A TE TRIPLE-MODE FILTER*

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ABSTRACT

A novel realization of triple-mode filters using only TE mode degeneracies is presented. This approach compares favorably with previous designs that employ mixed TE-TM modes. Experimental results obtained with a prototype six-pole, 11.9-GHz, quasi-elliptic, 30-MHz bandpass filter designed at the degeneracy of the TE_{114} and TE_{312} modes are shown to agree well with theory.

INTRODUCTION

Triple-mode degeneracy in cylindrical cavities has been successfully applied to the design of satellite communications filters and multiplexers. Previous approaches have employed either dual-TE/single-TM (1)-(3) or dual-TM/single-TE (4) modal combinations. This paper presents a novel realization of triple-mode filters that use only TE modes.

As an example, an 11.9-GHz, six-pole, quasi-elliptic response bandpass filter with two physical cavities, each operating at the degeneracy of the dual TE_{114} and single TE_{312} modes, is described. The unit's performance shows excellent agreement with the designed response.

TRIPLE DEGENERACIES IN CYLINDRICAL CAVITIES

Triple-mode degeneracies are illustrated in the mode chart of Figure 1. Previous bandpass filter designs employed mixed TE-TM triples (identified on the mode chart with a ○). However, triples with dual-TE/single-TE or dual-TM/single-TM modes (identified with a ◇) can also be used.

Table 1 lists several of these mode degeneracies. Each solution's applicability to a practical filter design depends on a tradeoff between weight/volume, resonator Q, and, in particular, the ability to independently tune and couple each mode. Further, for a filter having multiple cavities, independent coupling (or significantly different transverse fields) at the intercavity iris must be achieved. These concepts are illustrated in Figure 2 for a cavity employing the degeneracy of the dual-TE_{114} and single-TE_{312} modes (solution 7, Table 1).

External coupling to the TE_{312} modes can be achieved by using coaxial probes located at the point of null electric field for the TE_{114} mode. Coupling among TE_{114} modes in the same cavity is achieved via the conventional 45° coupling screw, and coupling of the TE_{312} to the TE_{114} modes is achieved with screws located at a position that perturbs both these modes. The tuning of each mode is accomplished at the point of maximum radial electric field.

Independent intercavity couplings for a multicavity filter can be realized with a pair of orthogonal slots, because of the difference between the radial magnetic field components of the two modes considered (see Figure 3).

EXPERIMENTAL FILTER AND RESULTS

A six-pole, quasi-elliptic bandpass filter response with a 30-MHz, 0.017-dB equiripple (24-dB return loss) bandwidth and 35-dB out-of-band rejection was chosen for synthesis. The coupling matrix (with normalized terminations R = 1.245) is as follows:

[M] =	1	2	3	4	5	6
1	0	0.924	0	0	0	0
2	0.924	0	0.616	0	-0.157	0
3	0	0.616	0	0.718	0	0
4	0	0	0.718	0	0.616	0
5	0	-0.157	0	0.616	0	0.924
6	0	0	0	0	0.924	0

Figure 4 depicts the selected topology and the modes corresponding to each resonator. The two cavities are cylindrical and dimensioned at the degeneracy of the TE_{114} dual and TE_{312} modes for a resonant frequency of 11.9 GHz.

The measured transmission and return loss exhibits excellent agreement with the designed performance (see Figure 5). The center frequency insertion loss of 0.7 dB corresponds to an average unloaded Q of 17,000, or a Q efficiency of 71 percent. The out-of-band response, plotted in Figure 6, exhibits a rejection greater than 34 dB

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Table 1. Triple TE-TM Degeneracies*

Solution Number	Dual	Single	D/L	$\Delta f/f_o$ (%) −	$\Delta f/f_o$ (%) +	$Q\sqrt{f}$ (K) (f in GHz) Dual	$Q\sqrt{f}$ (K) (f in GHz) Single	V/V_o**
	TE	TM						
1	112	211	0.896	17.1	10.1	58.5	45.5	3.07
2	112	311	1.388	6.9	5.2	63.5	52.2	5.523
3	113	211	0.548	6.8	10.5	66.4	43.3	4.21
4	113	311	0.850	7.9	6.0	79.8	50.9	7.29
5	114	212	0.448	4.8	10.1	76.3	47.6	6.14
6	114	213	0.386	4.3	3.2	88.7	61.7	8.61
7	114	312	0.694	5.5	5.2	95.7	56.1	11.05
8	115	213	0.388	3.8	7.7	85.9	52.4	8.41
9	116	211	0.262	5.4	2.6	76.5	41.5	8.07
	TM	TM						
1	110	011	1.899	8.5	8.5	46.0	30.9	2.14
2	110	012	0.950	7.3	7.3	60.9	46.0	4.28
3	110	013	0.633	4.9	3.3	68.2	55.0	6.42
4	120	011	4.196	2.5	2.5	53.1	31.6	5.95
5	120	012	2.098	2.5	2.3	80.2	53.0	11.90

*For degeneracies with $\Delta f/f_o > 2.1\%$.
**The normalizing volume, V_o, is the minimum volume of a cylindrical cavity resonating in the TE_{111} mode. This occurs for D/L = 0.83.

over a 1,430-MHz window, and a spurious free window in excess of 1,200 MHz. This correlates well with the predicted spurious modes positions, although these modes are shifted toward lower frequencies due to the presence of the tuning and coupling screws.

Figure 7 is a photograph of the bandpass filter.

CONCLUSIONS

A new triple-mode filter realization has been presented that has the advantages of high Q efficiency, a large spurious free window, and a geometry that lends itself to a series cascade of cavities, thus enabling easy realization of high-order transfer functions.

REFERENCES

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(4) R. R. Bonetti and A. E. Williams, "Application of Dual TM Modes to Triple and Quadruple Mode Filters," IEEE Transactions on Microwave Theory and Techniques, Vol. MTT-35, December 1987, pp. 1143-1149.

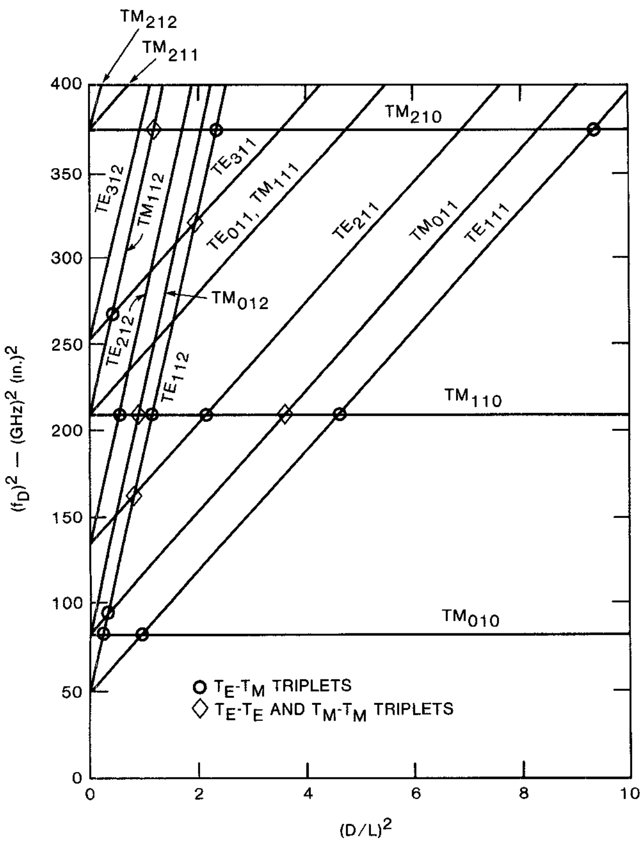

Figure 1. Mode Chart for a Right-Circular-Cylinder Resonator

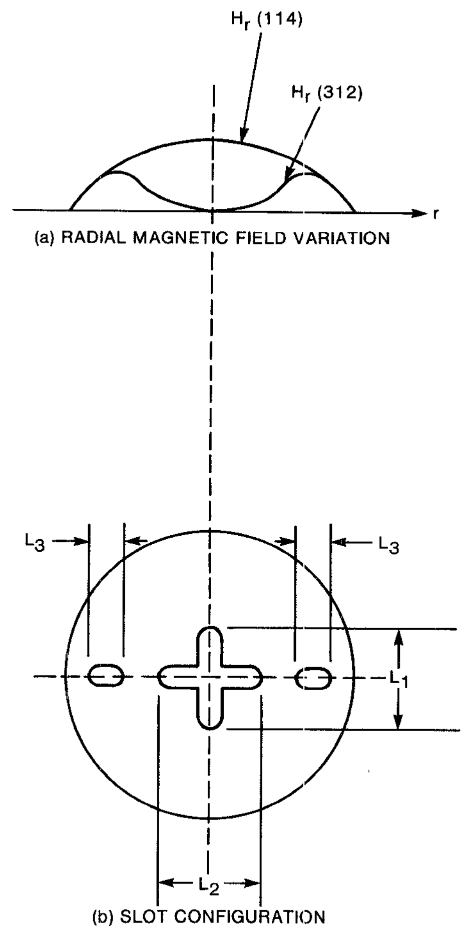

Figure 3. Iris and Field Variation

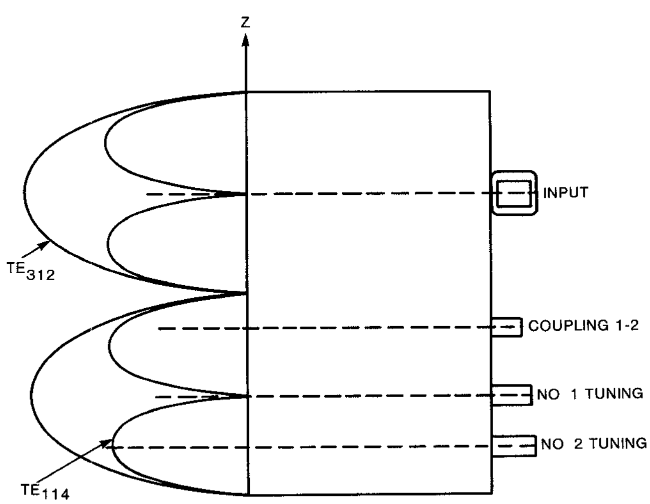

Figure 2. Tuning and Coupling of TE to TE Modes

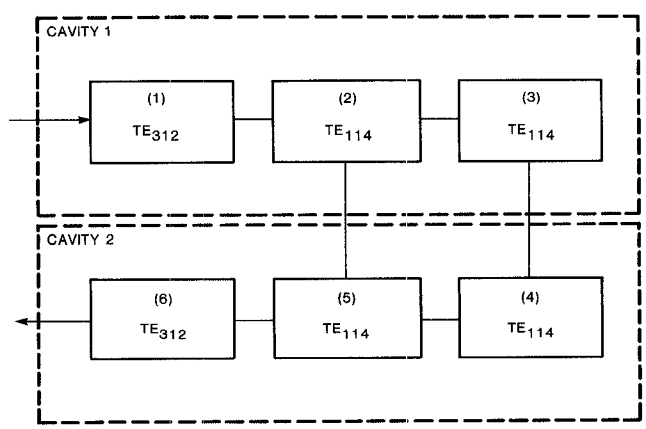

Figure 4. Quasi-Elliptic Triple-Mode Filter Topology and Modal Distribution

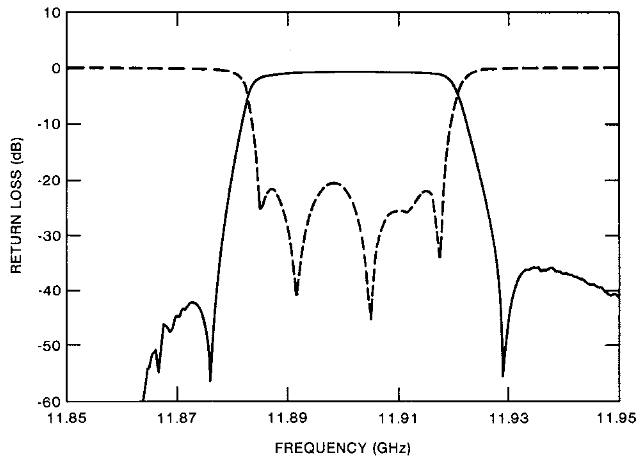

Figure 5. Measured Transmission and Return Loss

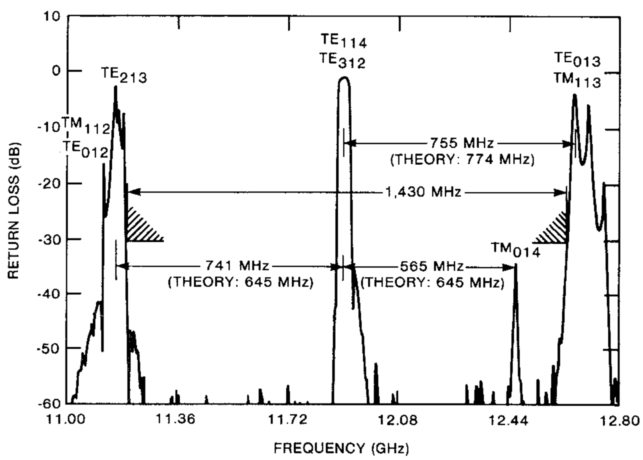

Figure 6. Out-of-Band Measured Response

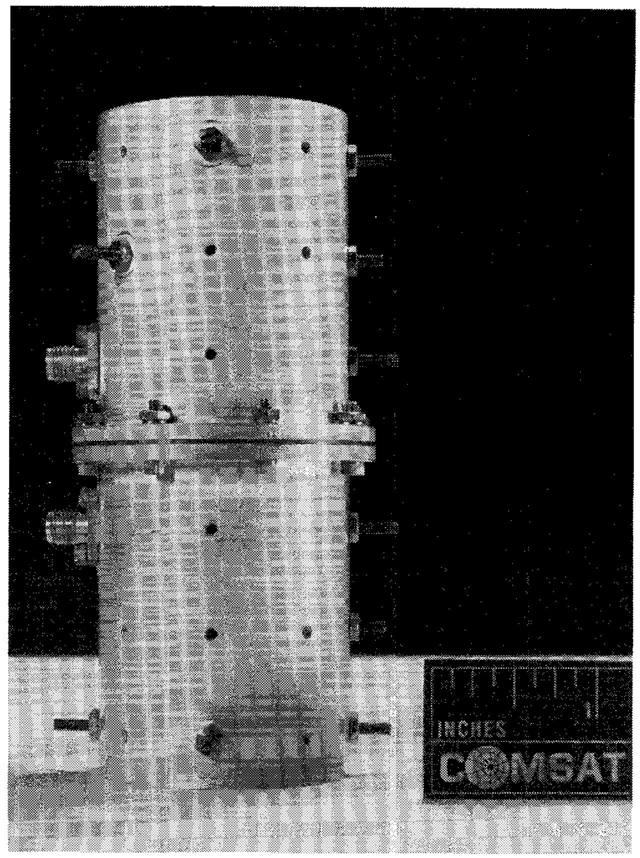

Figure 7. Triple-Mode Six-Pole Filter