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A CONTIGUOUS-BAND MULTIPLEXER DESIGN*

R. G. Egri and A. E. Williams
COMSAT Laboratories
Clarksburg, Maryland 20871

A. E. Atia
INTELSAT Technical Services
490 L'Enfant Plaza SW
Washington, D.C. 20024

Abstract

A general contiguous-band multiplexer design procedure is described whereby the total network, including both the filters and manifold, is accurately modeled. All parameters, such as line lengths and filter coupling values, are optimized on a digital computer. Excellent agreement between theory and experiment is shown for a five-channel, 11-GHz multiplexer.

Introduction

Designs of contiguous-band multiplexers have been presented previously [1]-[6]. The structures assumed in References 1 and 2 require that all channel filters be connected, either in series or in parallel, at the same junction, thereby limiting the number of channels and making the approach difficult to implement in waveguide.

These difficulties can be overcome by employing a manifold geometry whereby all the filters are located along either the broad or narrow wall of a waveguide [3]-[6]. This paper extends that previous work by using numerical optimization techniques to reduce the tuning requirement, once the individual filters are located on the manifold. The procedure described does not require dummy matching elements because all parameters, such as filter spacings and filter coupling parameters, are optimized.

Network Model and Optimization

Figure 1 illustrates the basic geometry of the manifold multiplexer. Spacing between the kth and k - 1 filters is represented by the distance L_{sk}, and the distance offset by the kth filter from the manifold is represented by L_{pk}. The filter coupling values M^k_{ij} and terminations R^k_1 are also shown. The multiplexer network model includes the following components:

a. The basic coupled-cavity filter network, including an accurate representation of the phase of the input reflection coefficient. The filter network is represented as a coupled-cavity structure, and the starting point before optimization is a singly terminated prototype.

b. The T junction of the manifold is represented as a transformer, with short circuit reference planes determined in both the series and shunt directions.

c. The waveguide spacings are represented as dispersive lines, so that the model is not restricted to narrow bandwidths and/or a small number of channels.

This accurate network model has been programmed on a digital computer, with all the parameters (L_{sk}, L_{pk}, M^k_{ij}, R^k_1, and R^k_n) being treated as variables. The computer optimization program was based on the algorithm developed by Levenberg [7], which employs an extension of the normal least square procedure. The objective function to be minimized was given by

$$\varepsilon = \varepsilon' + \varepsilon''$$

where

$$\varepsilon' = \sum_i (d'_{1i})^2 + \sum_i (d'_{2i})^2 \quad \text{the in-band part}$$

$$\varepsilon'' = \sum_i (d''_i)^2 \quad \text{the out-of-band part}$$

$$d'_{1i} = \begin{cases} W'_{1i}(20 \log |\rho(f'_i)| - q'_{1i}) & \text{if } 20 \log |\rho(f'_i)| > q'_{1i} \\ 0 & \text{otherwise} \end{cases}$$

$$d'_{2i} = \begin{cases} W'_{2i}(20 \log |t(f'_i)| - q'_{2i}) & \text{if } 20 \log |t(f'_i)| < q'_{2i} \\ 0 & \text{otherwise} \end{cases}$$

$$d''_i = \begin{cases} W''_i(20 \log |t(f''_i)| - q''_i) & \text{if } 20 \log |t(f''_i)| > q''_i \\ 0 & \text{otherwise} \end{cases}$$

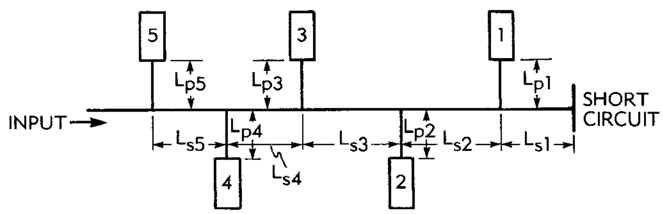
and where

f'_i, f''_i = in-band and out-of-band frequencies, respectively

q'_{1i}, q'_{2i}, q''_i = prescribed minimum return and maximum transmission loss values

W'_{1i}, W'_{2i}, W''_i = arbitrary non-negative weighting factors.

Experience has shown this program to be both efficient and reliable.



CHANNEL	CENTER FREQUENCY (MHz)
1	10992.5
2	10075
3	11155
4	11495
5	11618.5

Figure 1. Multiplexer Manifold Geometry

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Computed and Experimental Multiplexer Response

The above procedure was illustrated by designing an 11-GHz, five-channel multiplexer having the center frequencies and bandwidths given in Table 1.

Table 1. Multiplexer Center Frequency and Bandwidths

Channel	Center Frequency (MHz)	Bandwidth (MHz)
1	10992.5	77
2	11075.0	72
3	11155.0	72
4	11495.0	72
5	11618.5	150

A six-pole, quasi-elliptic, singly terminated prototype was chosen for the initial starting coupling values of each filter (see Figure 2). The shunt or parallel waveguide lengths (L_{pk}) were set equal to $\lambda gk/2$, and the series length spacings (L_{sk}) were set equal to $3 \cdot \lambda gk/2$. For five filters having six coupling values and two terminations, together with ten lengths, a total of fifty parameters were varied in the optimization program. The final optimized response is shown in Figure 3. Because the coupling parameters of each filter channel are modified, the final response of each individual filter will not be exactly as given in Figure 2. This is illustrated in Figure 4 for Channel 1.

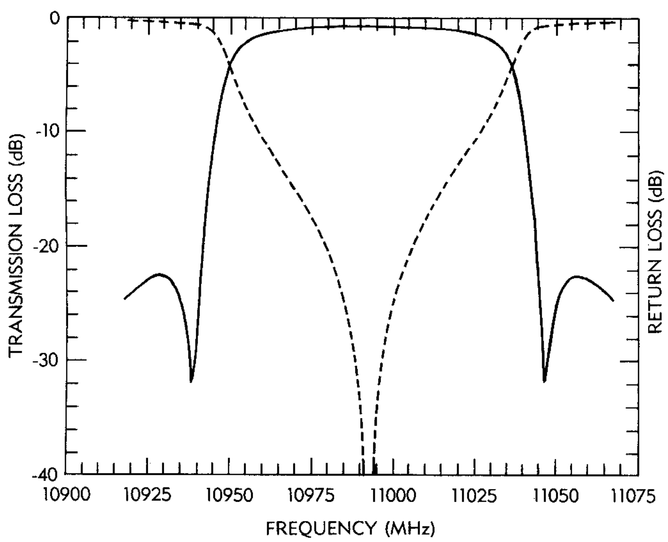

Figure 2. Six-Pole Quasi-Elliptic Single Terminated Filter Prototype: Channel 1

The four narrowband channel filters were constructed from TE_{113} dual-mode circular cavities, and the wideband channel filter was constructed with fundamental-mode TE_{111} dual-mode circular cavities. Each filter was tuned as closely as possible to the required response, measured, and placed on the minifold. The multiplexer transmission and return loss responses after filter assembly and minimum individual filter tuning are shown in Figure 5.

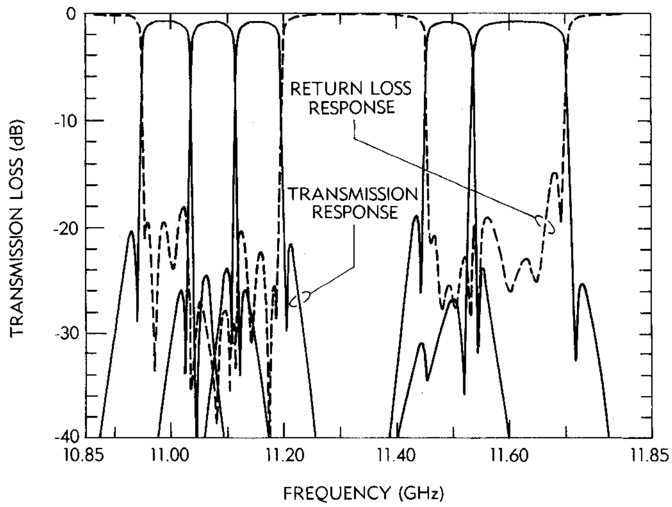

Figure 3. Optimized Five-Channel Multiplexer Response

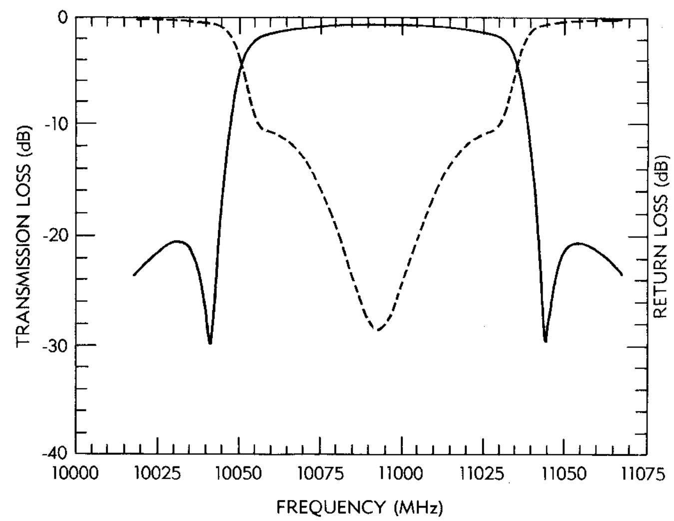

Figure 4. Six-Pole Filter Response After Optimization: Channel 1

Conclusions

This paper presents a rigorous model of the manifold multiplexer, beginning with a singly terminated filter prototype. A computer optimization program is employed to vary the waveguide spacings that separate the filters and filter couplings. The final design can then be accomplished by tuning the filters, and minimal adjustment is required after they are assembled on the multiplexer manifold.

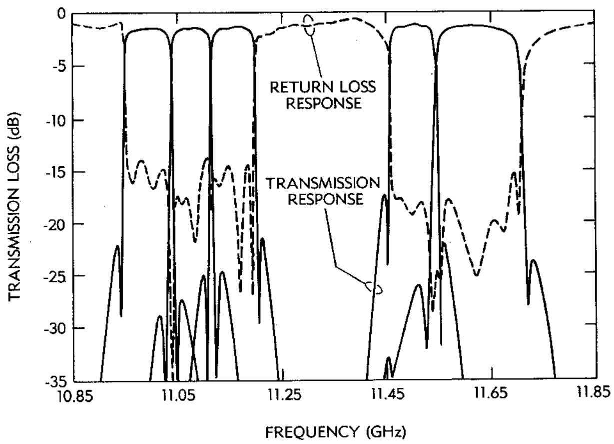

Figure 5. Multiplexer Transmission and Return Loss Responses

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