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NARROW BANDPASS FILTERS USING THE HIGH-Q CYLINDRICAL $TE_{0m\ell}$ RESONATOR MODES*

R. R. Bonetti and A. E. Williams

COMSAT Laboratories, Clarksburg, Maryland 20871

ABSTRACT

The realization of optimum-response, narrow bandpass filters in high-Q $TE_{0m\ell}$ cylindrical resonator modes is described. Experimental results are presented for 15- and 28-MHz bandwidth, 4-pole, elliptic function filters centered at 17.52 GHz using the TE_{021} mode. Unloaded Q's of 25,000 have been achieved with cavity shaping to suppress $TM_{1m\ell}$ mode degeneracy.

INTRODUCTION

The development of low-loss channeling filters for high-frequency 11/14-, 12/17-, and 20/30-GHz satellite communications bands places greater emphasis on achieving the highest possible cavity Q, and hence the lowest filter loss. This is especially important in earth station multiplexer applications, where low loss and maximum power capacities are required. The realization of multiple, coupled-cavity, bandpass filters using the cylindrical cavity TE_{011} mode has been described previously (1), where unloaded Q's of 20,000 at 12 GHz were reported (2).

This paper describes how optimum-response filter transfer functions can be realized using the higher order $TE_{0m\ell}$ modes. Experimental results are presented for the TE_{021} mode for two bandwidths, and the results are in good agreement with computed predictions. The degeneracy of the TM_{121} mode was removed by carefully shaping the cavity (2); while the effect of adjacent TE modes was minimized by the appropriate choice of cavity diameter and length and by aperture angular offset techniques (3).

THEORY

The multicoupled-cavity synthesis procedure developed by Atia, Williams, and Newcomb (4) is applied to derive the coupling matrix elements that generate the desired filter response. Figure 1 illustrates the symmetrical canonical realization of couplings for an even-order, coupled-cavity network. Since all series (i, i + 1) couplings are generally of the same sign, they can be easily realized by sidewall slots (5); however, the shunt couplings (i, N − i + 1) must be capable of both positive and negative signs (6). This argument also follows almost identically for the asymmetrical canonical realization described by Pfitzenmaier (7). Therefore, the key to this filter design is the realization of shunt couplings with opposite signs.

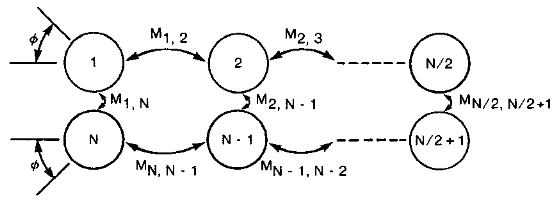

Figure 1. Multicoupled-Cavity Network of Nth Order: Symmetrical Realization

Figure 2 illustrates the technique whereby opposite shunt coupling signs are realized by displacing the top and bottom cavities one-half cycle of the Bessel function, $J_1(r)$ (approximately D/2m for the $TE_{0m\ell}$ mode). Figures 2a and 2b represent end-wall couplings through the radial magnetic field component. The coupling shown in Figure 2a is positive and that in Figure 2b is negative, relative to the field configuration excited by sidewall slot couplings (arbitrarily called positive).

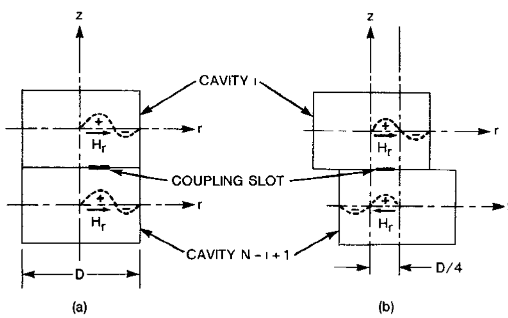

Figure 2. Positive and Negative Coupling Techniques for $TE_{02\ell}$ Mode

The degeneracy of the $TE_{0m\ell}$ and $TM_{1m\ell}$ modes can be removed if a cylindrical structure with corrugated ends is employed. When the circular

*This paper is based on work performed at COMSAT Laboratories under the sponsorship of the Satellite Television Corporation (STC).

corrugations coincide with the nulls of the radial standing wave for the tangential electric field of the $TE_{0m\ell}$ mode, a small perturbation is introduced in the resonant frequency. However, the effective length of the cavity will be shorter for the $TM_{1m\ell}$ mode, and its resonant frequency will be shifted higher by an amount proportional to the depth of the corrugation.

The influence of the adjacent TE modes can be minimized by selecting an appropriate diameter-to-length ratio without significant degradation in Q, and by using angular offset between the input and output slots in cavities 1 and N (3).

EXPERIMENTAL FILTERS

To illustrate the correctness of these generalized cylindrical $TE_{0m\ell}$ resonator filter design techniques, two fourth-order elliptic function filters were constructed in the TE_{021} mode. These filters were designed to operate at 17.52 GHz with bandwidths of 15 and 28 MHz. The cavity diameter/length ratio was chosen as a compromise between maximum mode separation and theoretical cavity Q. Figure 3 shows the experimental measurement obtained with the 28-MHz bandwidth. A center frequency loss of 1.14 dB was measured for the 15-MHz filter and 0.47 dB for the 28-MHz filter. These values correspond to unloaded Q's of 25,000.

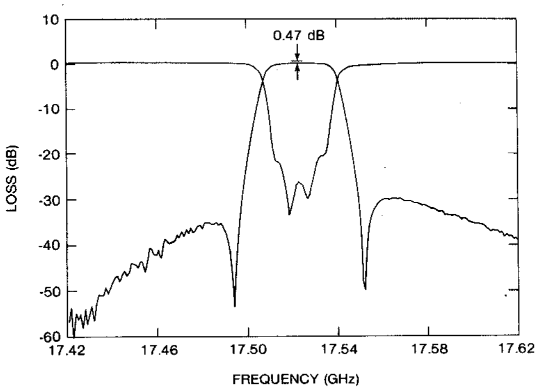

Figure 3. Experimental Transmission and Return Loss Responses of 28-MHz TE_{021} Filter

Figure 4 compares the out-of-band responses for the 28-MHz filter to illustrate the effect of the corrugation depth on the frequency shift of the degenerate TM_{121} mode. Some degradation in Q was observed for the larger corrugation depth.

CONCLUSIONS

A general design technique for the realization of narrow bandpass filters using the high-Q $TE_{0m\ell}$ modes was described. Experimental evidence was presented in the design of two 4-pole filters which realized Q's of 25,000 at 17.52 GHz. This compares to a realized Q of 16,000 for a TE_{011} moded cavity at the same frequency. The effects of the degenerate $TM_{1m\ell}$ modes and of the adjacent TE modes were successfully minimized in the two prototypes.

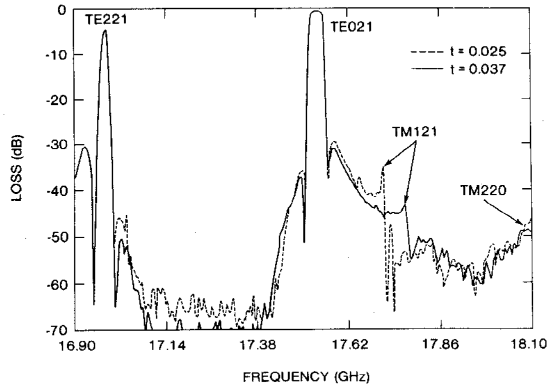

Figure 4. Typical Out-of-Band Transmission Response of 28-MHz TE_{021} Filters

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