4.2: MICROWAVE BANDSTOP FILTERS WITH NARROW STOP BANDS*

LEO YOUNG, GEORGE L. MATTHAEI and EDWARD M. T. JONES+

Stanford Research Institute, Menlo Park, California

In most microwave systems the signal frequency has to be transmitted and guided from one place to another with the minimum of attenuation, while guarding against unwanted frequencies by keeping them out with bandpass filters, which pass only the signal frequency. While the common types of bandpass filters do an adequate job for most applications, they suffer from some disadvantages in particular situations. It may, for instance, happen that some one interfering frequency is particularly strong and special measures have to be taken to suppress it; or that a limited number of frequencies are being generated in a frequency generator system, but these frequencies have to be kept apart and pure. In those cases, a bandpass filter, which discriminates against all frequencies outside the passband, will not be as efficient as one or more bandstop filters which discriminate especially against the strongest unwanted frequencies.

---

*This work was supported by the U. S. Army Signal Corps under Contract DA 36-039-sc-87398.

+Now with TRG-West, Menlo Park, California.

Generally one is concerned only with narrow frequency bands; the design formulas presented here are for such cases, with stopband bandwidths up to a few per cent. The realization of the lumped-constant resonant circuits with equivalent transmission-line elements is dealt with. In the experimental lining-up procedure, each resonant branch is first adjusted to give the proper 3-db bandwidth, and formulas for this are given. The effects of dissipation loss are then discussed. The dissipation limits the maximum attenuation, and the minimum return loss, and increases the insertion loss in the passband, especially in the region close to the stopband.

The lumped constant low-pass prototype circuit[1] shown in Figure 1 is used for the basis of the design. This is first transformed into a

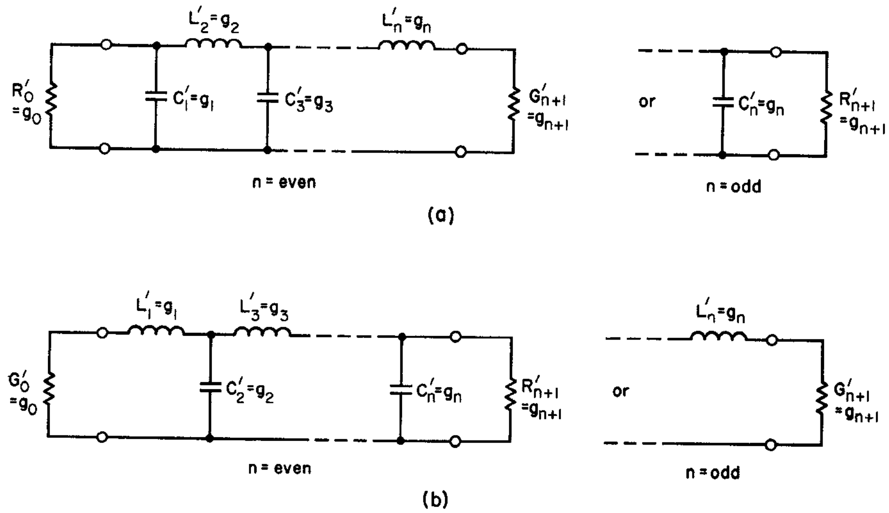

Fig. 1. Lumped constant lowpass prototype circuit.

circuit of the type shown in Figure 2a or Figure 2b. The former consists of series-resonant circuits placed in shunt across the junctions of 90-degree long transmission lines. The latter is the dual of this case. The circuit of Figure 2a can be realized closely in strip transmission line as shown in Figures 3a and b. The near 90-degree long short-circuited stubs act as the inductances, while the gaps between their ends and the main line form the capacitances. It can be shown that if the lowpass prototype elements are g_i (shown in Figure 1); the lowpass prototype bandwidth is ω_1'; the bandstop filter fractional bandwidth is w; the bandstop filter stub impedances are $Z_{b,i}$; and the stub lengths are $\phi_{0,i}$ at resonance; where i goes from 1 to n, then

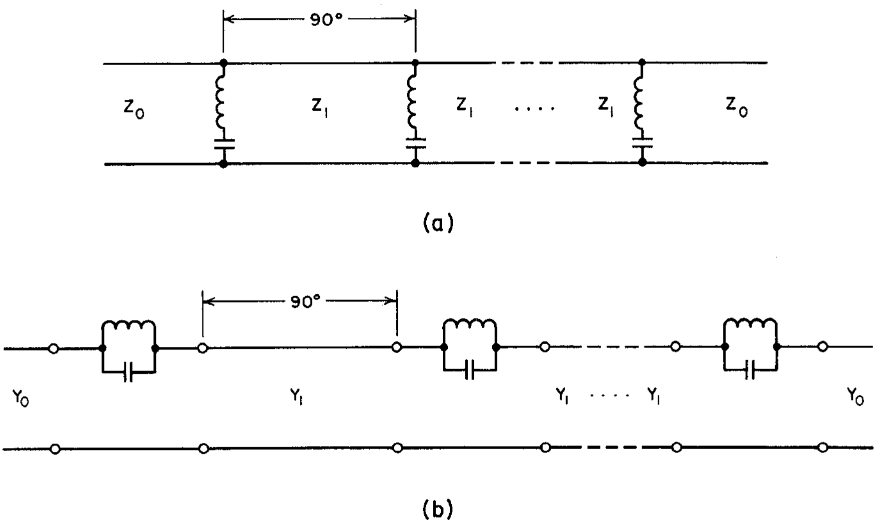

Fig. 2. Bandstop filter using lumped constant elements and quarter-wave couplings: (a) series-resonant circuits in shunt branches, (b) shunt-resonant circuits in series branches.

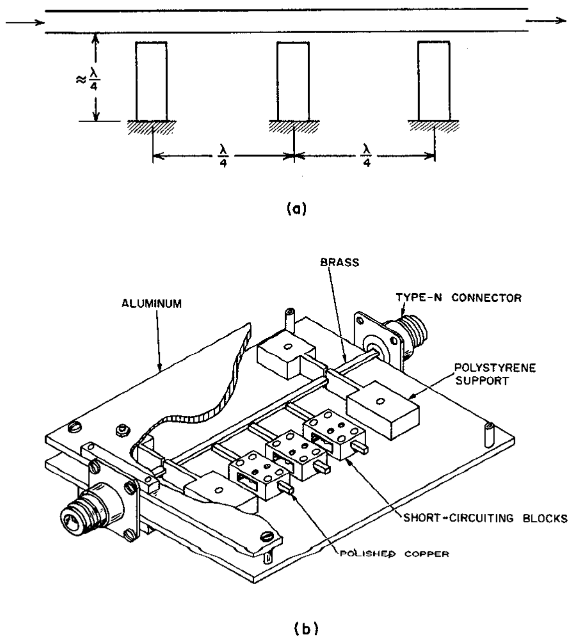

Fig. 3. Strip transmission line bandstop filter: (a) schematic, (b) sketch of actual filter with three stubs.

$$\frac{Z_{b,i}}{2Z_o} F(\phi_{0,i}) = \frac{1}{\omega_1' g_o g_i w} \qquad (i = \text{odd})$$

or

$$\frac{Z_{b,i}}{2Z_o} F(\phi_{0,i}) = \left(\frac{Z_1}{Z_o}\right)^2 \frac{g_o}{\omega_1' g_i w} \qquad (i = \text{even}) \tag{1}$$

where

$$F(\phi) = \phi \sec^2 \phi + \tan \phi \ . \tag{2}$$

This function has been tabulated to facilitate numerical calculation. The design and construction of a stripline filter centered at 4 Gc/s, and having a specified 5 per cent bandwidth and 0. 5 db ripple, is described. The experimental results are discussed. The filter characteristic was also computed on a digital computer. The computed response and measured points are both shown in Figure 4.

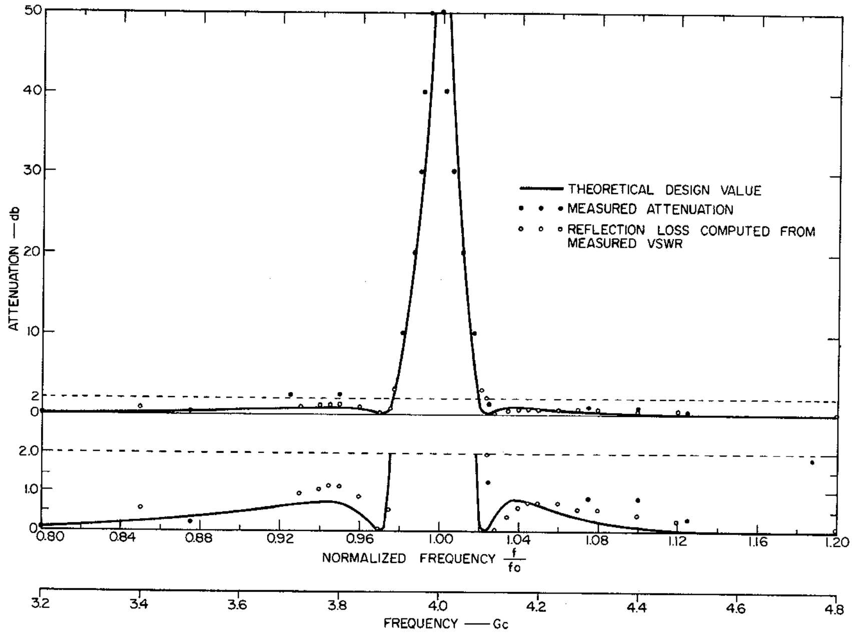

Fig. 4. Computed response (continuous curve) and measured points of stripline filter.

An X-band waveguide filter was also constructed. This corresponds to the circuit schematic of Figure 2b. A sketch of this filter is shown in Figure 5. In this case, the stub lengths are nearly 180 degrees long, and the stubs are coupled to the main line through irises. The separation

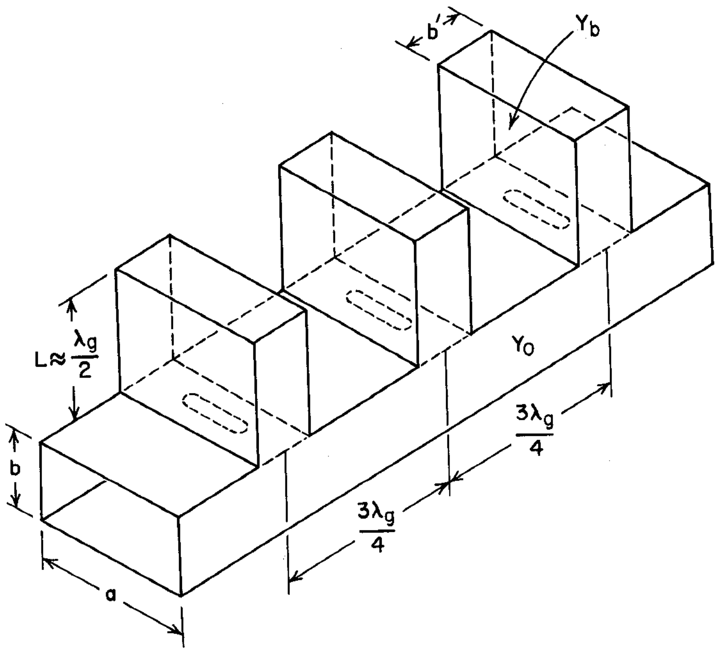

Fig. 5. Waveguide bandstop filter.

between stubs was increased from a quarter guide-wavelength to three-quarters of a guide-wavelength to reduce interaction effects. Similar design formulas as for the stripline case were worked out. The computed characteristic and the experimental points are shown in Figure 6.

The agreement between the design specification, the subsequently analyzed performance by computer, and finally the experimental results are very close. The main difference between the design specification and the computed curves is the increased ripple, by a few tenths of a decibel. This appears to be due to the fact that the separation between stubs is 90 degrees only at the center of the stopband and changes with frequency. There is a further small difference between the computed and measured performances. This can be shown to be due to the resistive losses in the resonators; the unloaded Q of the stripline stubs was about 1000, and that of the waveguide stubs 2500, as determined by the peak attenuation attainable with each stub individually.

---

1. S. B. Cohn, "Direct-Coupled-Resonator Filters," Proc. IRE 45, 187-196 (1957).

2. P. S. Carter, Jr., Leo Young, G. L. Matthaei and E. M. T. Jones, "Microwave Filters and Coupling Structures," Section III, SRI Third Quarterly Progress Report, Contract DA 36-039-sc-87398 (Oct. 1961).

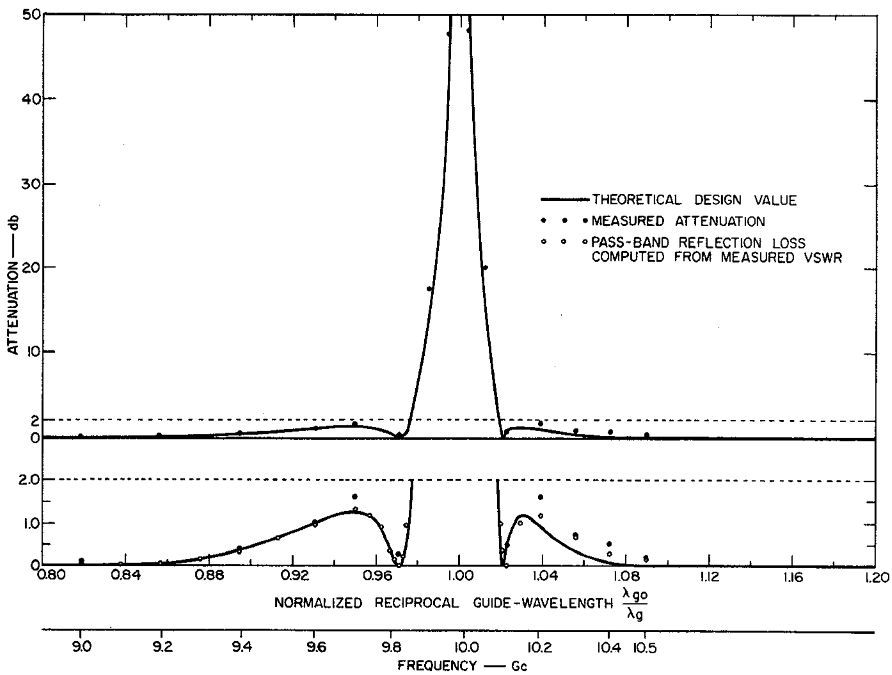

Fig. 6. Computed response (continuous curve) and measured points of wave-guide filter.