ISEE-3 Microwave Filter Requirements

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The 64-m subnet is committed to support the ISEE-3 spacecraft. The uplink and one of the downlink frequencies will be, respectively, 2090 and 2217 MHz. As these two frequencies fall outside the normal DSN transmit and receive bands, the 64-m antennas present new filter requirements, which will be analyzed here.

I. Introduction

The frequencies used to support ISEE-3 mission will be 2090 MHz for the uplink, 2270 and 2217 MHz for single and dual downlink.

Uplink power in excess of 20 kW (perhaps 150 kW) will be required at DSS-63 and at DSS-14. The S-Band Preamplifier Filter (SPF), which is a five-cavity waveguide filter, has to be retuned in order to prevent the power in the new transmitter frequency from going into the receiver path. Analysis shows that when using only one spacecraft transmitter, the signal level received is inadequate to attain the desired telemetry data rate; therefore, there is a requirement to provide dual downlink capability at DSS-14 and at DSS-63 when they return to operation in Mark IV configuration. As the existing Megawatt Transmitter Filter (MTF), which is a six-cavity waveguide filter, does not present any isolation at 2217 MHz, a new filter, designated MTF-II, has to be added in the transmitter path to stop the noise generated by the Klystron at that frequency.

Figure 1 shows the transmitter and receiver paths where the new filter requirements have to be met and the major components to be either added or modified.

II. S-Band Block V Maser

A new maser, S-Band Block V TWM, will be installed at DSS-14 and DSS-63. It will provide the capability of receiving a Left Circular Polarized (LCP) signal at 2217 MHz through the SPF. This signal will be combined with the Right Circular Polarized (RCP) signal at 2270 MHz to attain the adequate level of the telemetry data rate required.

The roll-off characteristic of the low frequency side of the new Maser bandwidth is shown in Fig. 2.

The threshold noise density for this Maser, for an estimated system noise temperature of 15 K, is

$$N_{th} = KT = -186.6 \text{ dBm/Hz}$$

III. Klystron Noise

The 20 kW Klystron generates an output noise with spectrum typified in Fig. 3. It can be seen that close to the Klystron passband the three-cavity roll-off effect dominates, while at frequencies far from the passband, a single cavity tends to become the dominant factor. The effective gain of the last cavity is -45 dB relative to the full Klystron gain at the center of the band; therefore, the remote noise spectrum can be modeled as a single-pole filtered white noise with a band center noise density 45 dB below that of the Klystron at band center. Thus the noise density is given by the following (see "Final RFI Report," Ford Aerospace and Communication Corporation, 333-561-ER-03, Dec. 7, 1981):

$$N(f) = KG\,(NF - 1)\,T_o A \frac{1}{(f/f_o)^2}$$

where

K = Boltzmann's constant (-198.6 dBm/Hz, K)

G = Klystron gain at small signal (56 dB)

NF = Tube noise figure (≤40 dB)

T_o = Ambient temperature, K

$(NF-1)$ = 64.6 dB (Ref. 1)

A = Relative gain of single cavity (-45 dB)

f_b = Single cavity "corner" frequency (center frequency plus 21.1 MHz)

At 2217 MHz,

$$\left[A \frac{1}{(f/f_b)^2}\right] \text{dB} = -45 + 10 \log \frac{21.1^2}{(2217 - 2215)^2} = -58.6 \text{ dB}$$

Hence, the noise density is

$$N_{20\text{ kW}, 2217\text{ MHz}} = -198.6 + 56 + 64.6 - 58.6$$

$$= -136.6 \text{ dBm/Hz}$$

For the 100 kW transmitter this value can be scaled, in the worst case, to account for the difference between output powers. Therefore, the noise density from the 100 kW tube will be

$$N_{100\text{ kW}, 2217\text{ MHz}} = -136.6 + 7 = -129.6 \text{ dBm/Hz}$$

IV. Transmitter Noise Filtering

From all the above it may be inferred that the minimum isolation needed to prevent the Klystron receiver-band noise from entering into the receiver path is

$$N_{100\text{ kW}, 2217\text{ MHz}} - N_{th} = -129.6 - (-186.6) = 57 \text{ dB}$$

Considering a typical safety margin of 25 dB, the isolation desired will be 82 dB.

In order to possibly eliminate the need for a new filter design, a spare MTF was retuned with the isolation curve and VSWR within the transmit band being measured. Figures 4 and 5 show the rejection of the MTF before and after it was retuned for 90 dB rejection over the 2200 to 2230 MHz band.

This exercise proved the feasibility of using the present MTF retuned to provide the isolation needed at the new receiver frequency. It also demonstrated that it has to be matched to reduce the transmit band VSWR, which increased when retuned. Note that the maximum measured isolation shown in Figs. 4 and 5 is limited by the 70 dB dynamic range of the instrumentation used. Additional isolation of some 25 to 30 dB between ports of the Orthomode will result in achieving the required total system isolation, including the 25 dB safety factor.

V. Transmitter Power Filters

The S-Band Block V Maser also has to be isolated from the transmitter output at 2090 MHz, which for the 100 kW Tube is 80 dBm.

This function will be provided by the existing S-Band Preamplifier Filter (SPF), after being retuned for 60 dB rejection over the 2090 to 2120 MHz band, and by the Orthomode.

Figure 6 illustrates the rejection before and after the SPF was retuned. The SPF insertion loss and input VSWR in the receiver bandpass were not changed as a result of the retuning.

VI. Conclusion

As a result of the previous considerations, the following modifications are being implemented:

(1) Install a new filter, in addition to the existing MTF, between the transmitter and the diplexer. This filter is the same design as the present MTF but tuned to

provide more than 90 dB of isolation at 2217 MHz. This filter (designated the MTF-II) will be matched to present a VSWR low enough so it does not disturb the transmitter path.

(2) Retune the existing SPF to obtain a minimum of 60 dB of isolation at 2090 MHz.

With these two changes, plus the addition of a matching section at the diplexer transmitter port (the subject of a later report), the transmitter and receiver paths of the 64-m antennas will meet the ISEE-3 requirements. Figure 7 compares the receiver and transmitter bandwidths and the MTF-II and SPF isolation curves. Figure 8 is a layout of the S-Band Polarization Diverse (SPD) cone components.

References

1. Krauss, John D., *Radio Astronomy*, McGraw-Hill, 1966.

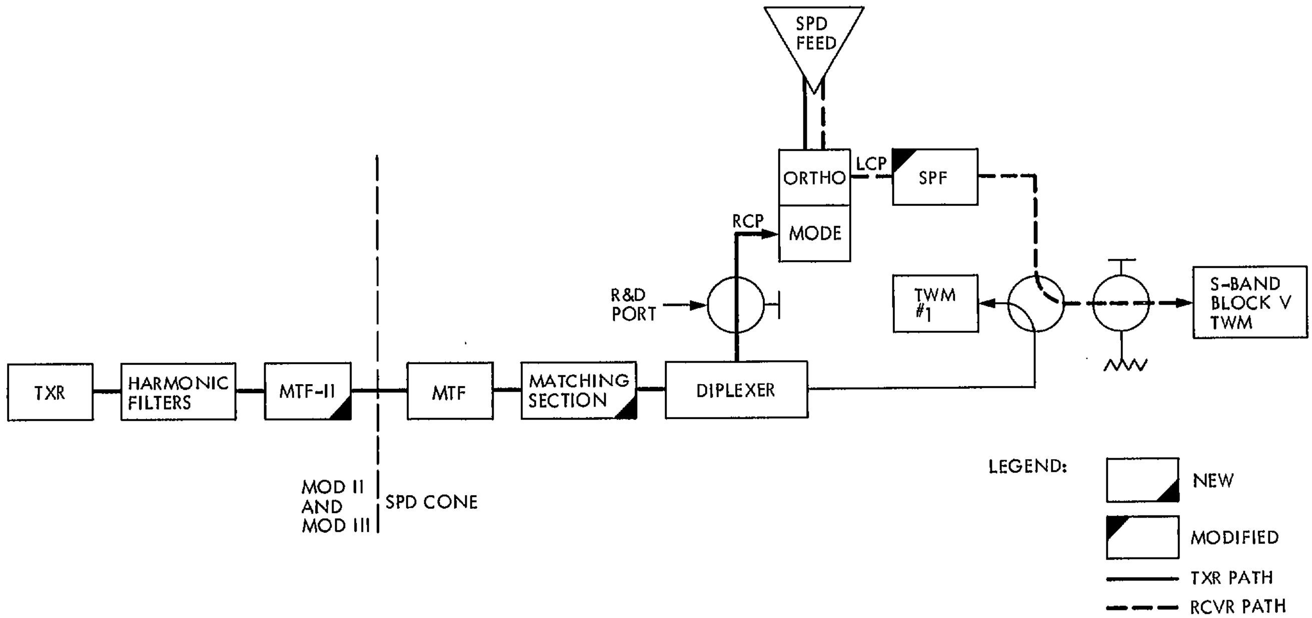

Fig. 1. 64-meter antenna: ISEE-3 transmit and receive paths

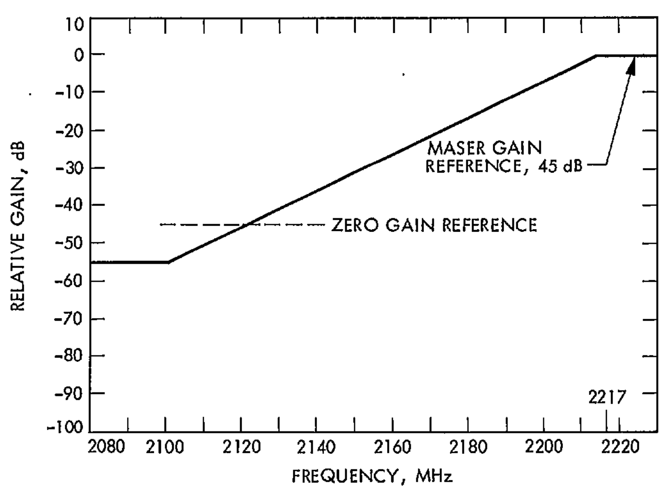

Fig. 2. S-band Block V TWM bandwidth

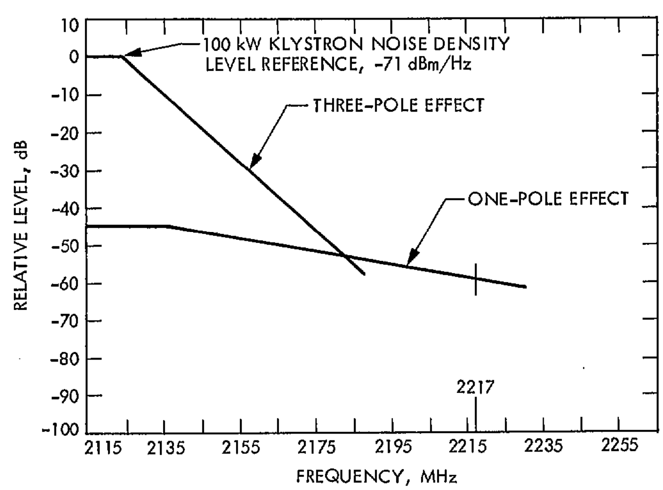

Fig. 3. Klystron noise characteristic

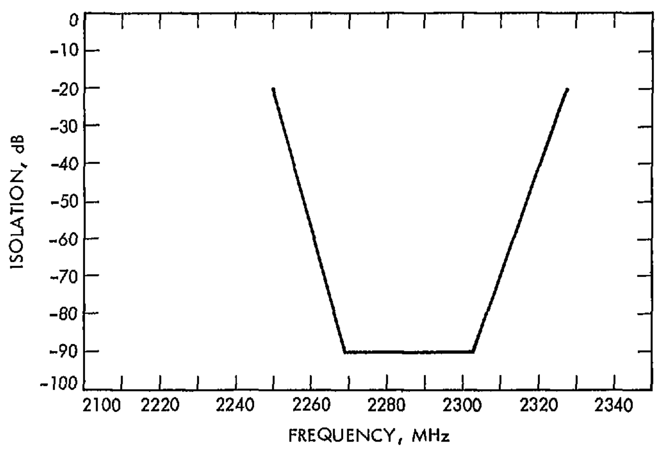

Fig. 4. MTF isolation before retuning

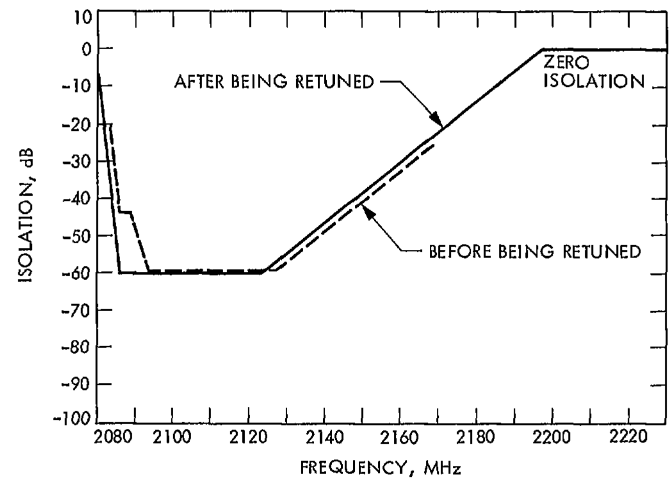

Fig. 6. SPF isolation curve

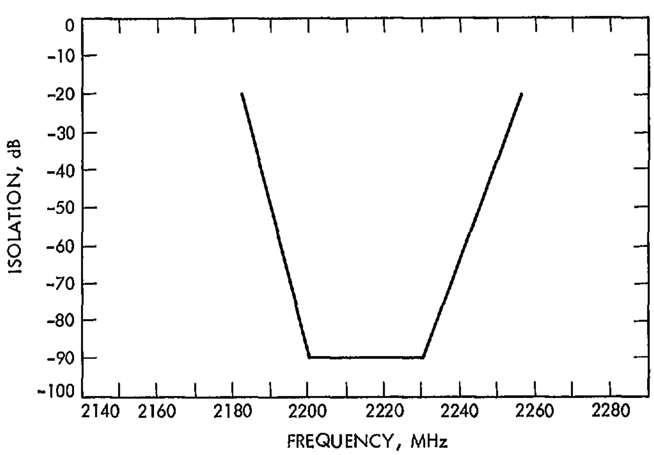

Fig. 5. MTF isolation from 2200 to 2230 MHz

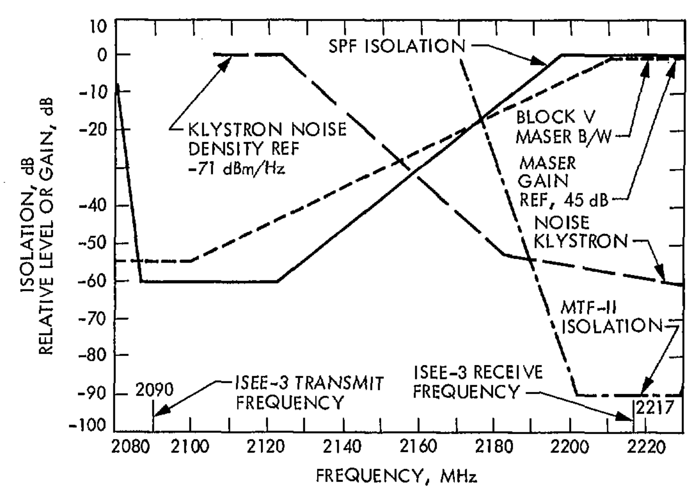

Fig. 7. Combination of transmit and receive bandwidths and isolation of SPF and MTF-II

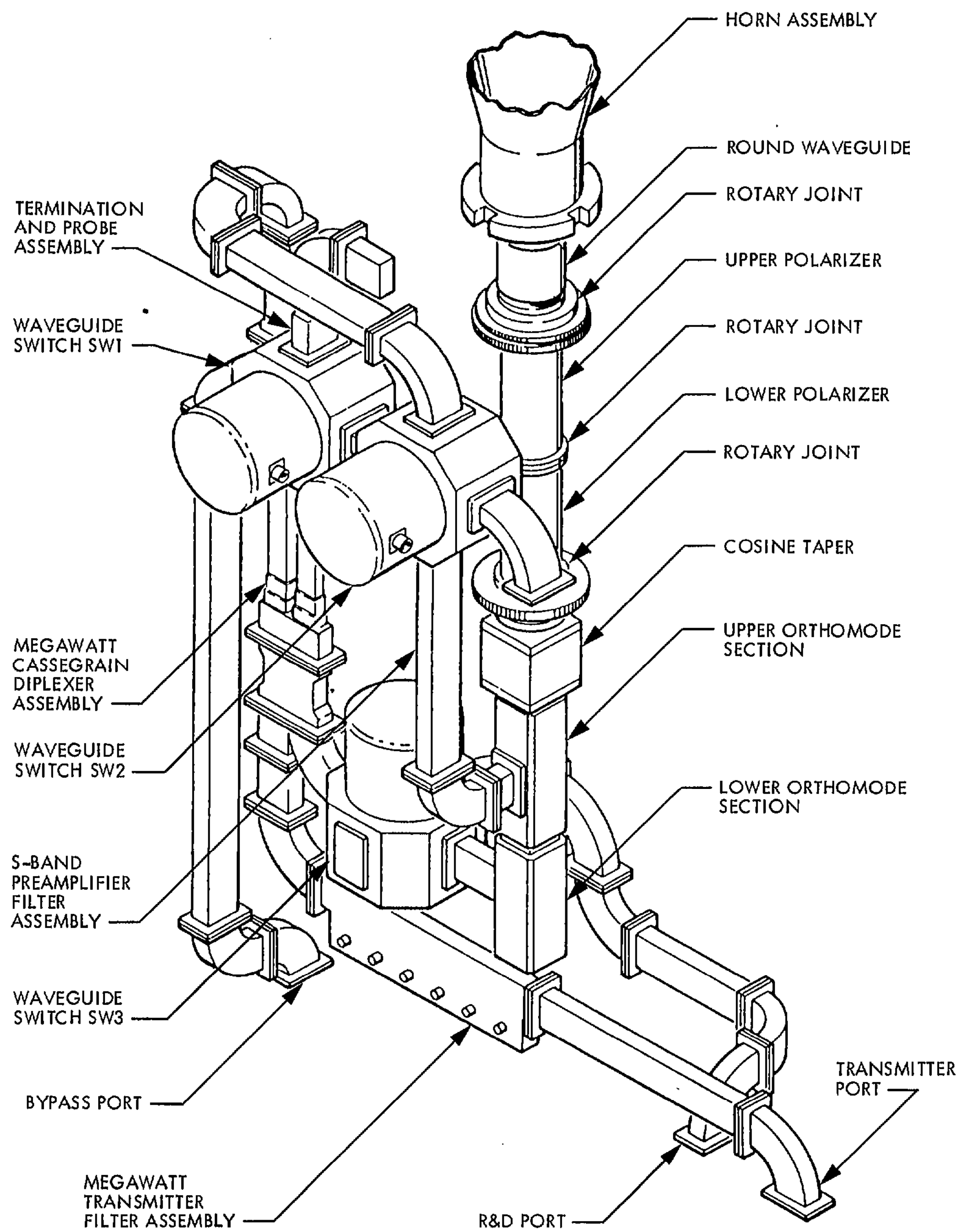

Fig. 8. SPD cone assembly microwave components