SHORT-CIRCUIT TUNING METHOD FOR SINGLY TERMINATED FILTERS*

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Abstract

This paper describes a filter tuning method based upon the match of measured and computed input impedances for a short-circuited filter. Two singly terminated filters, an 8-pole Chebychev filter and a 6-pole pseudo-elliptic function filter, tuned by using this method have demonstrated excellent performance.

Introduction

Singly terminated filters are the key elements in constructing a contiguous band multiplexer.[1] Due to the lack of a systematic tuning method for the singly terminated filter, the contiguous band multiplexer would be difficult to construct and tune. This may be why the contiguous band multiplexer is seldom used in a practical system.

The conventional filter tuning is based upon the return loss characteristics of a filter. Minimum reflection in the passband with correct center frequency and bandwidth is usually the criterion for tuning doubly terminated filters. Since the input port for a singly terminated filter is not matched over the entire passband due to the existence of passband reactance, the criterion of minimum reflection cannot be used for filter tuning. A method based upon the filter's short-circuit impedance, which has been used for the measurement of intercavity couplings,[2] has been further developed for tuning singly terminated filters. This paper presents this filter tuning method, as well as the experimental results for two model filters tuned by using this method.

Network Model and Tuning Procedure for the Filter

With the short-circuit filter tuning method, the tuning and coupling screws are set one by one according to the match of measured and computed input impedances for a short-circuited filter. Therefore, the correct network representation for the filter is extremely important. Consider a multiple-coupled cavity network[3,4] whose currents and voltages are related by an impedance matrix Z as follows:

$$\begin{bmatrix} V_1 \\ V_2 \\ \vdots \\ V_N \end{bmatrix} = Z \begin{bmatrix} I_1 \\ I_2 \\ \vdots \\ I_N \end{bmatrix} \qquad (1)$$

with

$$Z_{ii} = \frac{1}{Q_u \times BW} + j\,\frac{2}{\pi \times BW}\left(\frac{\lambda_{oi}}{\lambda g_{oi}}\right)^2 \tan\left(\frac{\pi\lambda g_{oi}}{\lambda_g}\right) \qquad (2)$$

$$i = 1, 2, \ldots, N$$

$$Z_{ij} = jM_{ij}, \qquad i \neq j \qquad (3)$$

where Q_u is the unloaded cavity Q, BW is the fractional bandwidth, and λ and λ_g are the free space and guide wavelengths, respectively.

When the cavity i is resonant, λ and λg_{oi} are set according to the mid-band frequency of the filter; when i is not resonant, λg_{oi} and λ_{oi} are set according to a detuned frequency, which may be measured in advance. The coupling coefficients, M_{ij}, the input resistance, R_1, and the output resistance, R_2, define the network as shown in Figure 1 with the input at AA' and output at BB'. A short-circuited filter is a 1-port network with a short circuit at BB' and the input at AA'. Thus, this short-circuited filter may be used to set the tuning and coupling screws one by one as the cavity resonance is progressively changed from a detuned to a tuned condition. However, the reference plane for a waveguide filter in the tuning setup is usually coincident with the input slot, which is unfortunately not on plane AA' in the network model of Figure 1. Therefore, it would be necessary to modify the network model to have a reference plane at the location of the input slot.

As is well known, the first or last section of a waveguide filter is usually an impedance inverter with the parameter determined by the input or output impedance of the filter. The network in Figure 1 may be reconstructed as shown in Figure 2, where two impedance inverters have been added in cascade at the input port. Adding two impedance inverters as shown in Figure 2 does not change the impedance characteristics for the filter, but provides access to the inside of an impedance inverter without disturbing the network representation from AA' and BB'. The shunt inductance X' is the normalized inductance for the input slot and,[5]

$$\phi = -\frac{1}{2}\tan^{-1} 2X' \qquad (4)$$

$$K = \tan|\phi| \qquad (5)$$

As shown in Figure 2, a network with an input port at tt' may be realized by adding an impedance inverter, K; a section of 1-ohm transmission line with a phase shift of ϕ; and a shunt inductance X' in front of the input port of the original network. The shunt inductance X' represents the input slot, which is located on the tt' plane in a practical waveguide filter. Since this network has access to the inductance that represents the input slot, the frequency dispersion of the input slot may also be added conveniently.

At the beginning of filter tuning, all the cavities should be set in the detuned condition. Cavities 1, 2, 3, . . ., may be changed from a detuned to a tuned condition one by one according to the match of the measured input impedance and the impedance computed through equation (1) with the resonance conditions for Z_{11}, Z_{22}, . . ., changed accordingly. Since the input impedances to be compared are for the short-circuited filters, the reflection amplitude is near unity and insensitive to frequency; therefore, the main task during

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the filter tuning is matching of the reflection phase. Although the computed and measured reflection phase should be matched over a wide frequency range for every frequency, it has been found that matching them at the frequency interval which corresponds to a 90° phase change is sufficient during practical tuning.

Experimental Results

An 8-pole singly terminated Chebychev filter (see Figure 3a) and a 6-pole singly terminated pseudo-elliptic function filter (see Figure 3b) tuned by using this short-circuit tuning method have yielded satisfactory results. Since the filters have been constructed as cascading structures, each filter may be divided into two short-circuited pieces and tuning may proceed from both input and output ports.

In tuning the Chebychev filter, tuning screws 1, 2, 3, and 4 and coupling screws (1, 2), (2, 3), (3, 4), and (4, 5) may be set by the input port tuning, and tuning screws, 8, 7, 6, and 5 and coupling screws (7, 8), (6, 7), and (5, 6) may be set by the output port tuning. After the tuning screws and coupling screws have been set, the filter may be reassembled and should have the correct responses without any adjustment. The transmission loss, return loss, and reflection phase performance is presented in Figure 4.

In tuning the 6-pole pseudo elliptic filter, tuning screws 1, 2, 3, and 4 and coupling screws (1, 2) and (3, 4) may be set by the input port tuning, and tuning screws 6 and 5 and coupling screw (5, 6) may be set by the output port tuning. The transmission loss, return loss, and reflection phase performance is presented in Figure 5.

Conclusions

The short-circuit tuning method is a step-by-step tuning method which is both accurate and time saving. It is applicable to singly as well as doubly terminated filters.

Correct tuning for the singly terminated filter is a key to the success of a contiguous band multiplexer.[5] The out-of-band reactance, which has usually been disregarded in conventional tuning, plays an important role in a contiguous band multiplexer. With the short-circuit tuning method, the out-of-band reflection phase can be correctly tuned.

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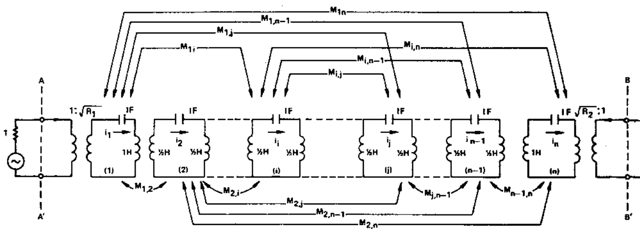

Figure 1. Lumped Circuit Representation for an N-Pole Synchronously Tuned Cavity Filter

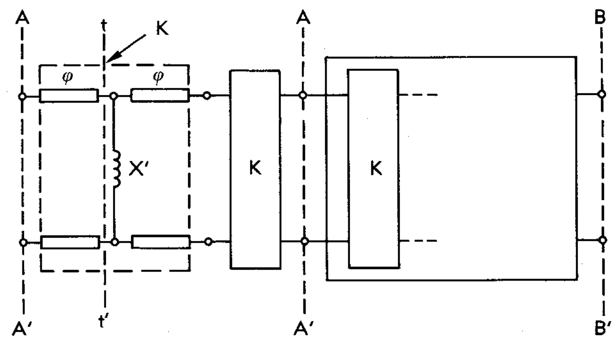

Figure 2. Modified Representation with Proper Reference Plane for the Network in Figure 1

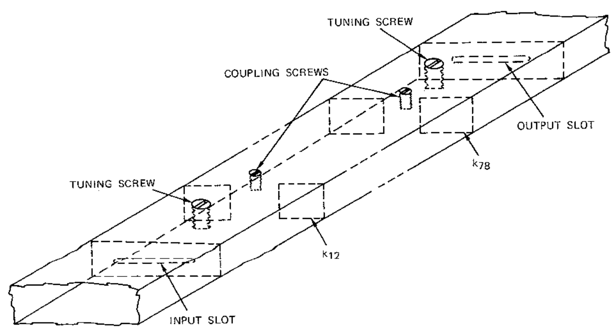

Figure 3a. 8-Pole Chebychev Filter Configuration for Experimental Model

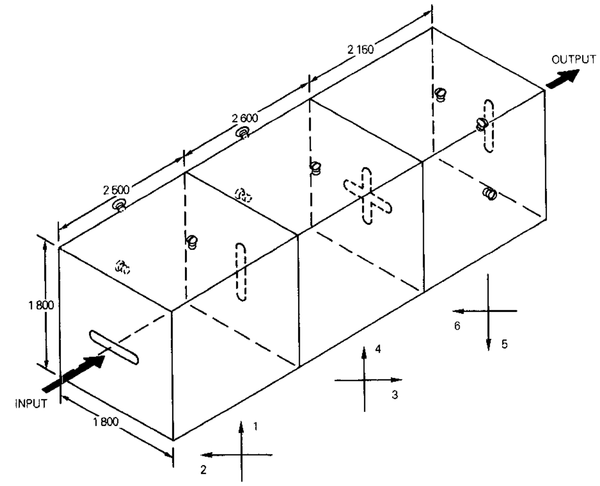

Figure 3b. 6-Pole Pseudo-elliptic Function Filter Configuration for Experimental Model

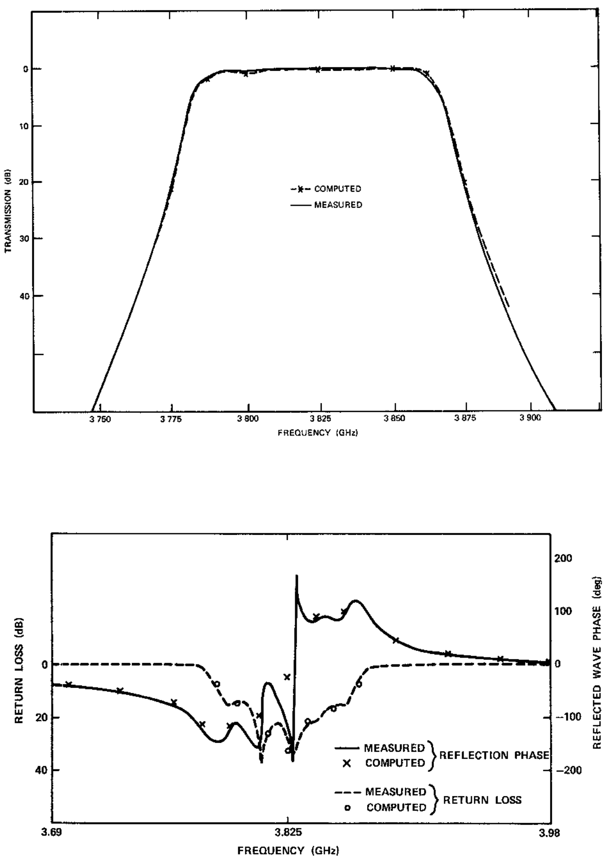

Figure 4. Filter Performances for an 8-Pole Chebychev Filter

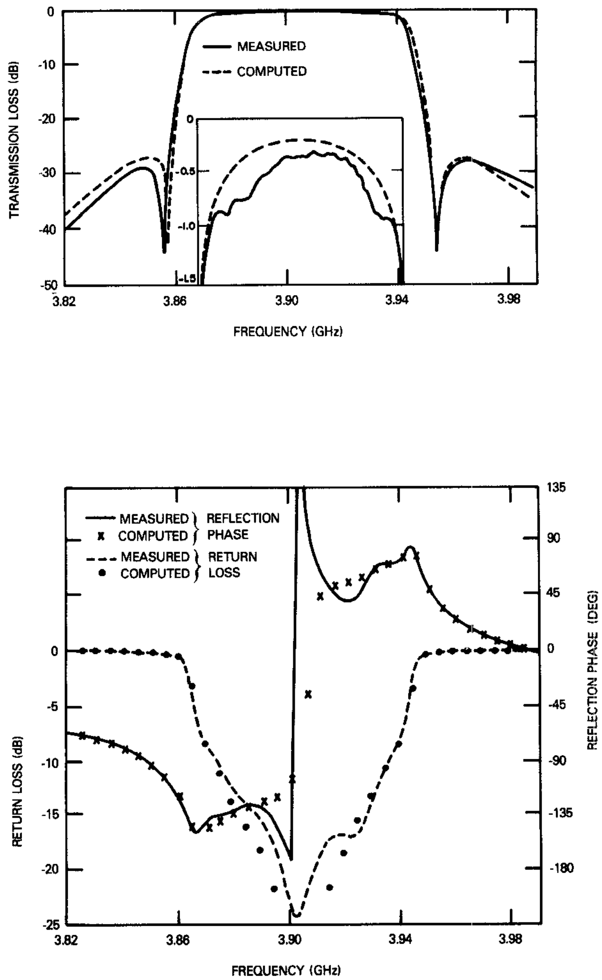

Figure 5. Filter Performances for a 6-Pole Pseudo-elliptic Filter