Cylindrical TE_{011}/TM_{111} Mode Control By Cavity Shaping

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ABSTRACT

An appropriate modification of the shape of a cylindrical filter cavity has been used to separate the degenerate TM_{111} (doublet) modes while at the same time providing a slight increase in the already high unloaded Q of the desired TE_{011} mode.

SUMMARY

The TE_{011} cylindrical cavity mode is potentially attractive for use in low-loss filters since it offers a higher unloaded Q than other modes having comparable cavity volumes, and it is easily tuned by a non-contacting, movable end wall. However, it is degenerate with a pair of TM_{111} modes which must be perturbed in some manner to make the TE_{011} mode usable. Previously described reactive or dissipative techniques degrade the TE_{011} Q in the process of controlling the TM_{111} mode whereas the approach covered in this paper yields a significant detuning of the TM_{111} resonance with a small increase in the TE_{011} Q as a by-product.

This method may be understood by relating the modes of a cylindrical cavity to those of a spherical cavity as illustrated in Figure 1. The normalized parameter $Q\delta/\lambda_0$ is shown for each mode; δ is the skin depth, and λ_0 is the resonant wavelength. The value of 0.641 for the TE_{011} mode is close to the maximum of 0.659 which occurs at a D/L of 1.00. Because of its symmetry the sphere has fewer different resonant frequencies but higher-order degeneracies at each as indicated by the superscripts in parentheses. In general the spherical mode Q's are higher than the corresponding cylindrical ones. If the cavity were deformed from a cylindrical to a spherical shape, the resonances would move continuously from one family to the other as indicated schematically by the straight lines. Thus the figure suggests that there should be intermediate shapes which isolate the desired (cylindrical) TE_{011} mode from the degeneracies that exist in the cylindrical and spherical cases.

A chamfer at the cavity ends provides a mechanically-convenient transitional shape which has been studied experimentally. Each cavity was excited through a small coupling aperture to minimize perturbations. Measurements were taken over several half-power bandwidths using an automatic network analyzer. These data were then computer processed to obtain best-fit values for the resonant frequency and the unloaded and external Q values. Figure 2 shows some results. The resonant frequencies exhibit the behavior indicated by Figure 1. The Q_u values of the chamfered cavities fall between the cylinder and the higher spherical values. Chamfering could be used at one end only with correspondingly less effect if necessary for mechanical reasons, but no single-end configurations were measured.

The amount of mode separation required depends on the type of coupling (e.g., side-wall or end-wall) and the desired filter bandwidth. For multiplexer applications, each filter should be free of spurious modes over the entire mutiplexed frequency band. Cavity shaping of this type has been used in filters having various side- and end-wall coupling arrangements which yield Chebyshev or elliptical responses. Figure 3 shows an aluminum 12 GHz, four-pole Chebyshev filter which utilizes cavity shape B. Coupling is provided by circular apertures in the sidewalls. For this arrangement the TE_{211}/TE_{311} modes are the most difficult to control (after the TM_{111} mode has been displaced). Separating the coupling apertures in each cavity by 145 degrees (as shown) minimizes the distortion of the TE_{011} passband by residual TE_{211}/TE_{311} coupling and tends to suppress the spurious passbands at the TE_{211} and TE_{311} resonant frequencies.

Figure 4 shows a wideband response of this filter (after silver-plating) taken on an automatic network analyzer. Figure 5 shows the in-band transmission response, and Figure 6 gives an expanded polar plot of the in-band reflection coefficient. The effective unloaded Q is in excess of 20,000 based not only on the insertion loss of Figure 5 but also on the complex values of all the scattering parameters. Reducing the bandwidth should increase the Q towards the unperturbed value of 29,600 projected from the measurements of Figure 2.

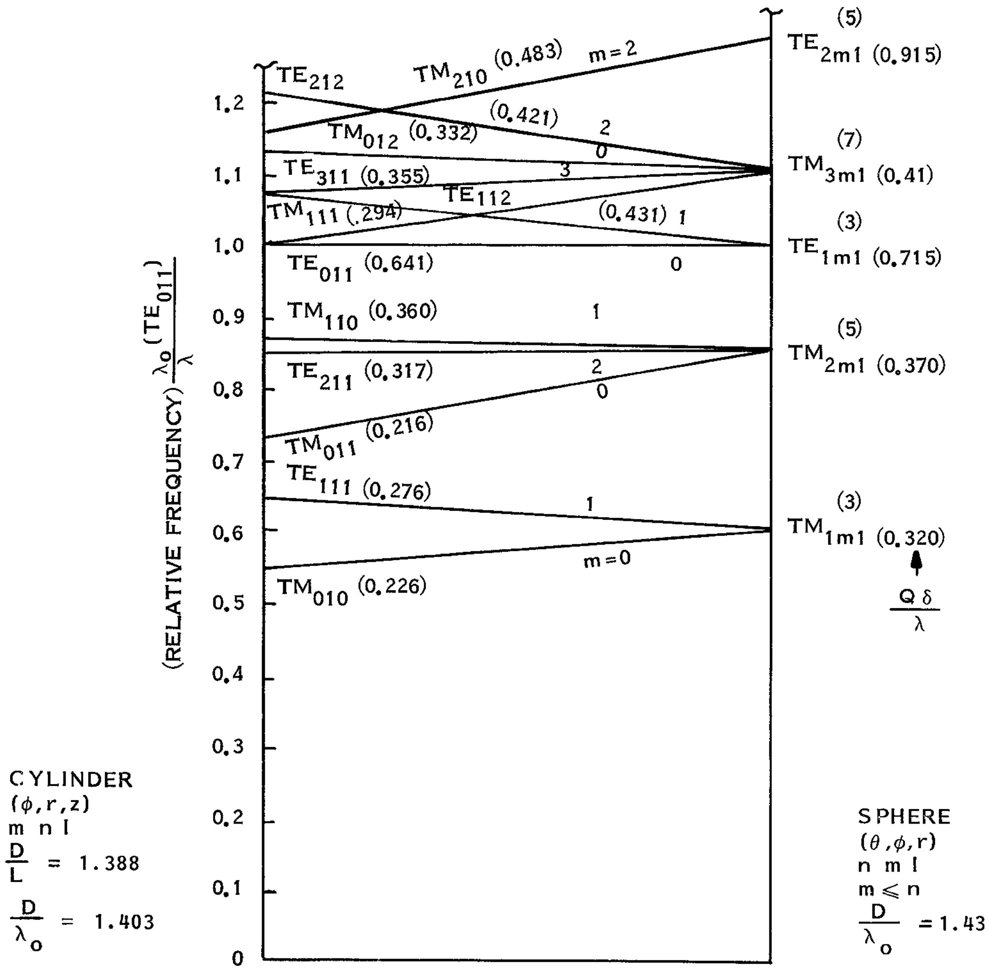
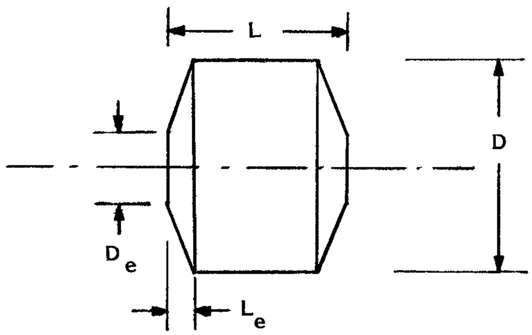


Figure 1. Cavity Resonances



Shape	Cylinder	A	B	C	Sphere
D (inches)	1.378	1.378	1.378	1.378	1.408*
L	0.993	1.097	1.142	1.213	----------
D_e	0	0.520	0.520	0.520	----------
L_e	0	0.110	0.165	0.250	----------
f_0 (TE_{011}) MHz	12009	11944	11936	11990	12009
Relative $\frac{Q\delta}{\lambda}$	1.000	1.053	1.077	1.042	1.115*
Relative Mode Frequencies					
(Cylinder Notation)					
TE_{311}	1.074*	1.0851	1.0900	1.0964	1.1067*
TE_{112}	1.074*	1.0498	1.0408	1.0275	1.0000*
TM_{111}	1.000*	1.0289	1.0445	1.0624	1.1067*
TE_{011}	1.000	1.0000	1.0000	1.0000	1.0000
TM_{110}	0.869*	0.8812	0.8817	----------	0.8613*
TE_{211}	0.851*	0.8579	0.8605	0.8633	0.8613*

*Computed Value

Figure 2. Measured Characteristics of Shaped Cavities

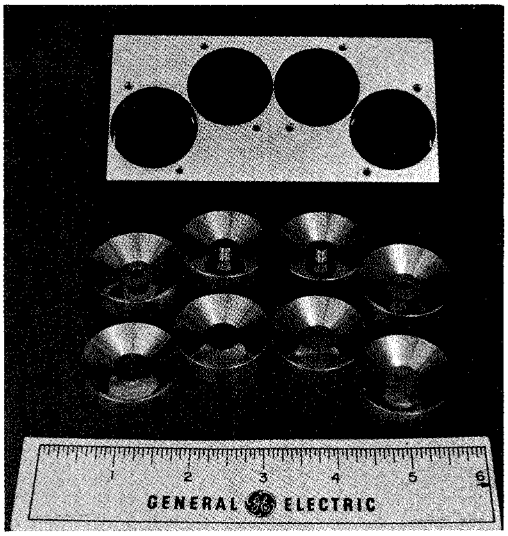


Figure 3. Four Pole Chebyshev TE_{011} Filter using Shaped Cavities

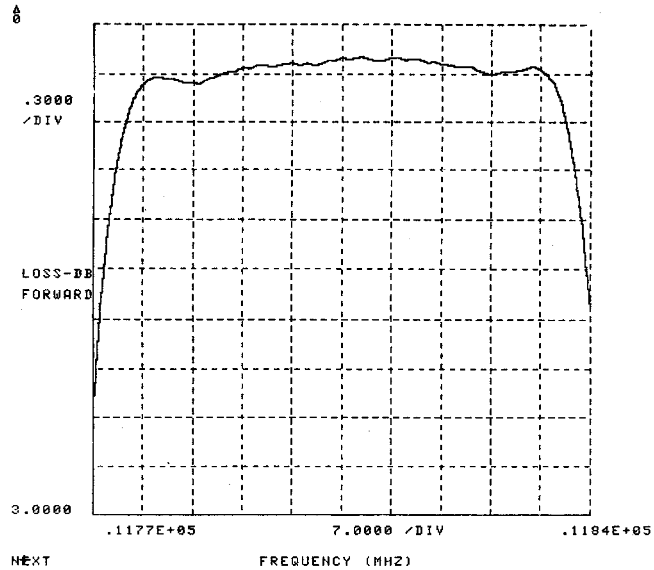


Figure 5. Insertion Loss of TE_{011} Filter

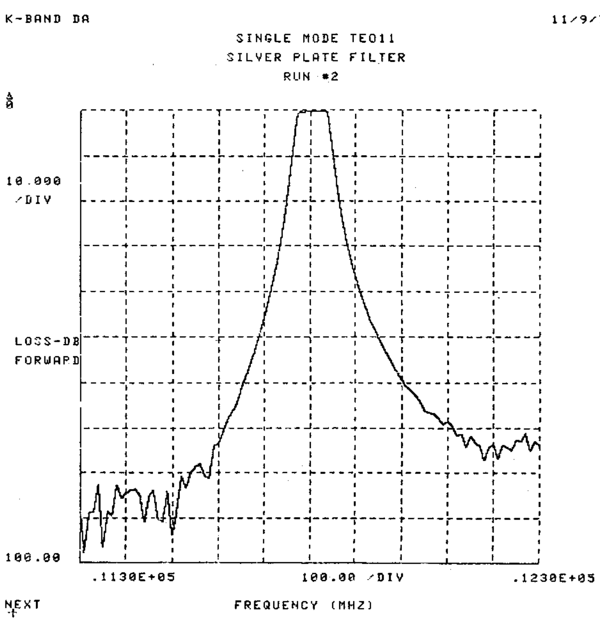


Figure 4. Rejection Response of Silver-Plated TE_{011} Filter

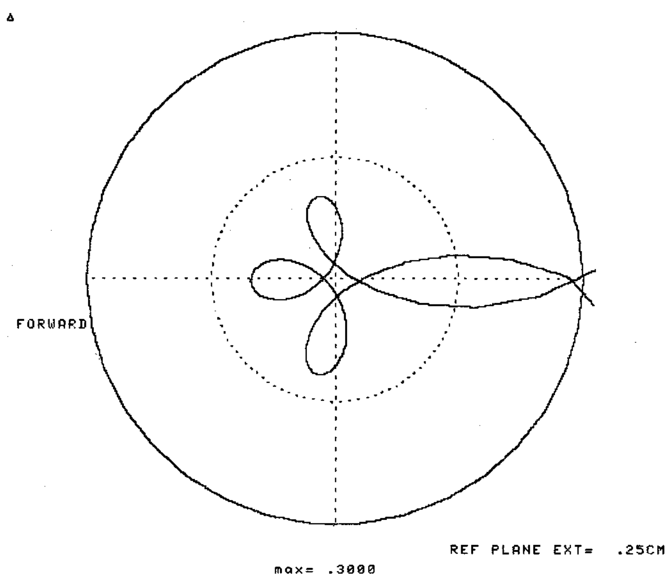


Figure 6. Reflection Coefficient of TE_{011} Filter