

X-Band Preamplifier Filter

F. Manshadi

Radio Frequency and Microwave Subsystems Section

This report describes a low-loss bandstop filter designed and developed for the Deep Space Network's 34-meter high-efficiency antennas. The filter is used for protection of the X-band traveling wave masers from the 20-kW transmitter signal. A combination of empirical and theoretical techniques was employed as well as computer simulations to verify the design before fabrication.

I. Introduction

The X-band preamplifier filter (XPF) is a bandstop filter used for protection of the traveling wave masers of the DSN 34-meter high-efficiency antennas from the high-power (20-kW) transmitter signal. The requirements are as follows:

Rejection = 70 dB from 7.145 to 7.235 GHz

VSWR = 1.05:1 from 8.4 to 8.5 GHz

Insertion loss = 0.05 dB (0.03 dB goal) from 8.4 to 8.5 GHz.

During design and measurements, consideration was also given to the entire 8.2- to 8.6-GHz band in order to permit wideband VLBI without significant degradation compared to the present non-filtered (no transmitter) systems at DSS 15 and DSS 45.

The theory of passive microwave bandstop filters is well known and documented in numerous papers. It has also been compiled in a book by Matthaei et al. (Ref. 1). These filters are traditionally designed based on lumped-element prototype filters such as the one shown in Fig. 1. The component values

are determined by considering either maximally flat or equi-ripple characteristics for the filter. At microwave frequencies and for waveguide filters, the resonant circuits are most often realized by cavities coupled to the top or the side wall of a waveguide through some irises. Over narrow frequency bands, these cavities behave very similarly to lumped-element resonant circuits such as the one shown in Fig. 1. The number of resonant circuits used is a function of the stopband rejection requirements. In practice, because of the physical size of waveguide cavities as well as for simplicity, either parallel or series resonant circuits are used and the adjacent cavities are spaced a multiple of quarter wavelength apart.

For the design requirement of 70-dB rejection over the stopband, figures 4.03-4 through 4.03-10 of Ref. 1 suggest that a four-cavity filter would be marginal. Therefore, it was decided to use five cavities. Additionally, since for our application the passband is well away from the stopband, designing the filter based on maximally flat or equi-ripple criteria would not be advantageous. Therefore, for ease of fabrication, all cavities were assumed to be identical. Finally, for better tuning of the passband as well as the stopband, the cavities were coupled to the side wall as shown in Fig. 2.

II. Design Procedure

For the filter of Fig. 2., values of L_c , D_I , and D_c are to be determined. In order to model the cavity waveguide junction, the return loss and transmission loss of a one-cavity filter was measured for several values of D_I and L_c . Typical curves for each value of D_I and L_c are shown in Figs. 3(a) and 3(b). By use of a simple computer code, these curves were fitted to the response of a series inductance and capacitance and the equivalent lumped inductance and capacitance for each cavity/waveguide junction was computed. These values were later used for simulation of multi-cavity filters. Additionally, a series of curves were obtained showing the variation of the resonant frequency as a function of D_I and L_c (Fig. 4). For the XPF, the stopband is centered at 7.190 GHz; however, the filter was designed for 7.240 GHz to allow for a 50-MHz tuning capability in the stopband. Figure 4 shows that an infinite number of D_I and L_c pairs yield the same resonant frequency. But, in selection of the optimum pair, it should be noted that the stopband transmission loss as well as the passband insertion loss is dependent on D_I . The larger D_I is, the larger are the transmission and insertion losses. Therefore, the optimum L_c and D_I pair is the one with the smallest value for D_I that will provide the required transmission loss over the stopband. This would guarantee the smallest possible insertion loss for the filter. The optimum pair of D_I and L_c

was selected by use of the equivalent inductance and capacitance of cavity waveguide junction in a computer program that simulated the characteristics of a five-cavity filter. This computer program found the optimum value for cavity spacing D_c (corresponding to highest transmission loss) for each pair of D_I and L_c by varying D_c about three quarters of the guide wavelength, at 7.240 GHz. The optimum values for the filter were computed to be $L_c = 0.82$ in., $D_I = 0.78$ in., and $D_c = 1.58$ in. The computed stopband characteristic of the filter, after it is tuned to 7.190 GHz, is shown in Fig. 5. This figure shows a minimum transmission loss of approximately 72 dB from 7.145 to 7.235 GHz.

III. Test Results

The filter was fabricated from the standard WR125 stock with a tuning screw in each cavity (for the stopband) as well as waveguide/cavity junctions (for passband VSWR) as shown in Fig. 6. The filter was tested by the HP 8510 automatic network analyzer; its passband and stopband characteristics are shown in Figs. 7 through 9. The stopband transmission loss is better than what was computed, which is due to the fact that in the computer simulation the resistive loss of each cavity/waveguide junction was not taken into account. All other characteristics are better than the specification.

Acknowledgment

The author would like to thank Mr. Philip H. Stanton for his valuable discussions and comments throughout this work.

Reference

1. Matthaei, G., Young, L., and Jones, E. M. T., *Microwave Filters, Impedance-Matching Networks, and Coupling Structures*, Artech House, Delham, MA, 1964.

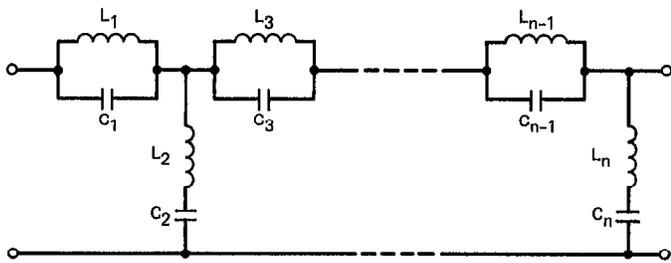


Fig. 1. A bandstop prototype filter

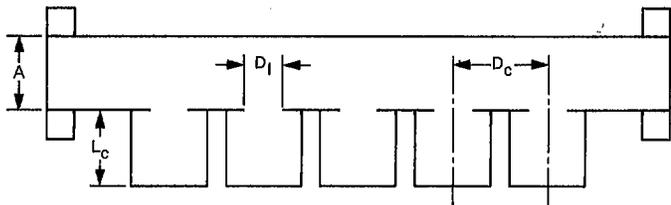


Fig. 2. Five-cavity bandstop filter in waveguide

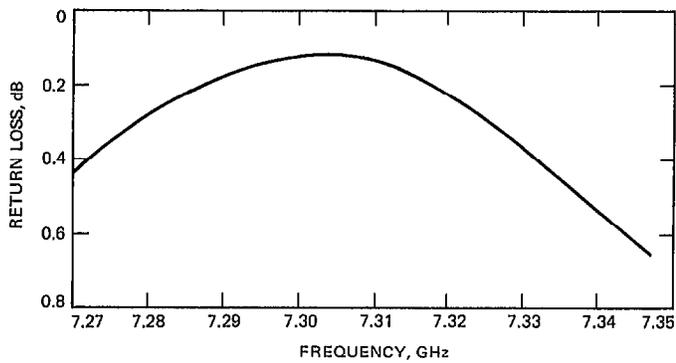


Fig. 3(a). Return loss for one-cavity bandstop filter
($D_I = 0.7''$, $L_C = 0.85''$)

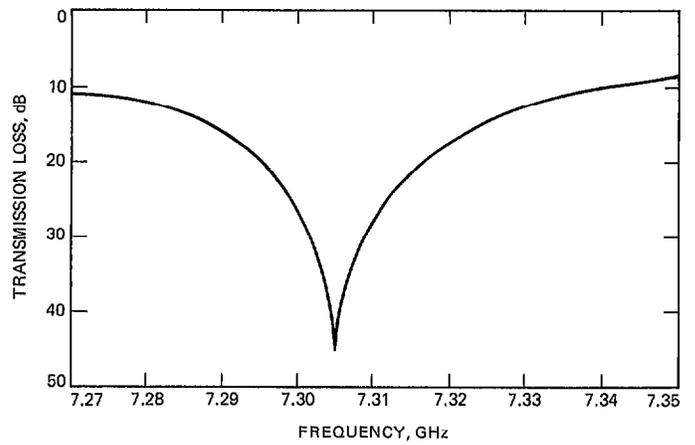


Fig. 3(b). Transmission loss for one-cavity bandstop filter
($D_I = 0.7''$, $L_C = 0.85''$)

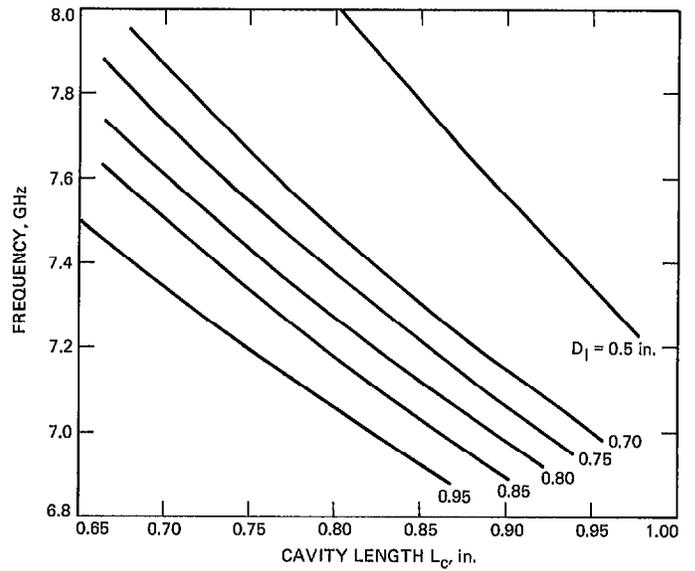


Fig. 4. Resonant frequency of one cavity coupled to waveguide through an iris of size D_I vs cavity length L_C

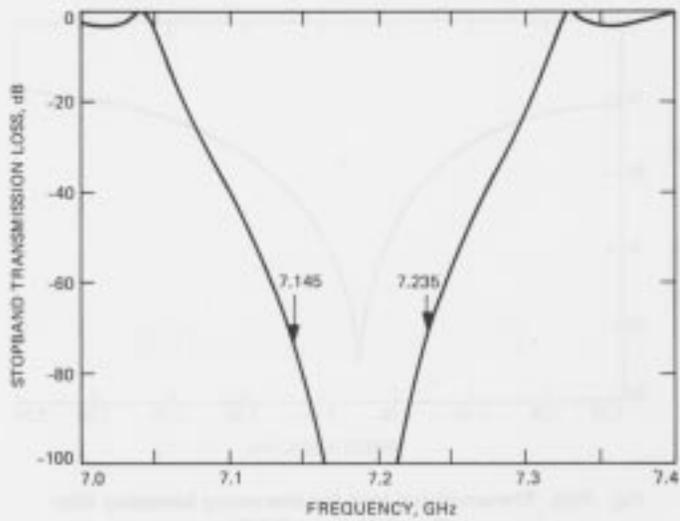


Fig. 5. Theoretical stopband transmission loss of the X-band preamplifier filter vs frequency

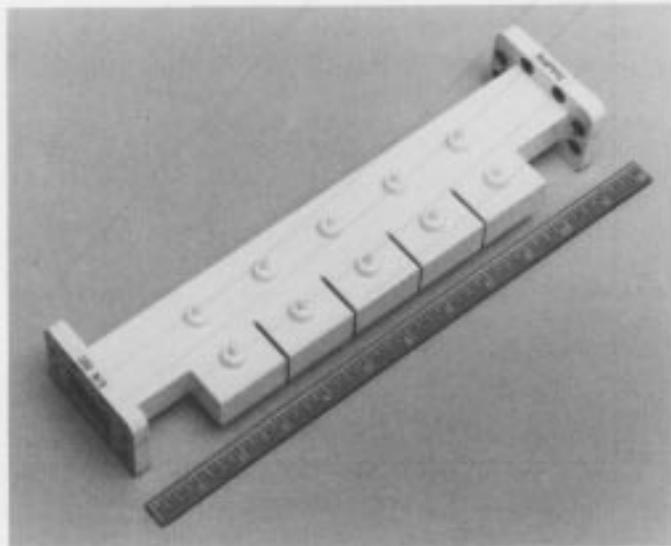


Fig. 6. X-band preamplifier filter: production unit

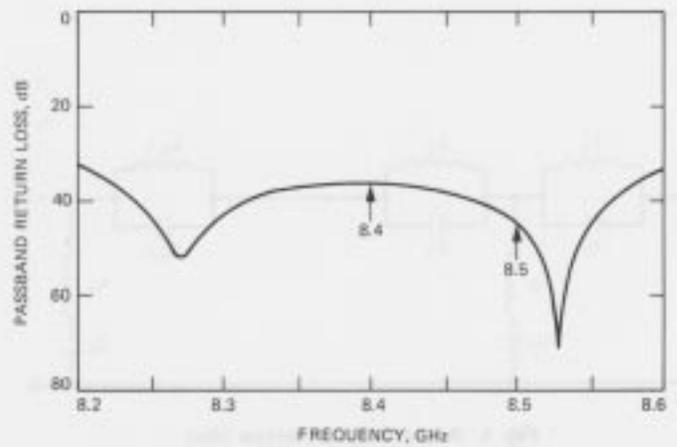


Fig. 7. Passband return loss of the X-band preamplifier filter vs frequency

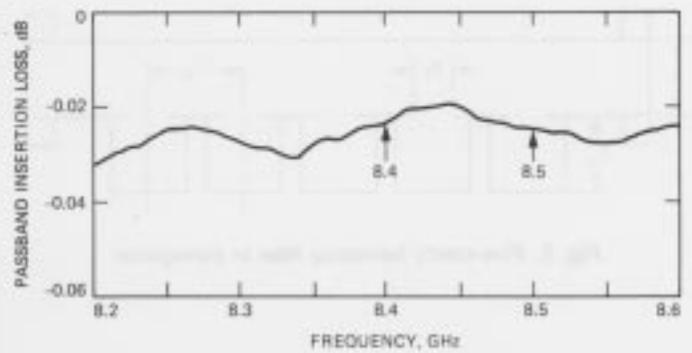


Fig. 8. Passband insertion loss of the X-band preamplifier filter vs frequency

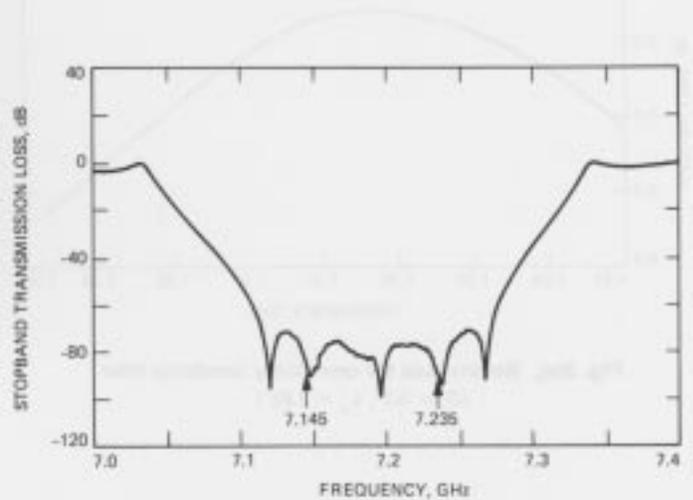


Fig. 9. Stopband transmission loss of the X-band preamplifier filter vs frequency