NASA Ultra Low Noise X-band Microwave Feeds for Deep Space Communication

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Abstract: This paper describes the configuration, detail design, and final performance of a new ultra low noise diplexed X-band microwave feed system, called X/X diplexing feed, for the Deep Space Network (DSN) 70-m antennas. In this microwave feed, the transmitter signal is combined with the receive signal in a diplexing junction placed near the input of a wide-band feedhorn. This configuration allows the majority of the components in the receive path to be placed in a cryogenically cooled container resulting in a major reduction in the noise temperature of the feed. Combined with a low noise HEMT amplifier this feed provides the lowest noise diplexed feed in the DSN. The total noise temperature of the 70-m antennas at Zenith with this feed is approximately 14.6 Kelvin.

INTRODUCTION: DSN owns and operates three 70-m antennas, which are geographically located to provide near continuous communication for NASA's deep space probes. These antennas are located at Goldstone, California, near Madrid, Spain, and near Canberra, Australia. Each 70-m antenna contains 3 feedcones. Originally one feedcone contained microwave feed equipment for X-band receive only (called XRO). This feed was replaced with the new diplexed feed called XTR. The second feedcone contains microwave feed equipment for S-band receive and transmit (called SPD). See Figure 1 for the XRO and the SPD feedcones optics and configuration. The third feedcone is dedicated to radar and radio astronomy applications.

X-band uplink has been available on DSN 34-m antennas since mid 1980s. However, due to the advent of smaller spacecraft requiring higher data rates and the need for high power X-band for emergency situations, NASA/JPL was funded to implement X-band uplink on all 70-m antennas. The 70-m antennas offer an additional gain of approximately 6 dB compared to the 34-m antennas.

The most critical requirement in the design and development of microwave feeds for the DSN is low noise receive capability, and in the case of diplexed feeds, high power transmission, simultaneously. Currently the existing DSN antennas operate with a total antenna X-band noise temperature of about 20 to 30 Kelvin depending on if Maser or HEMT amplifiers are used, respectively. For diplexed systems, the transmitter power is nominally about 20 kW. What makes the design and development of these microwave feeds challenging, is isolating the super sensitive Low Noise amplifiers (LNA) and receivers form the high power signal, its harmonics, and the spurious signals generated by the high power transmitter located in the same feedcone.

In the traditional microwave feeds, a waveguide diplexer and a stop band filters were used to provide the necessary isolation between the transmit and receive signals (See Figure 2-a). Even though these components were designed in oversized waveguides, they still introduced significant additional loss for the receive paths. For this reason, NASA/JPL designed an ultra low noise feed (X/X diplexing feed) by cryogenically cooling most of the components in the receive signal path to liquid Nitrogen temperatures. The major problem in doing so was the waveguide diplexer. With 20 kW passing through the diplexer it was not practical to cool it to liquid Nitrogen temperatures. To alleviate this problem, the diplexer was eliminated and in its place a diplexing junction was developed which combined the X-band uplink and downlink signals near the input of the feedhorn (see figure 2-b). With this design it was then possible to place most of the receive path components, including some of the filters, required for high isolation, in a cryogenically cooled container. The reduction in the receiver losses were so high that less expensive and more reliable HEMT amplifiers could be used in place of the more expensive but lower noise Maser amplifiers, with the overall antenna loss still less than the traditional design.

As part of the this X-band upgrade, a wide-band S/X-band dichroic mirror was also designed and developed. This mirror reflects the S-band signal while passes the X-band uplink and downlink signals through with very low loss (see figure 1).

NEW DSN X/X DIPLEXING MICROWAVE FEED: Figure 2-b shows a simplified block diagram of the new DSN X/X diplexing microwave feed. In this design, a diplexing junction is used for combining the transmit and receive signals. This diplexing junction is a 6-port device. Two of the ports are in circular waveguide. One is connected to a 22 dB feedhorn through a coupler and the other is connected to the LNA package through a

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transmitter reject filter and an ambient load sliding switch. The filter provides 40 dB of rejection for the fundamental transmitter frequency. The ambient load switch is used for calibration of the LNAs. The 4 rectangular ports are used for injection of the transmitter signal. These ports are combined into one port with a network of Hybrids, Tees, and a polarization selection switch. For additional protection against the spurious signal generated by the transmitter, an 80 dB absorptive filter is used before the polarization switch. In the Receive path, the signal coming out of the ambient load switch is guided to the LNA package. The LNA package consists of a large cryogenically cooled container that holds the rest of the receive path components. These components include a polarizer/orthomode junction to convert the circularly polarized signal to linear polarization, additional band pass filters for protection of the super sensitive LNAs, and circulators for improving the match and reducing the standing wave generated between the reflective filters in the receive path. The noise contribution of the microwave circuits in this feed is approximately 2.9 Kelvin for diplexed operation. The overall antenna noise temperature at zenith is approximately 14.6 Kelvin. Figure 3 shows the variation of the total antenna noise temperature, including atmospheric losses, as function of the elevation angle for dichroic mirror retracted or extended.

CONCLUSION: This paper presented the design of the new DSN X-band diplexed microwave feed for the NASA 70-m antennas. This design provides a configuration which allows most of components in the receive path to be cryogenically cooled. Table 1 shows a comparison between the performance of the old DSN diplexed feed and the new X/X diplexing feed. As can be seen, the new feed improves the diplexed performance of the antennas by about 3 dB. Additionally, by utilizing HEMT LNAs, the new feed will be much easier to maintain and has lower implementation cost as well as much lower lifetime cost.

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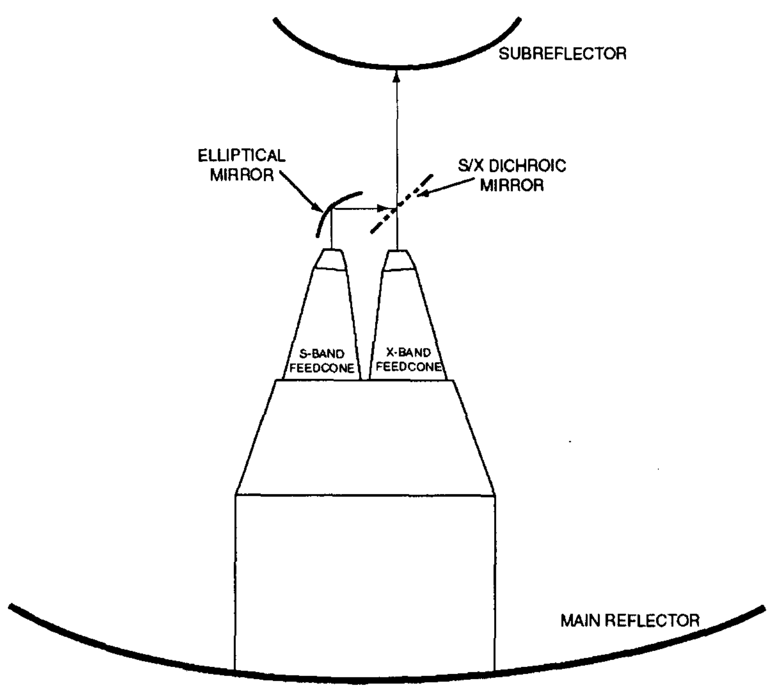
Figure 1. NASA 70-m Antennas S/X-Band Optics



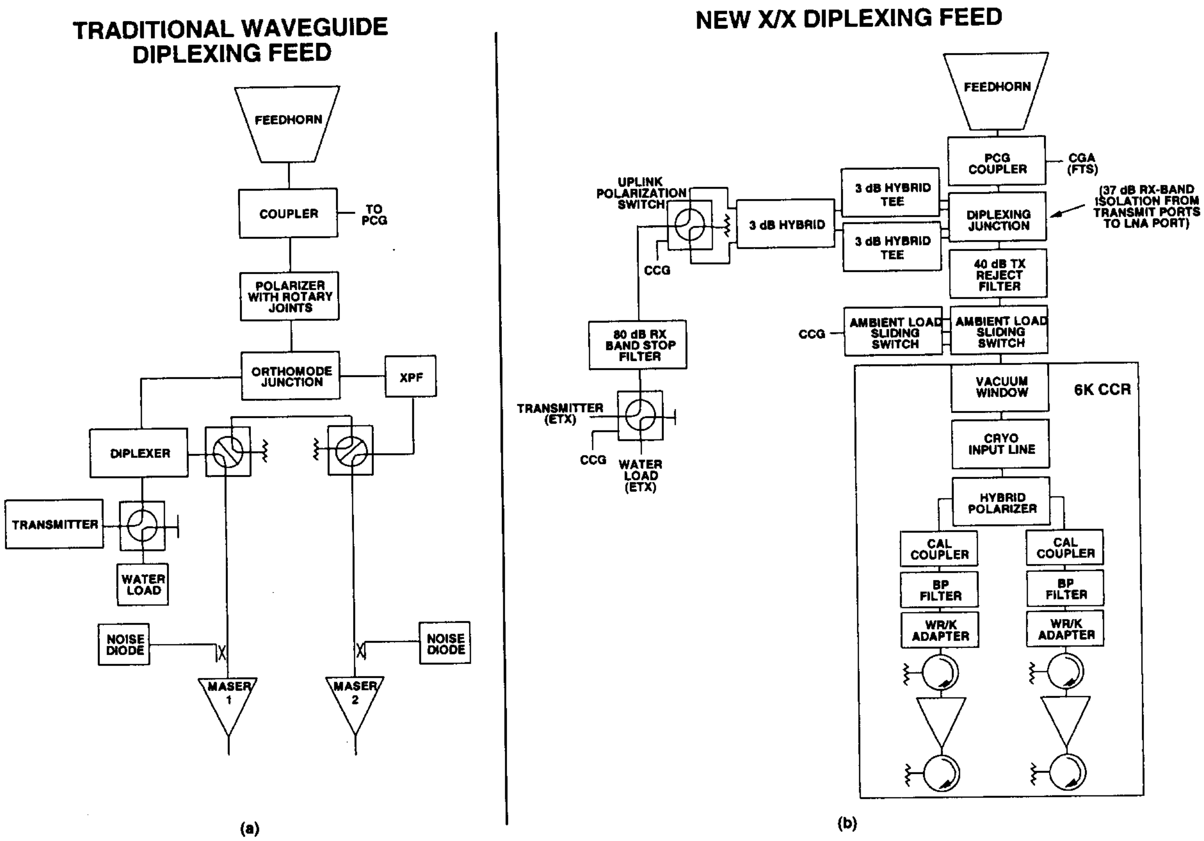


Figure 2. Traditional DSN diplexed microwave feed versus the new X/X Diplexing microwave feed.

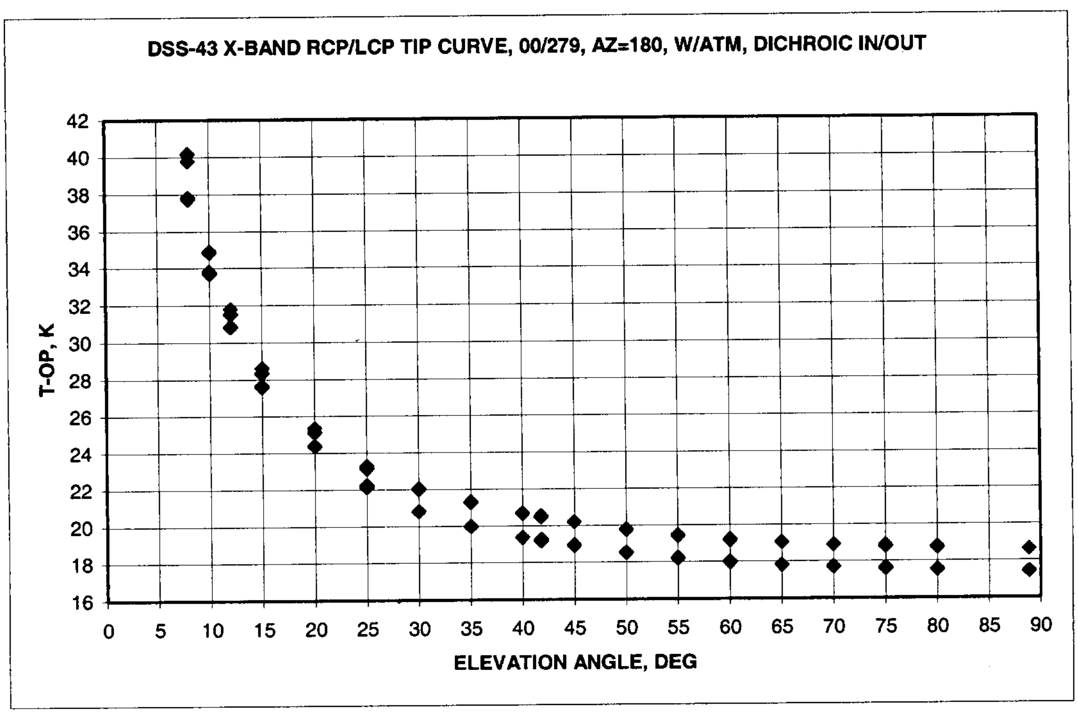


Figure 3. Noise Tempreature vs. Eleveation angle

Table 1. NASA 70-m Antennas Noise Temperature Performance with Old Diplexed Feed VS. X/X Diplexing Feed, Kelvin

Item	Old Diplexed Feed, Low Noise Path	Old Diplexed Feed, diplexed path	X/X Diplexed Feed Predicts	X/X Diplexing Feed
Cosmic Background	2.5	2.5	2.5	2.5
Antenna	3.8	3.8	3.8	3.8
Microwave Circuit	8.3	17.3	3.2	2.9
Low Noise Amplifier	5	5	4.8	5.3
Follow-on	.1	.1	.1	.1
Total	19.7 K	28.7 K	14.4 K	14.6 K