Realization of Dual-Mode Longitudinal Filters with Arbitrary Polarization of Input and Output Ports

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ABSTRACT

This paper describes the synthesis techniques and experimental verification for the realization of dual-mode longitudinal filters with arbitrary polarization of input and output ports. This represents a generalization of the synthesis procedure and offers the possibility of different physical form factors in the implementation of filters and multiplexing networks for satellite systems.

INTRODUCTION

Synthesis of dual-mode longitudinal bandpass filters is characterized by its input and output ports co-polarized for order 4, 8, 12,..., and cross-polarized for order 6, 10, 14,... This restriction stems from synchronously-tuned filter cavities. The theory and physical realization of these conventional dual-mode filters is well described in the literature [1,2]. More recently, Cameron [3] has extended the dual-mode network synthesis to include asynchronously-tuned cavities. This allows realization of asymmetric electrical response functions. The work described in this paper represents an extension of Cameron's work. By allowing asynchronous-tuning of waveguide cavities and iris rotations with respect to the input and output ports, it is possible to realize an infinity of solutions for both electrically, symmetrical or asymmetrical response functions as a function of the angle between the input and output polarization of the signals. The experimental results are described which show excellent correlation with theory. This represents a complete generalization of the synthesis procedure within the constraint of a dual-mode longitudinal structure. Conventional dual-mode designs with symmetrical or asymmetrical response functions having co- or cross-polarized input and output ports represent a sub-set of the more general realization described here.

GENERAL SYNTHESIS OF DUAL-MODE LONGITUDINAL FILTERS

The conventional dual-mode longitudinal structure is shown in Figure 1.

Such a filter network is characterized by:

(i) Synchronously-tuned coupled cavities ($M_{ii} = 0$);

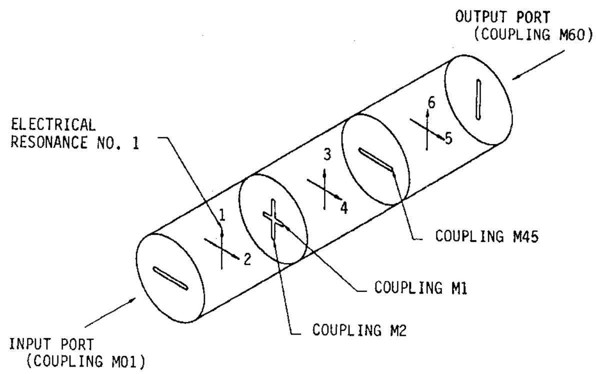

Figure 1 : Conventional Dual-Mode Longitudinal Structure, 6th Order Example

(ii) Couplings between non-adjacent physical cavities are zero;

(iii) All iris couplings are polarized parallel or perpendicular to the input and output ports.

Consequences of condition (iii) imply that certain couplings like M_{13}, M_{24}, M_{35}, etc., are zero and that the input/output ports would be either co- or cross-polarized.

The above constraints for the conventional dual-mode filters restrict the number of feasible solutions, quite often rendering them unique depending upon the required response function. Intuitively, one can say that removal of these restrictions should permit other solutions. A general dual-mode longitudinal structure is shown in Figure 2.

The only restriction is that couplings between non-adjacent physical cavities be zero. It is possible to realize such solutions via similarity transformations [1] in conjunction with an optimization routine to reduce couplings between non-adjacent cavities to zero. A simpler and more elegant realization of the general dual-mode networks is described in the following steps:

(a) Obtain the solution of a conventional dual-mode longitudinal network in canonical form. This is characterized by alternate cross-couplings only or a cascade quadruplet structure [2];

(b) Perform a similarity transformation using pivot [2,3].

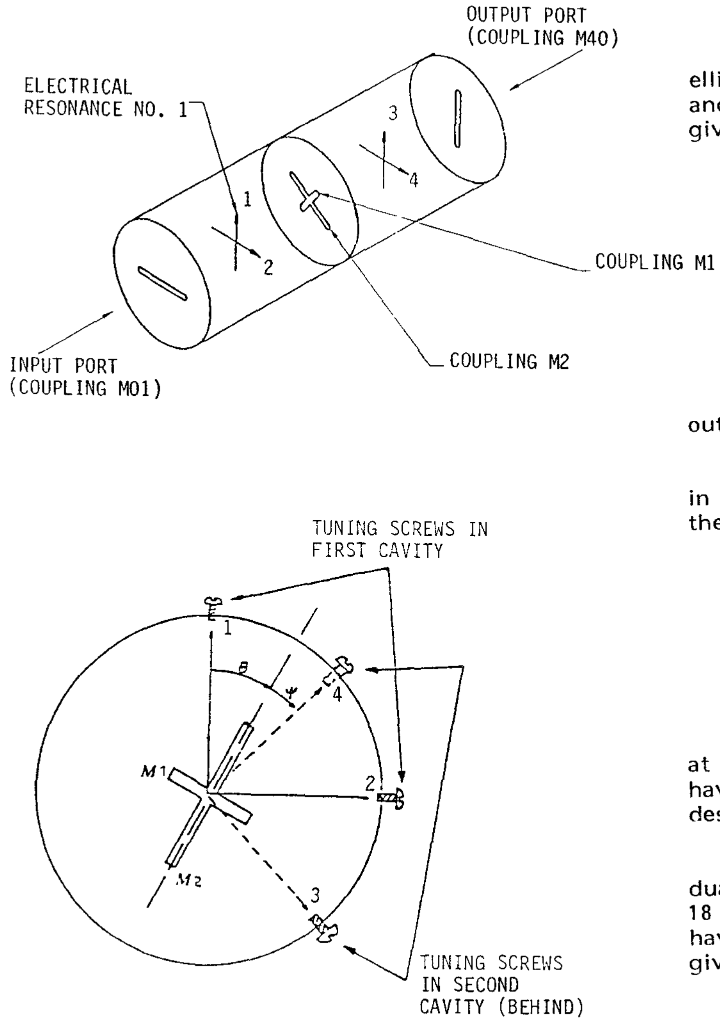

Figure 2 : General Dual-Mode Longitudinal Structure, 4th Order Example

Such a rotation maintains couplings between non-adjacent physical cavities to be zero and allows rotation of the first iris only;

(c) The rotation angles of the first iris and subsequent cavities can be determined by [3].

From Figure 2 it can be clearly seen that θ is the angle of rotation of first iris, whereas $\theta+\psi$ represents the rotation of cavities as well as the angle between the input and output ports.

In order to estimate α the angle of rotation of the coupling matrix for a specific angle between input and output ports, it is convenient to compute and plot α vs. $\theta+\psi$.

MEASURED DATA

The coupling matrix of a conventional 4-pole elliptic function filter with a return loss of 30 dB and a pair of transmission zeros at $\omega = \pm j2.1702$ is given by:

$$M = \begin{bmatrix} 0 & 1.1074 & 0 & -0.3035 \\ 1.1074 & 0 & 0.9448 & 0 \\ 0 & 0.9448 & 0 & 1.1074 \\ -0.3035 & 0 & 1.1074 & 0 \end{bmatrix}$$

Normalized Terminations = 1.551.

This network has co-polarized input and output ports.

Following the synthesis procedure described in the preceding sections, the coupling matrix with the input and output ports at 90° is given by:

$$M = \begin{bmatrix} 0 & 0.9001 & 0.6451 & -0.3035 \\ -0.9001 & -0.8947 & 0.3035 & -0.6451 \\ 0.6451 & 0.9448 & 0.8947 & 0.9001 \\ -0.3035 & -0.6451 & 0.9001 & 0 \end{bmatrix}$$

Normalized Terminations = 1.551.

The measured response of this filter realized at 12 GHz with an equi-ripple bandwidth of 40 MHz having cross-polarized input and output ports is described in Figure 3.

Similarly, the coupling matrix of a 6-pole dual-mode longitudinal filter with a return loss of 18 dB and a pair of transmission zeros at $\pm j1.4258$ having co-polarized input and output ports is given by:

$$M = \begin{bmatrix} 0 & 0.6155 & 0.4669 & -0.1941 & 0 & 0 \\ 0.6155 & -0.6933 & 0.1941 & -0.3193 & 0 & 0 \\ 0.4669 & 0.1941 & 0.6933 & 0.4210 & 0 & 0 \\ -0.1941 & -0.3193 & -0.4210 & - & 0.5872 & 0 \\ 0 & 0 & 0 & 0.5872 & 0 & 0.7966 \\ 0 & 0 & 0 & 0 & 0.7966 & 0 \end{bmatrix}$$

Measured response of this filter is shown in Figure 4. There is excellent correlation between measured and simulated responses for both the 4-pole elliptic and 6-pole quazi-elliptic filters. Photographs of the actual 4-pole and 6-pole brass breadboard filters are given in Figures 5 and 6 respectively.

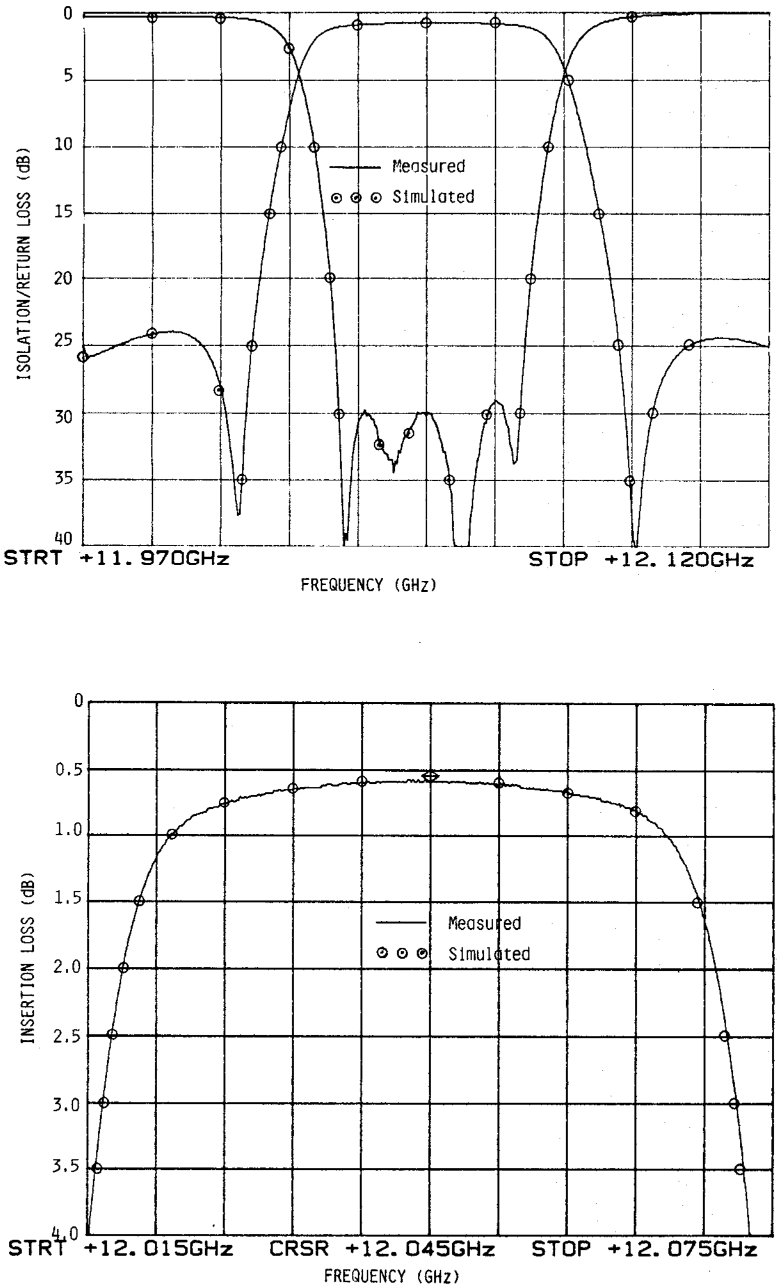

Figure 3 : Measured Frequency Response for the 4-Pole Elliptic Filter Realized in Longitudinal Dual-Mode Structure with Cross-Polarized Input and Output Ports.

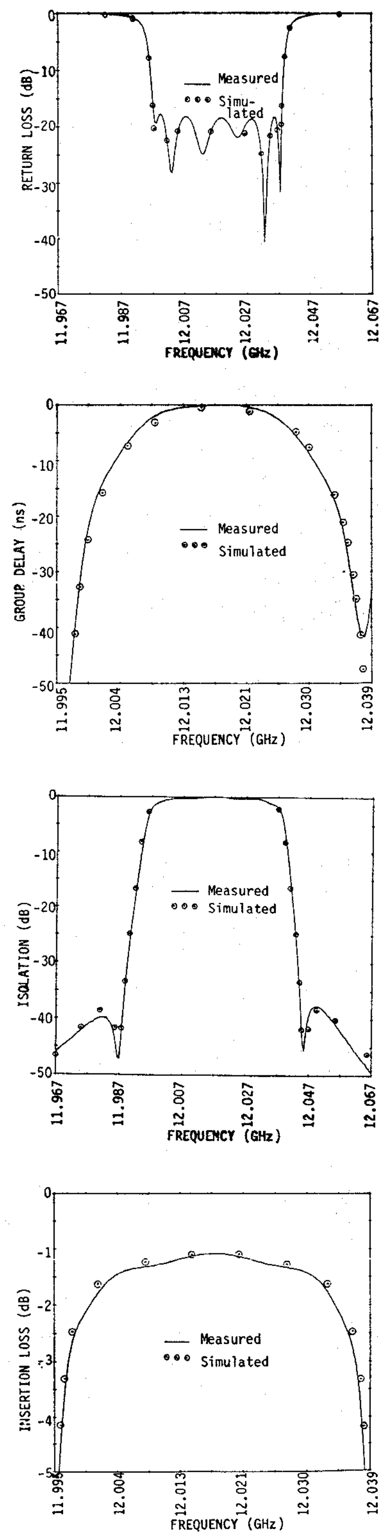

Figure 4 : Measured Frequency Response of the 6-Pole Dual-Mode Longitudinal Quazi-Elliptic Filter with Co-Polarized Input and Output Ports.

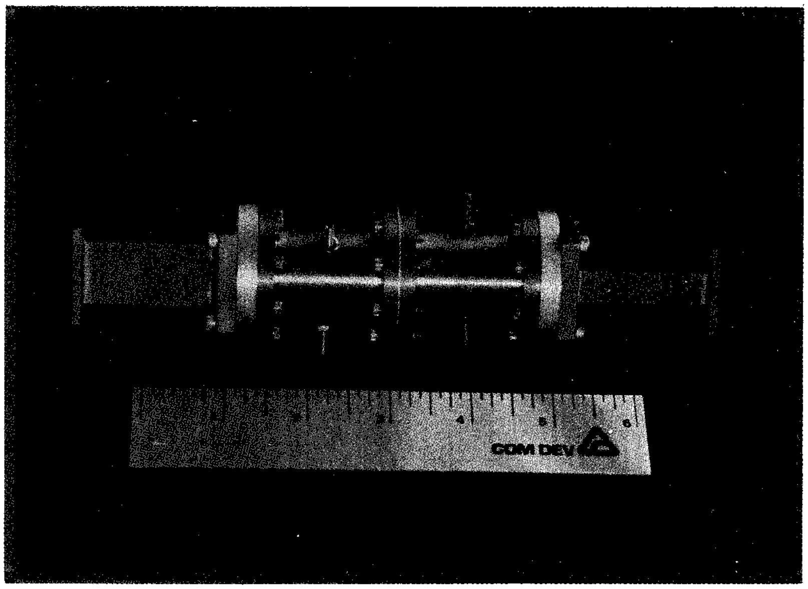

Figure 5 : Photograph of the Experimental Dual-Mode Longitudinal 4-Pole Elliptic Filter with Cross-Polarized Input and Output Ports.

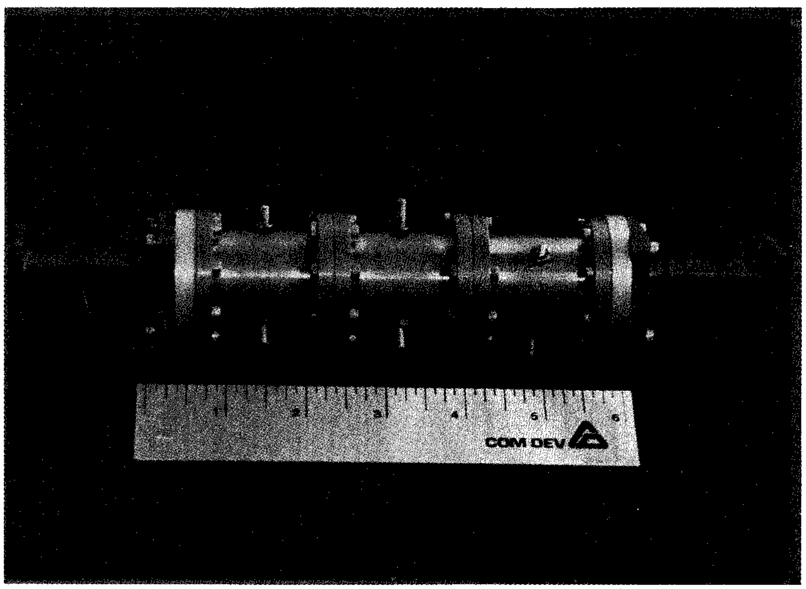

Figure 6 : Photograph of the Experimental Dual-Mode Longitudinal 6-Pole Quazi-Elliptic Filter with Co-Polarized Input and Output Ports.

CONCLUSIONS

A synthesis procedure is described to realize dual-mode longitudinal filters having arbitrary polarizations of input and output ports. Experimental 4-pole and 6-pole filters have been built for the extreme cases, when the input and output ports are cross-polarized for the 4-pole filters and co-polarized for the 6-pole filter. The infinity of solutions imply different physical form factors which could offer advantages in the practical implementations of filters and multiplexing networks for satellite and earth station systems.

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