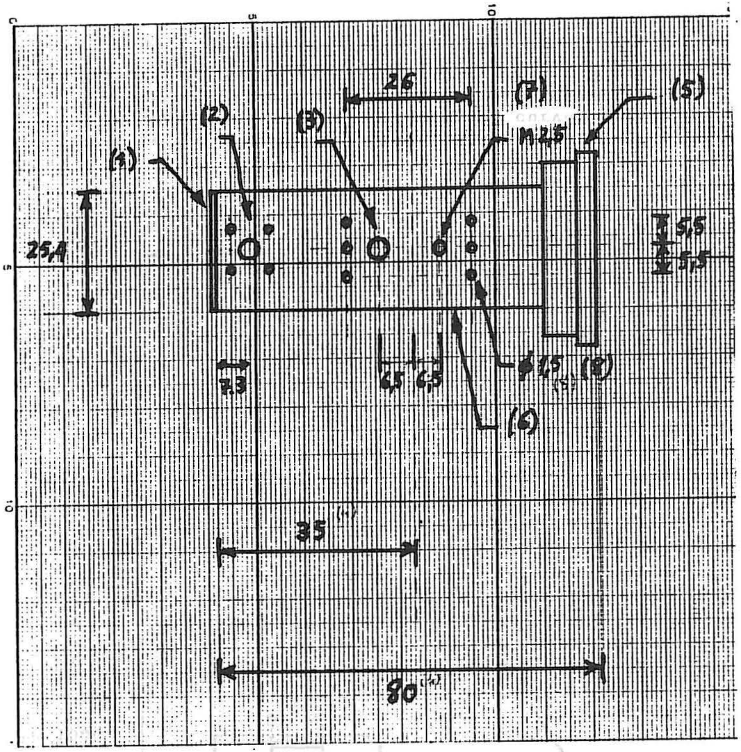


Fig. 2.- Factor γ as defined by (3) as a function of post diameter D. Upper curve: τ/V. Circles: Measured values of $x=\gamma\tau/V$. Squares: values for γ.



(1),(2) Transition coaxial-waveguide.

(3) Hole for tuning post.

(5) Flange.

(6) WR 90 guide.

(7) Hole for positioning the teflon post.

(8) Holes for inductive wires.

Fig. 3.- Layout of X-band transmission cavity compensated with a teflon post.