A HEXA-MODE BANDPASS FILTER*

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Abstract

A 6-pole, K_u-band, pseudo-elliptic bandpass filter which utilizes the sixfold degeneracy of a single rectangular cavity is presented. This design achieves significant savings in mass and volume when compared to 6-pole dual and/or triple-mode filters of equivalent performance.

INTRODUCTION

Cylindrical cavity quadruple-mode (quad-mode) degeneracies permit innovative filter and multiplexer designs for satellite transponders. For example, 8-pole filters have been built from combinations of two quad-modes (1), 10-pole filters from two quad and one dual-mode cavities (2), and a contiguous-band multiplexer from a single quad-mode cavity per channel (3). Extending the concept of multiple degeneracies to more than four modes is possible, but independent tuning and coupling of the desired modes is difficult to control.

In comparison, the rectangular cavity has one more degree of geometric freedom than the cylindrical cavity, namely, the a/b ratio (where a and b are the rectangular base dimensions). This permits practical sixfold degeneracies, such as the hexa-mode cavity. Not only will this cavity realize a 6-pole response, but it can also act as a building block for higher order filter designs such as hexa-dual-mode to provide 8-pole filters, and hexa-quadruple for 10-pole designs.

This paper presents some of the practical mode degeneracies of rectangular cavities, together with properties applicable to filter designs. These parameters are used to generate a novel bandpass filter realization: a single cavity, 6-pole filter called the hexa-mode. A K_u-band prototype was successfully designed and built.

RECTANGULAR CAVITY-MODE DEGENERACY

The resonant frequencies of rectangular cavity modes were computed from the well-known eigenvalue equations (*e.g.*, Reference 4), and the mode degeneracies were evaluated using a numerical search subroutine. For each solution, the adjacent modes were determined and spurious-free frequency windows were computed. Table 1 presents a representative set of these degeneracies, along with the following relevant properties for multimode filter designs:

- Cavity shape ratios (a/c, a/b) where a, b, and c are the three dimensions of the rectangular cavity
- Mode nomenclature
- Spurious-free frequency windows (normalized with respect to the center frequency, f_o) below f_o ($\Delta f-$) and above f_o ($\Delta f+$)
- Normalized theoretical Q ($Q\sqrt{f_o}$) for silver-coated cavities
- Normalized volume—relative to the minimum volume of the fundamental, cylindrical-mode TE 111 cavity to facilitate direct comparison with previously published data (1).

The first two sets show triple TE mode degeneracy, while the third set is a quadruple degeneracy of three TE and one TM mode. The last two solutions give sixfold degeneracy in cubic cavities. The most interesting modal set from a practical viewpoint is the fourth, since it allows a wider, spurious-free window and a more compact cavity. This cavity was chosen for realization of a 6–pole response.

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Table 1. Representative Sets of Rectangular Cavity-Mode Degeneracies

		Modes		$\Delta f-$	$\Delta f+$	$Q\sqrt{f}$	
a/c	a/b	TE	TM	(%)	(%)	(K)	V/V_0
0.612	2.000	011		24.4	6.9	32.5	2.66
		103				45.5	
		201				39.3	
0.612	1.000	021		10.5	6.9	52.7	5.32
		103				64.4	
		201				52.7	
1.000	2.000	011		36.7	9.5	35.9	1.99
		102	110			41.3; 35.9	
		201				41.3	
1.000	1.000	021	120	22.5	9.5	55.1	3.98
		102	210				
		201					
		012					
1.000	1.000	031	130	5.1	4.9	77.9	11.35
		103	310				
		301					
		013					

PROTOTYPE DESIGN

A 6-pole, pseudo-elliptic bandpass filter was designed with the following properties:

Center Frequency	11.86 GHz
Bandwidth	85 MHz
Return Loss	>20 dB

The computed frequency response is shown in Figure 1, and the corresponding normalized coupling matrix elements are

$$M(1,2) = 0.942 = M(5,6)$$
$$M(2,3) = 0.615 = M(4,5)$$
$$M(3,4) = 0.655$$
$$M(1,6) = -0.13$$

with $R_{in} = R_{out} = 1.290$.

Figure 2 depicts the mode routing selected for the hexa-mode filter implementation, and Figure 3 shows the position of tuning and coupling screws. Input and output connections are provided via coaxial probes. This technique limits the maximum achievable out-of-band rejection because spurious coupling occurs between the probes. This problem can be resolved in the realization of filters with order greater than 6 by selecting a topology that allows the input and output coupling to occur in different physical cavities (1).

The filter was tuned using techniques similar to those described previously (1),(2). Four resonators

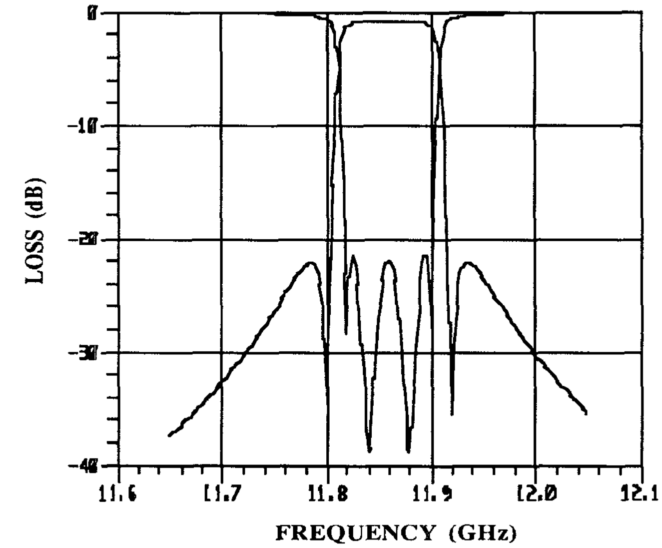

Figure 1. Pseudo-Elliptic Function, 6-Pole Bandpass Filter Theoretical Response

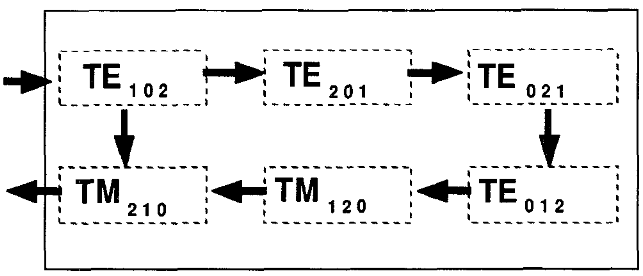

Figure 2. Mode Routing for Hexa-Mode Filter Realization

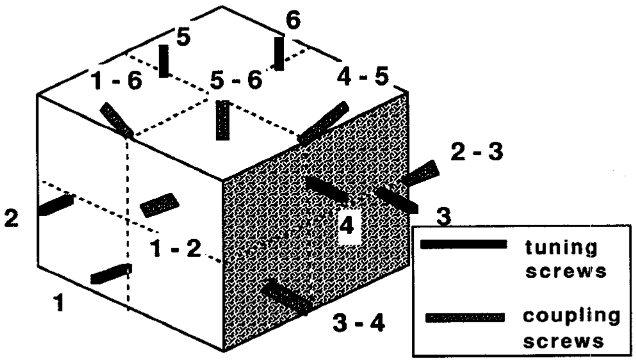

Figure 3. Hexa-Mode Filter Tuning and Coupling Screws Configuration

were initially aligned and their couplings adjusted. The input and output ports were then interchanged and the remaining two modes resonated. This technique led to an initial 10-dB return loss, while the final 20-dB return loss was achieved by normal tuning of the swept frequency response.

MEASURED PERFORMANCE

Figure 4 shows the measured transmission and return losses of the prototype hexa-mode filter (not silver-plated), and Figure 5 depicts the measured out-of-band response. Note that the spurious passband frequency was shifted lower due to the presence of the tuning screws. The midband insertion loss of 0.9 dB corresponds to an unloaded Q of 6,000, whereas a silver-plated filter is estimated to have a Q of 8,000.

CONCLUSIONS

The practical multiple-mode degeneracies of rectangular cavities which are directly applicable to multimode bandpass filter designs have been presented. A 6-pole K_u-band, pseudo-elliptic, single-cavity bandpass filter was successfully designed and built. Since all inter-resonator couplings were realized via tuning screws, fabrication and alignment were greatly simplified. This design offers significant savings in mass and volume compared to dual- and triple-mode, 6-pole filter designs with equivalent Qs.

REFERENCES

(1) R. R. Bonetti and A. E. Williams, "Application of Dual TM Modes to Triple- and Quadruple-Mode Filters," *IEEE Trans Microwave Theory Tech*, Vol. MTT-35, pp. 1143–1149, Dec. 1987.

(2) A. E. Williams and R. R. Bonetti, "A Mixed Dual-Quadruple Mode 10-Pole Filter," European Microwave Conference, Stockholm, *Proc*, pp. 966–968, Sep. 1988.

(3) R. R. Bonetti and A. E. Williams, "A Quadruple-Mode Contiguous-Band Multiplexer for Communications Satellites," European Microwave Conference, London, *Proc*, pp. 687–692, Sep. 1989.

(4) G. Matthaei, L. Young, and E. Jones, *Microwave Filters, Impedance Matching Networks and Coupling Structures*, New York: McGraw-Hill, Chapter 5, 1964.

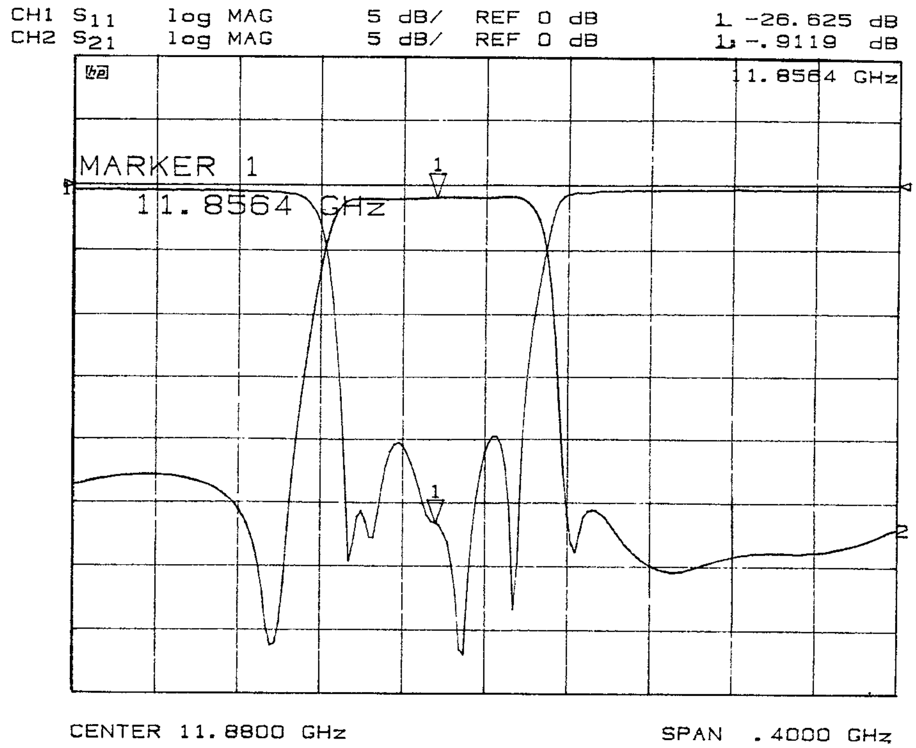

Figure 4. Measured Filter Response

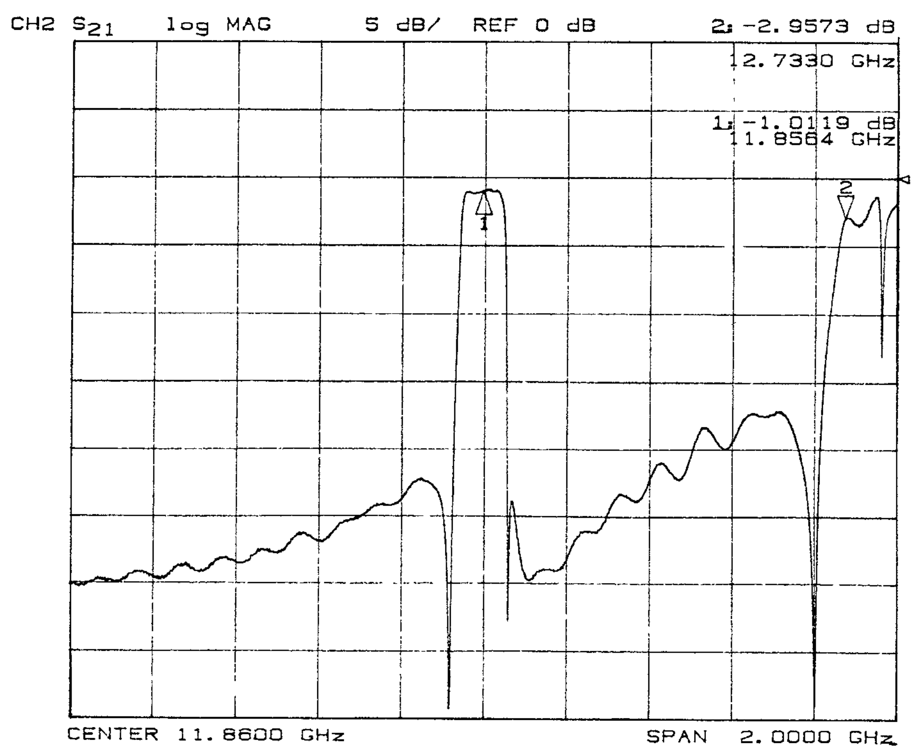

Figure 5. Measured Out-of-Band Response