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Realization of an Exact 5-Pole Elliptic Function Filter Employing Dielectric Loaded Triple-Dual-Mode Cavity Structure

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ABSTRACT

A novel 5-pole symmetrical elliptic (with four transmission zeros) dielectric resonator filter has been built, using a cascade of a triple-mode and a dual-mode cavity and an unconventional resonant cross-coupling screw structure. Such a structure offers performance improvement over existing designs and makes it an attractive candidate for output multiplexer applications for future C-band satellite systems.

INTRODUCTION

Recent developments in dielectric resonator filters and multiplexers have proven significant weight and size reductions for satellite applications. A further reduction in weight and size has also been achieved through the use of triple-mode dielectric resonators, as reported by Tang, et al [1].

The use of triple-mode dielectric resonators also enables the realization of more exotic filter functions due to the availability of cross-couplings not physically possible for single- or dual-mode filters. Previously, Atia and Williams [2] showed that, for resonant cavity bandpass filters using conventional iris and screw couplings, the maximum number of transmission zeros that can be realized is n-2, where n is the order of the filter. This means that, for a 5th order filter, the maximum number of transmission zeros is three (5-3) and two (5-2) for the asymmetric and symmetric cases respectively. A.E. Williams [3] has illustrated a single-mode 3-pole elliptic (3-2) filter in waveguide using a resonant iris structure. This paper attempts to show that a truly elliptic symmetric triple-mode odd-order dielectric resonator filter (with number of transmission zeros equal to n-1, where n is odd) can be realized through the use of resonant coupling structures and cross-couplings available only to triple-mode filters.

An odd order symmetrical 5-4 triple-mode dielectric resonator filter has been developed. The design and measured results of this filter are described in this paper.

FILTER DESIGN

A study conducted for a U.S. satellite prime contractor (COM DEV internal report) showed that a contiguous multiplexer design using 5-2 channel filters yielded the best overall channel performance compared to the more conventional 4-2 and 6-2 designs when multipath effects are taken into account. However, a more recent study has demonstrated significant improvement in electrical performance over the 5-2 design by using 5-4 channel filters. However, realization of such a function was not possible using conventional dual or even triple-mode structures. This paper describes how such a filter function can be realized in a triple-dual-mode structure.

The 5-4 filter built utilizes a cascade of a triple-mode and a dual-mode dielectric loaded cavity. The triple-mode cavity contains two HE_{112} modes and a TM_{011} mode, and the dual-mode cavity has two orthogonal HE_{112} modes. Figure 1 shows the coupling matrices of a 5-pole filter with two transmission zeros on the lower and upper stopband respectively, the computed responses of which are shown in Figure 2. The realization of the 5-4 filter required that coupling M_{15} and M_{35} reverses its sign about the resonant frequency of the filter under consideration. This can be achieved through a resonant M_{15} and M_{13} coupling structures.

$$M = \begin{bmatrix} 0 & 1.0657 & -0.4000 & 0 & 0.150 \\ 1.0657 & 0 & 0.6927 & 0 & -0.3497 \\ -0.4000 & 0.6927 & 0 & 0.7814 & 0 \\ 0 & 0 & 0.7814 & 0 & 0.8400 \\ 0.150 & -0.3497 & 0 & 0.8400 & 0 \end{bmatrix}$$

$R = 1.0329$

Figure 1: Coupling Matrix for 5-4 Filter with Two Pairs of Transmission Zeros

The vector diagram showing the different resonant modes is presented in Figure 3. As illustrated in Figure 2, the required cross couplings are M_{13}, M_{15} and M_{25}. M_{25}, being an inter-cavity cross-coupling, can be realized by an iris between the triple-mode and dual-mode cavities. On the other hand, the required resonant couplings, M_{15} and M_{13} are respectively an inter-cavity and intra-cavity cross coupling. This resonant coupling structures can be physically realized by using resonant iris for M_{15} [3] and an extra coupling screw for M_{13}.

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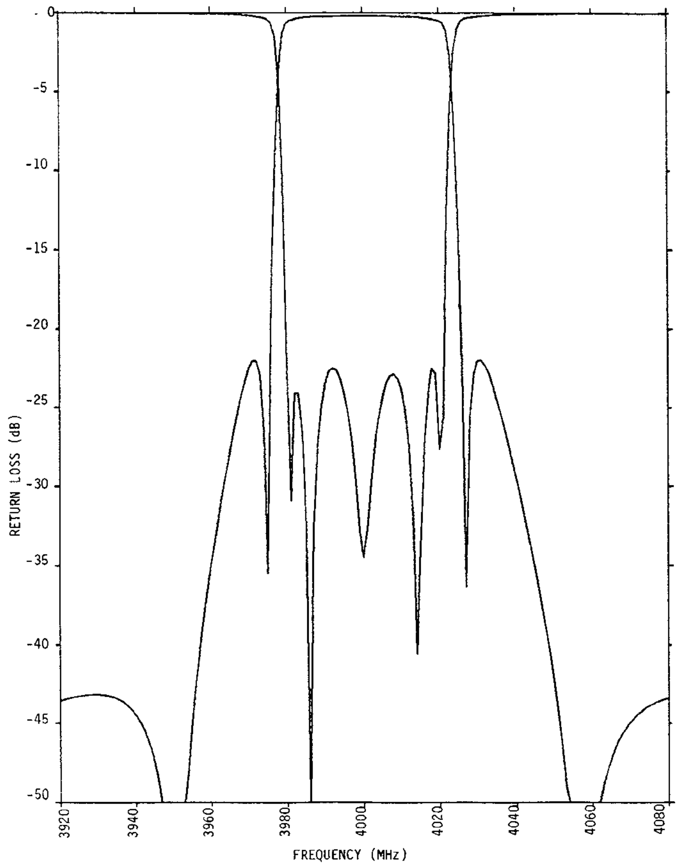

Figure 2: Computer Simulated 5-4 Filter Based on Coupling Matrix Presented in Figure 1.

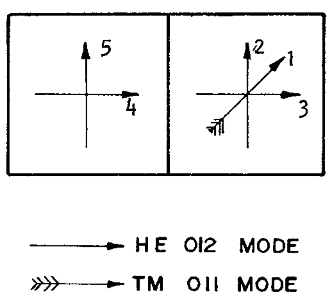

Figure 3 : Vector Diagram Showing Mode Coupling of 5-4 Triple-Mode Dielectric Resonator.

MEASURED RESULTS

Based on the design illustrated in the above section, a 5-4 triple-mode dielectric resonator filter has been built. The physical structure of the 5-4 dielectric resonator filter breadboard model is shown in Figure 4. The test results, shown in Figures 5(a) and 5(b), demonstrate return loss of 22 dB and notch levels of 30 and 37 dB respectively. The filter had a center frequency of 4332 MHz and a usable bandwidth of 37 MHz.

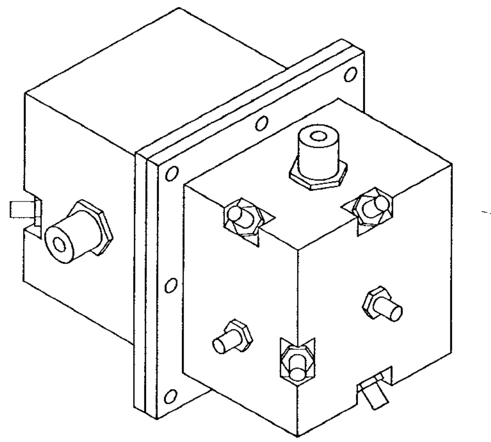

Figure 4 : 5-4 Triple-Mode Dielectric Resonator Breadboard Model.

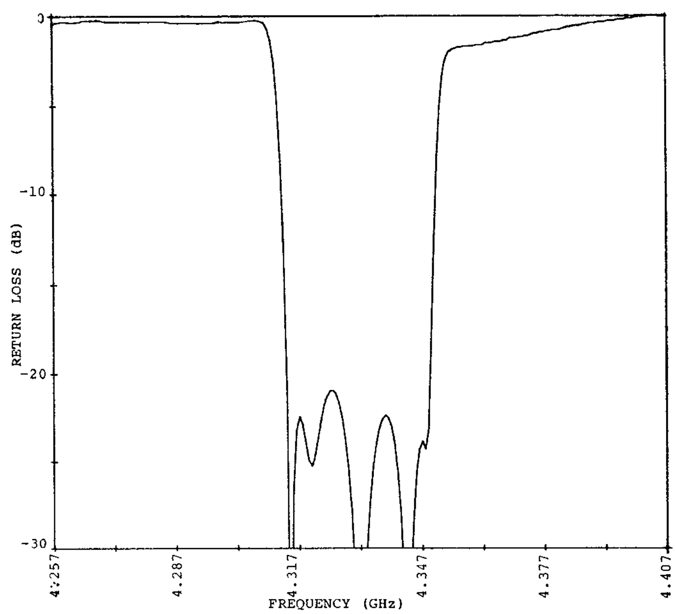

Figure 5(a): Measured Return Loss Response of 5-4 Triple-Mode Dielectric Resonator Filter.

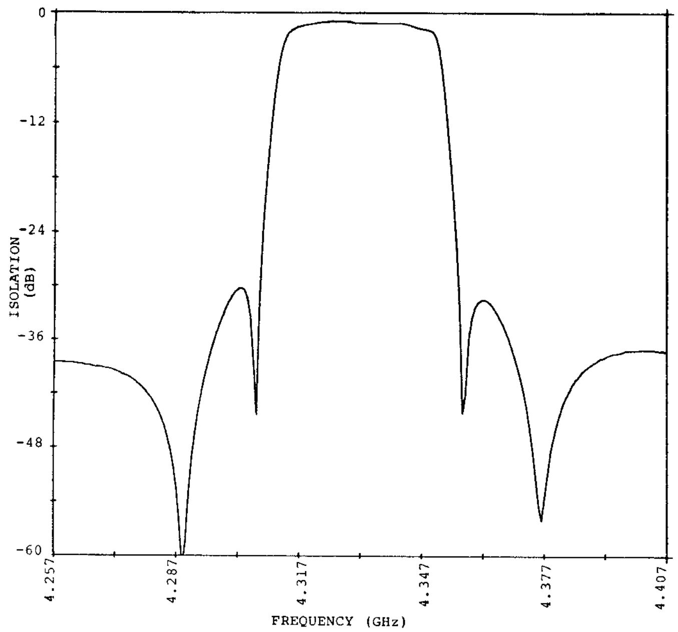

Figure 5(b): Measured Isolation Response of 5-4 Triple-Mode Dielectric Resonator Filter.

CONCLUSIONS

Based on the design and measured results of the 5-4 triple-mode dielectric resonator filter, the following conclusions are:

- 5-4 channel filters provide superior overall multiplexer performance to that of 5-2, 4-2 or 6-2 filter design;
- Physical realization of the 5-4 filter can be made possible through the use of resonant coupling structures and cross-couplings only available to triple-mode filters;
- Measured results demonstrate close correlation with theory.

These conclusions indicate that this design would be an attractive candidate for output multiplexer application for future C-band satellite systems.

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