LOSS MECHANISMS IN COUPLED CAVITY FILTERS

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Abstract

The losses in coupled cavity filters due to coupling apertures, tuning screws and surface roughness have been determined experimentally. This information can be used to predict and minimize the insertion loss in various filter configurations.

The losses in coupled cavity filters due to coupling apertures, tuning screws and surface roughness have been determined experimentally. By proper interpretation of these results, it is possible to estimate how the effective unloaded Q of a filter (and thus its insertion loss) varies as a function of bandwidth, configuration (e.g., single or dual-mode) and response type (e.g., Chebyshev or elliptic). It is also possible to predict other effects such as response skewing due to losses and spatial distribution of dissipated power.

The accuracy required for this study was achieved by using an automatic network analyzer with direct computer reduction of the data to resonant frequency and Q values. Figure 1 shows one of the solid copper test structures used for the investigation of aperture losses. It consists of a full cavity with a small excitation slot at one end for coupling to the network analyzer and a larger test aperture at the other. The test aperture is backed by a short-circuited half-cavity (non-resonant). The test procedure consisted of measuring the unloaded Q and resonant frequency of a cavity without a test aperture and then repeating these measurements on the same cavity for a series of progressively larger apertures.

Figure 2 gives Q_u as a function of f_o for different aperture configurations. The value of Q_u decreases as frequency decreases from its unperturbed value. The significance of presenting the results in this manner is that all filter performance can ultimately be related to frequency shifting (or splitting). That is, apertures which shift the resonant frequency by the same amount yield essentially the same coupling regardless of the physical configuration, but the unloaded Q degradation is much more severe for a thin slot than for a circular aperture that gives the same frequency shift. Extrapolating out the Q_u loss due to the excitation aperture leaves an unloaded Q which is four percent below the theoretical value; this discrepancy is apparently due to surface roughness (8 microinch finish).

Similar results were obtained for dielectric (sapphire) and silver (plated) tuning screws at the mid-plane of the cavity. Whether tuning screws are used to compensate for mechanical variations or to provide cross-coupling in dual-mode operation, the amount of frequency shift achieved relative to the Q_u degradation is still the key parameter. Measurements were taken with the screw in the strong electric field region where the frequency decreases with increasing penetration; they were also taken in the inductive field region where the frequency increases for metal screws (but remains constant for dielectric). Furthermore, various combinations of screws were measured to establish that the process is essentially linear; that is, the net frequency and Q shifts are the sum of those obtained with the screws separately.

The results of the aperture and tuning screw measurements were used to establish a complete loss budget for filters. Figure 3 illustrates how single- and dual-mode filters may be compared in this manner. The largest single Q_u perturbation results from the output aperture; in dual-mode filters the two resonances that exist in each end cavity are affected. The internal circular apertures of the single-mode filter yield less loss than the dual-mode coupling screws and slots (required for selective mode coupling), but intentional detuning of the single-mode resonances to avoid contamination by the unused doublets penalizes the single-mode filter. The dual-mode filter suffers a greater tuning screw loss due to the inductive-capacitive interactive effects. The net results predict a slight advantage for single-mode operation of short filters where end effects are significant but little difference for long filters which are dominated by the internal resonance Q's.

The two-cavity, four-pole, dual-mode filter shown in Figure 4 was built to verify the predictions of Figure 3. The response shown in Figure 5 along with the results of a computer response-fitting routine indicate an effective Q_u of 8000. The use of a circular aperture for the output coupling should be noted. A 0.047" wide slot instead of the circular aperture would introduce a Q reduction of 3900 instead of 1100 for the end resonance, and a relative detuning of the dual mode which would have to be compensated by a crossed slot or large tuning screw penetration with corresponding Q_u reduction. The net result would be an effective filter Q between 5000 and 5500.

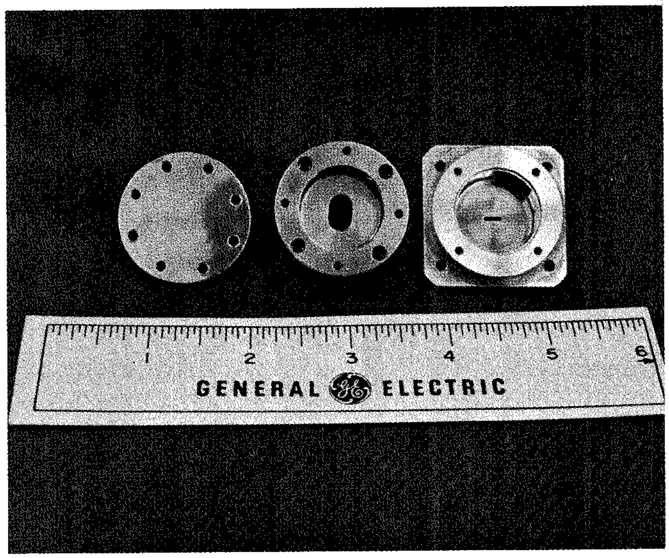

Figure 1. Copper Test Structure

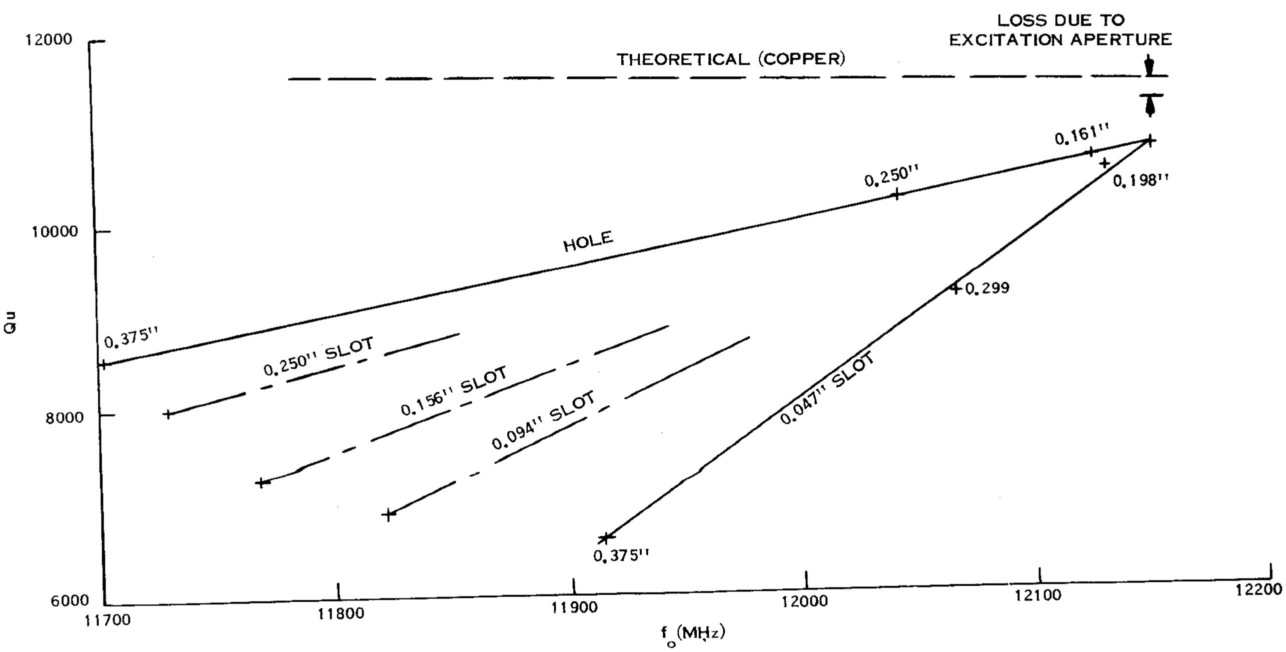

Figure 2. Unloaded Q for Various Apertures

	DUAL MODE		SINGLE MODE	
	TWO END RESONANCES	INTERNAL RESONANCES	END RESONANCES	INTERNAL RESONANCES
OUTPUT COUPLING HOLE	1100	—	1100	—
INTERNAL HOLE/SLOT	100	200	150	300
COUPLING SCREW	500	500	—	—
ORTHO-MODE DETUNING (60 MHz)	—	—	800	800
TUNING SCREW (50 MHz)				
CAPACITIVE	875	875	700	700
INDUCTIVE	300	300	—	—
TOTAL Q LOSS	2875	1875	2750	1800
NET Q	7875	8875	8000	8950

Figure 3. Q_u Reductions in 0.5% Bandwidth Filter at 12000 MHz

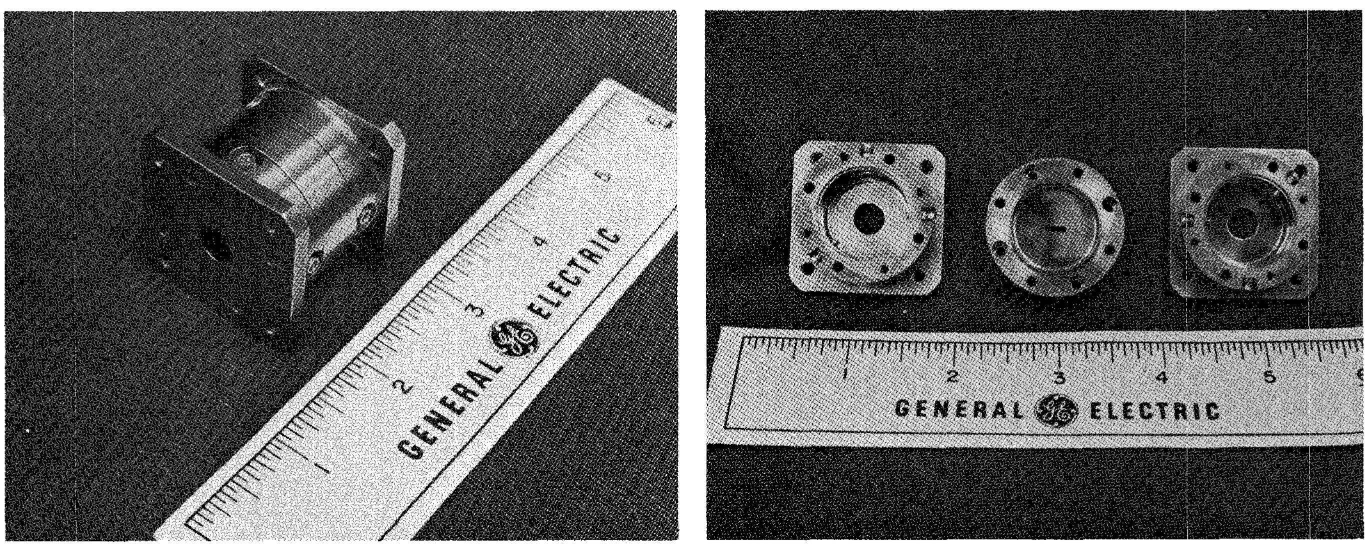

Figure 4. Four-Pole Dual Mode Filter (Copper)

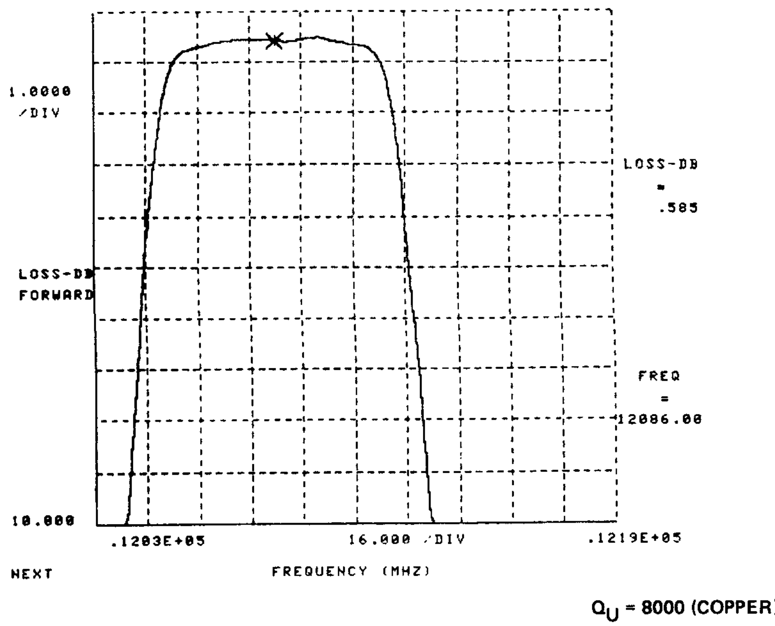

Figure 5. Response of Four-Pole Filter