NOISE TEMPERATURE CONTRIBUTION OF A DICHROIC PLATE IN A BEAM-WAVEGUIDE ANTENNA SYSTEM

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INTRODUCTION

A 34-m-diameter antenna, built for NASA/JPL in 1990 at Goldstone, California, utilizes a beam-waveguide (BWG) design (Fig. 1). The BWG antenna performances at three different focal points were reported in [1]. The ellipsoid in the subterranean room has since been made rotatable so that numerous feed systems can be installed in a circular perimeter around the ellipsoid and operated from their own individual f3 positions.

One of the recently installed front-end systems at a new f3 position is the S/X system, which permits simultaneous operation of S-and X-band downlink. Measurements of the X-band system (Fig. 2) showed that the dichroic plate noise temperature contribution was 18 K compared to a predicted value of 1.5 K,

It was discovered that if a dichroic plate is installed in a BWG antenna environment, high noise temperatures can result if the receive system passband is greater than the passband for which the plate was designed. A method is presented for accurately calculating dichroic plate noise temperature for these conditions.

ANALYTICAL METHOD

Figure 3 shows the geometry for a Deep Space Network (DSN) dichroic plate illuminated by a plane wave. The S/X-band dichroic plate (shown in Fig. 2) is purposely tilted an angle $\theta_0 = 30$ deg so that the central ray from X-band system will be incident on the plate at 30-deg incidence angle. At this incidence angle, this DSN-type plate is designed to have minimum insertion losses between 8.4 and 8.5 GHz [2].

in practice, the dichroic plate is not illuminated by a plane wave, but by rays that originate from a feed horn and illuminate the dichroic plate at various theta and phi angles. Noise temperature of the dichroic plate is calculated from

$$T_{dp} = \frac{\int_0^{2\pi}\int_0^{\pi} p(\theta_h,\phi_h)T_b(\theta_h,\phi_h)\sin\theta_h\, d\theta_h\, d\phi_h}{\int_0^{2\pi}\int_0^{\pi} p(\theta_h,\phi_h)\sin\theta_h\, d\theta_h\, d\phi_h} \tag{1}$$

where θ_h,ϕ_h are spherical coordinate angles of the horn system. The parameter $p(\theta_h,\phi_h)$ is the normalized horn pattern obtainable through the use of horn computer programs. Brightness temperature data is obtained from

$$T_b(\theta,\phi) = (1-|S_{21}|^2)T_p, \tag{2}$$

where (θ,ϕ) are spherical coordinate angles of the dichroic plate system (Fig. 3), S_{21} is the plate transmission coefficient [2], and T_p is the noise temperature of the absorbing environment. For circular polarization, $|S_{21}|^2$ for perpendicular and parallel polarizations are averaged. For a dichroic plate installed in a BWG antenna subterranean room, it is assumed that T_p is 300 K. If instead the dichroic plate is mounted at the Cassegrain focal point location, then T_p is approximately equal to T_{sky}. Note that brightness temperatures calculated from Eq. (2) will include contributions from losses due to (1) reflection, (2) plate resistivity (if taken into account by the computer program), and (3) grating lobes (if they exist).

Accurate knowledge of the horn-plate geometry and use of coordinate transformation equations lead to derivation of expressions and contour plots (Fig. 4) that relate horn pattern angles (θ_h,ϕ_h) to dichroic plate angles (θ,ϕ). Use of these relationships allow $T_b\ (\theta_h,\phi_h)$ values to be determined from brightness temperatures calculated from Eq. (2). Substitutions of horn pattern and brightness temperature data into Eq.(1) lead to a calculated value of T_{dp} at a particular frequency.

The above process is repeated at other frequencies in the receive system passband and used in the following equation to calculate the effective dichroic plate noise temperature.

$$(T_{dp})_{eff} = \frac{\int_{f1}^{f2} g(f)\, T_{dp}\,(f)\, df}{\int_{f1}^{f2} g(f)\, df} \qquad (3$$

where $g(f) = 10^{G_{db}(f)}$ where $G_{dB}(f)$ is receive system relative gain response in dB at frequency f, and f1 and f2 represent the cutoff frequencies.

PRELIMINARY RESULTS

Further investigations of the cause of the 16.5-K discrepancy between measured and expected values led to the discovery that the actual passband of the receive system was 8.17 to 8.65 GHz in comparison to the dichroic plate passband, which was designed to be 8.4 to 8.5 GHz.

Preliminary calculations yielded a value of 14.8 K when using only (1) insertion loss data at 30-deg incidence angle, and the (2) measured receive system passband data (Fig. 5). If the hole and plate resistive losses contribute an additional 1.0 K, the preliminary calculated value for dichroic plate noise temperature is 15.8 K (as compared to a measured value of 18 K) .

Brightness temperature and horn pattern data are currently being obtained for all theta and phi values for the horn-plate geometry shown in Fig. 4. It is expected that when these data are used in the equations presented in this article, better agreement will be obtained between calculated and measured values.

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REFERENCES

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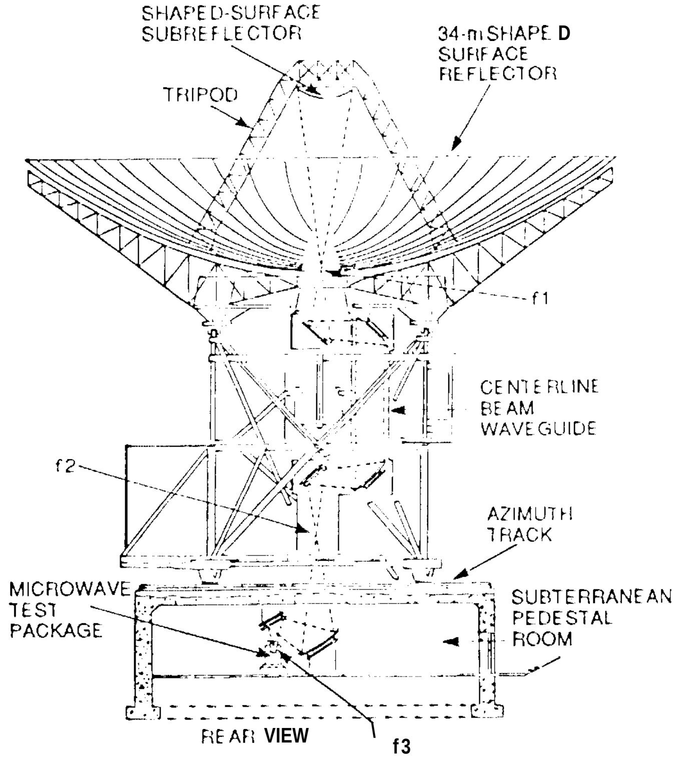

Figure 1. BWG antenna in the. centerline mode showing focal points f], f2, and f3.

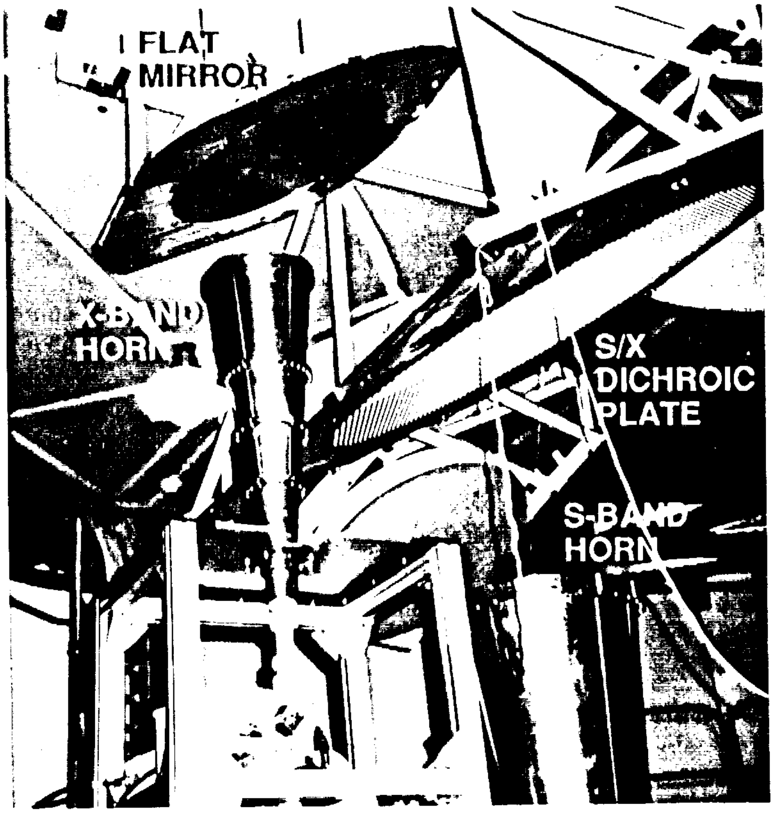

Figure 2. X-band feed-horn and dichroic plate of the S/X-band system at f3.

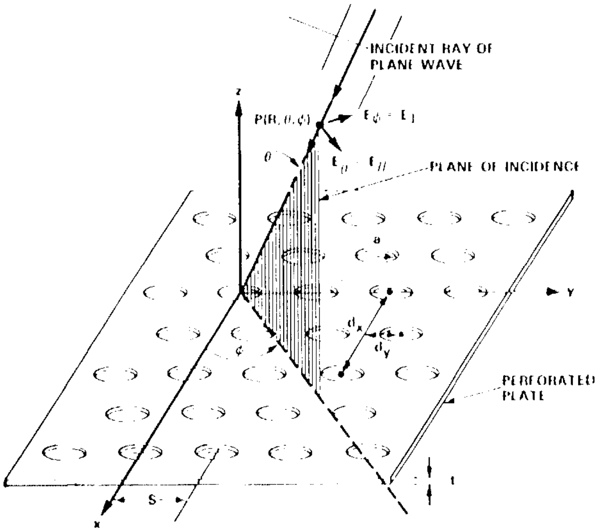

Figure 3. Dichroic plate geometry.

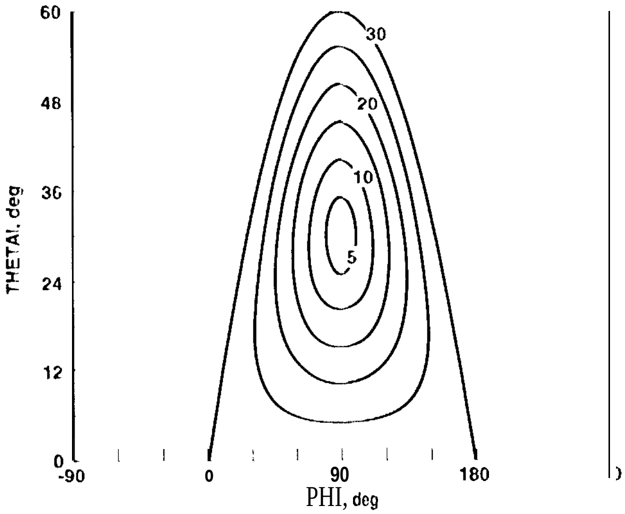

Figure 4. Horn pattern contour on the dichroic plate for $\theta_0 = 30$ deg.

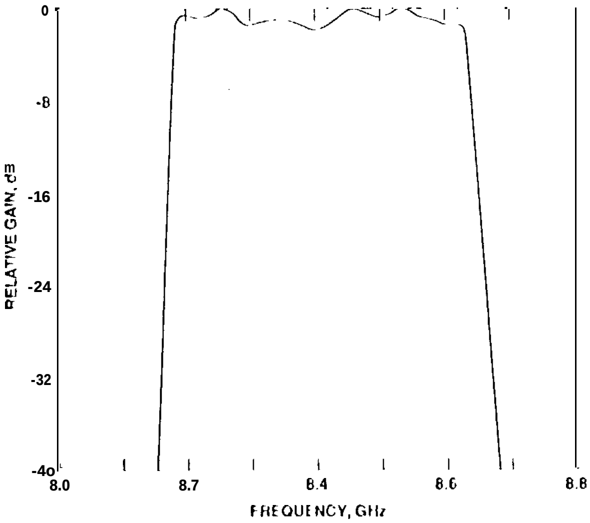

Figure 5. Measured passband of the X-band receive system.