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Noise-Temperature Measurements of Deep Space Network Dichroic Plates at 8.4 Gigahertz

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The addition of 7.2-GHz (X-band) uplink capability to Deep Space Network (DSN) 70-m antennas required the development of a new dual-band dichroic-plate-type frequency-selective surface. This plate passes both the uplink and the 8.4-GHz (X-band) downlink signals. The plate contributes to the overall noise temperature of the antenna receiving system as well as efficiency loss. Tests were performed to measure the noise-temperature contribution of the plate. This article describes the measurements and the results. The results of noise-temperature measurements of the new dual-band plate and the existing narrowband design are presented. The effect of the plate on antenna efficiency is also discussed.

I. Introduction

The Deep Space Network (DSN) 70-m antennas use dichroic-plate-type frequency-selective surfaces to separate the 2.3-GHz (S-band) and 8.4-GHz (X-band) downlink signals to achieve simultaneous S-/X-band operation. The 2.3-GHz energy is reflected off the first surface of the plate, and the 8.4-GHz energy is passed through. Until recently the plates only needed to pass 8.4-GHz downlink signals. The 70-m X-Band Uplink Project added the capability of 7.2-GHz (X-band) uplink operation. The addition of the uplink using the X-/X-band diplexed feed required a dual-band plate that will pass both the uplink signals at 7.2 GHz and the downlink at 8.4 GHz [1]. This article reports the results of measurements of the noise-temperature contribution of both the new dual-band plate and the existing plate.

II. Noise Contribution of Dichroic Plates

The noise-temperature contribution of the dichroic plate is the result of two effects: (1) ohmic loss as the signal propagates through the holes in the plates and (2) the mismatch or scattering loss of energy that is reflected from the plate surface. The ohmic loss tends to be small, contributing less than 1 K. The scattering loss has two effects: signal energy is reflected away from the front surface, and ambient noise is reflected off the back surface into the feed. On Cassegrain antennas where the dichroic plate is located in the dish, the rear scatter is largely reflected to the sky and causes a small (1-K) contribution. On beam-waveguide antennas, the rear scattering is more significant. The scattered energy is reflected to ambient temperature surroundings or makes multiple reflections off of surfaces. The noise contribution behaves as if all the scattered energy is from an ambient temperature source.

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III. Test Setup

The dichroic plates were mounted on test frames in the position to simulate installation on an antenna at zenith. The frames and plates were assembled on the roof of Building 238 at JPL. A 70-m 8.4-GHz feed horn and high-electron-mobility transistor (HEMT) low-noise amplifier (LNA) were placed on a rolling fixture to allow the same LNA and feed to be placed under each plate in the required physical orientation. The movable feed allowed both systems to be measured quickly to minimize changes in the atmospheric conditions between the separate measurements. The test setup is shown in Fig. 1.

Fig. 1. View of the test setup on the roof.

IV. Measurement Technique

The losses associated with dichroic plates are small (<0.1 dB). Losses this small are difficult or impossible to measure with conventional insertion loss techniques [2]. Noise-temperature measurements can resolve changes in noise temperature as small as 0.1 K. If the scattered energy is from a 290-K source, the resolution of loss values derived from noise-temperature measurements is 0.03 percent or 0.0015 dB.

The total system operating temperature, T_{op}, of the system under test was measured using an automated noise-measurement system developed by the Cryo-Electronics Front-End Equipment Group. The system automatically measures and records the T_{op} at specified frequencies.

For these measurements, T_{op} is the sum of the noise from the sky, including background radiation and atmosphere, the noise contribution of the plate, and the noise contribution of the feed, LNA, and receiver. Subtracting the zenith T_{op} of the feed/LNA from the T_{op} measurements of the system under test determines the contribution of the dichroic plate.

To account for any variation in the atmosphere or instrumentation, the T_{op} of the feed and LNA alone was measured before, during, and after the measurements. The results of the feed-only tests are shown in Figs. 2 and 3 for both right-hand circular polarization (RCP) and left-hand circular polarization (LCP). The maximum difference from the average was less than 0.17 K and is assumed to be the uncertainty in the measurement. The average value was used as the baseline for the measurements and was subtracted from the T_{op} of the system under test.

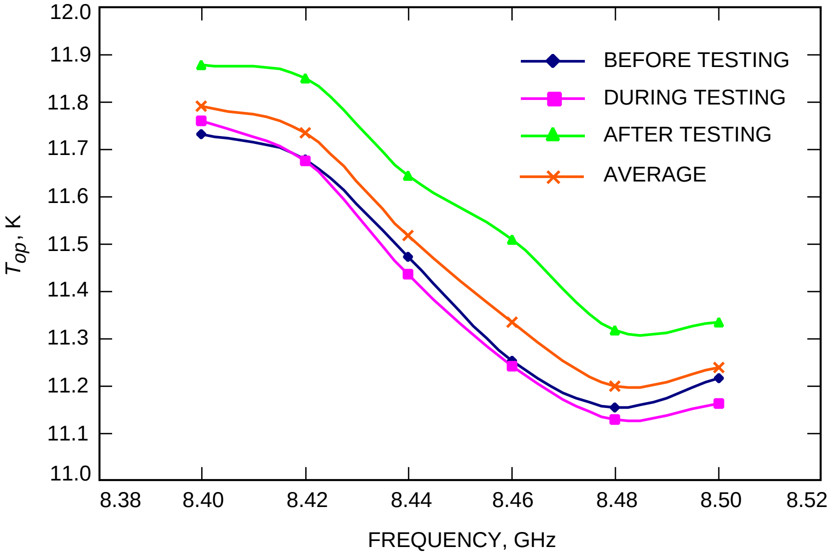

Fig. 2. Zenith noise temperature, T_{op}, of the feed system before, during, and after the dichroic tests: RCP.

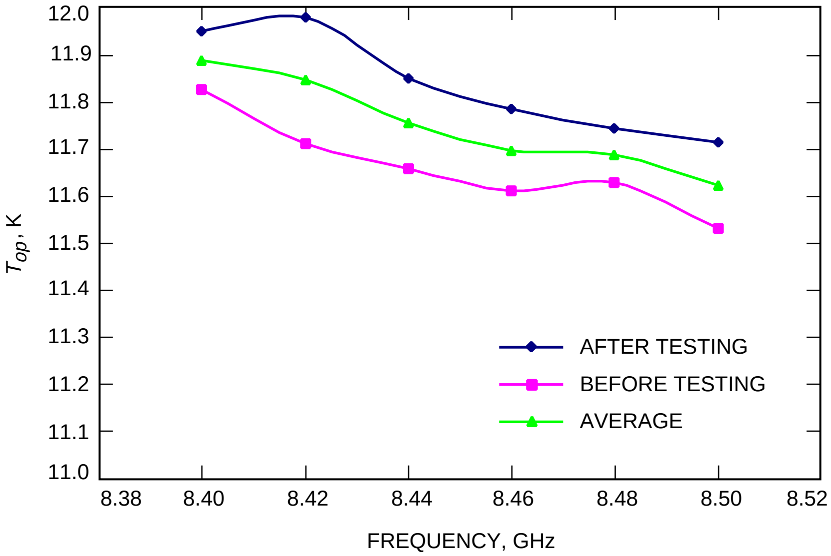

Fig. 3. Zenith noise temperature, T_{op}, of the feed system during and after the dichroic tests: LCP.

In addition to measurements of the noise contribution of the plates, a separate test was performed to measure the effect of the perforated area of the plate. The dual-band plate has a smaller perforated area than the original. The narrowband plate was tested with the same perforated area as the new plate. This was done by covering the front side of the plate with an aluminum mask the same size and shape as the dual-band perforations. The rear view of the masked plate is shown in Fig. 4. The dark region outside the center is the area masked.

V. Results

The results of the measurements in both RCP and LCP are shown in Figs. 5 and 6. The dual-band plate contributes 12 to 18 K in the band of 8.4 to 8.5 GHz. The narrowband plate contributes 3.5 to

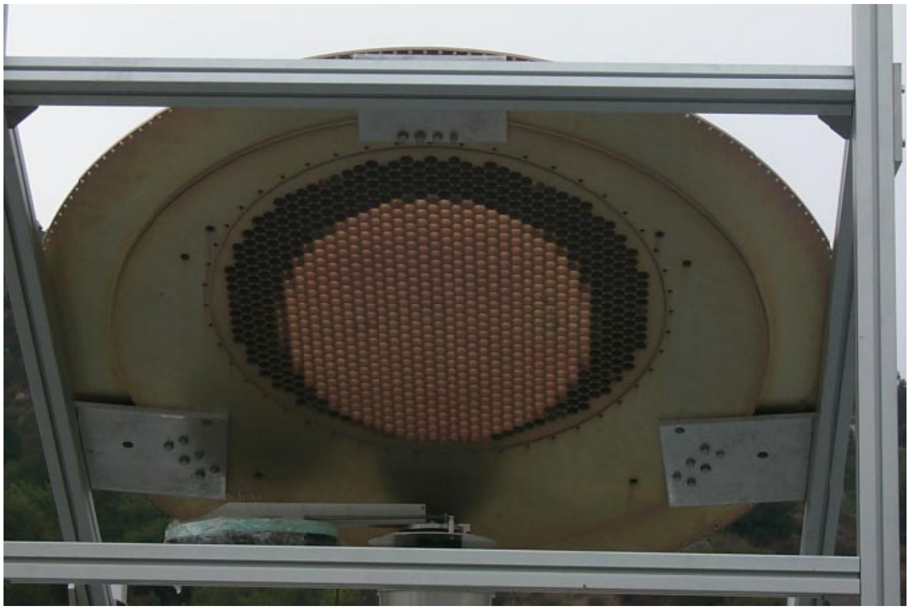

Fig. 4. Rear view of the masked plate.

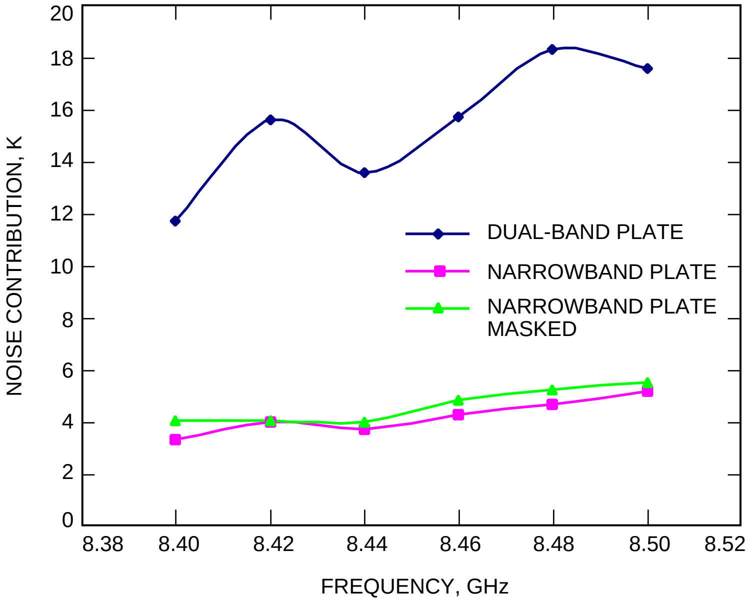

Fig. 5. Noise contribution of dichroic plates: RCP.

5 K in the same band. The narrowband plate masked to the same physical size as the dual-band plate showed only a 0.5- to 2-K additional contribution over the plate alone.

The roof tests represent the worst-case situation for noise contribution from the plate. All the energy scattered into the feed is from sources near 290 K. On the antenna, the scattered energy comes mainly from the sky, with a source temperature of 5 K. When the plates are installed on Cassegrain antennas, the measured noise contribution is less than 1 K. This was verified qualitatively during the roof tests by using a sheet of aluminum behind the dichroic plate to redirect spillover to the sky rather than to the ambient surroundings. With the spillover redirected, the noise contribution of the plate was less than 4 K. This would not be the case for a similar plate used in a beam-waveguide antenna application. The

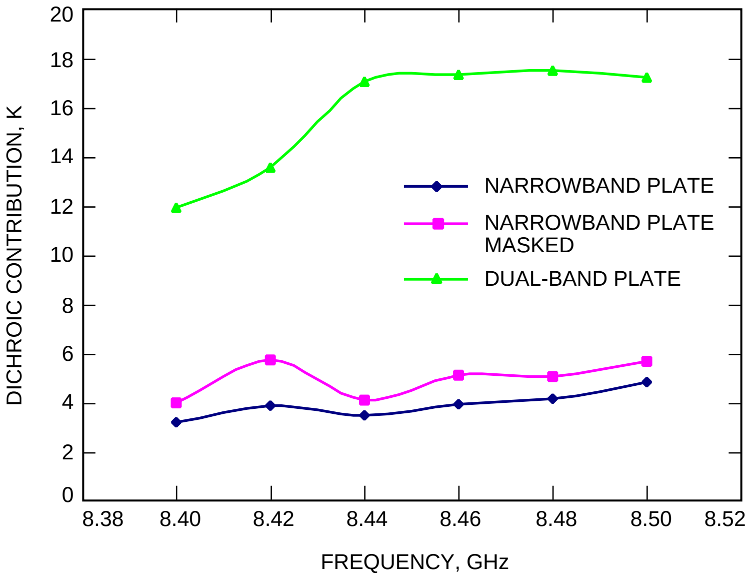

Fig. 6. Noise contribution of dichroic plates: LCP.

spillover energy from dichroics in beam-waveguide antennas sees either 290-K sources directly or multiple reflections from surfaces that have the effect of radiating ambient energy.

The noise-temperature contribution can be used to estimate the antenna-efficiency loss due to the plate. If it is assumed that all the spillover energy is from 290-K sources, the 12- to 18-K contribution corresponds to an efficiency loss of 4 to 6 percent (0.2 dB). This is consistent with preliminary measurements of the antenna efficiency with and without the plate in place.

Acknowledgments

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