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# S/Ka Dichroic Plate with Rounded Corners for NASA's 34-m Beam-Waveguide Antenna

Watt Veruttipong,* Behrouz Khayatian,* and William Imbriale*

ABSTRACT. — An S-/Ka-band frequency selective surface (FSS) or a dichroic plate is designed, manufactured, and tested for use in NASA's Deep Space Network (DSN) 34-m beam-waveguide (BWG) antennas. Due to its large size, the proposed dichroic incorporates a new design feature: waveguides with rounded corners to cut cost and allow ease of manufacturing the plate. The dichroic is designed using an analysis that combines the finite-element method (FEM) for arbitrarily shaped guides with the method of moments and Floquet mode theory for periodic structures. The software was verified by comparison with previously measured and computed dichroic plates. The large plate was manufactured with end-mill machining. The RF performance was measured and is in excellent agreement with the analytical results. The dichroic has been successfully installed and is operational at DSS-24, DSS-34, and DSS-54.

## I. Introduction

Deep Space Network (DSN) 34-m beam-waveguide (BWG) antennas operate in various transmit/receive configurations to support uplink (UL) and downlink (DL) communications with several current and future spacecraft. The S/Ka dichroic plate is designed to support the Lunar Reconnaissance Orbiter (LRO) and the James Webb Space Telescope (JWST). The dichroic will pass DL Ka-band (25.5–27.0 GHz) and reflect UL/DL S-band (2.025–2.300 GHz) in the BWG configuration as shown in Figure 1. The S/Ka dichroic plate is composed of a large number of small perforated areas as shown in Figures 2 and 3. As opposed to conventional types of rectangular waveguides with sharp corners, this structure employs rectangular openings with rounded corners. This will eliminate the need for the wire electrical discharge machining (EDM) technique during fabrication. Wire EDM technique requires very long fabrication time and it is not cost-effective for a very large plate. A new dichroic with rounded corners can use an end-mill machining, which significantly reduces fabrication time and cost.

* Communications Ground Systems Section.

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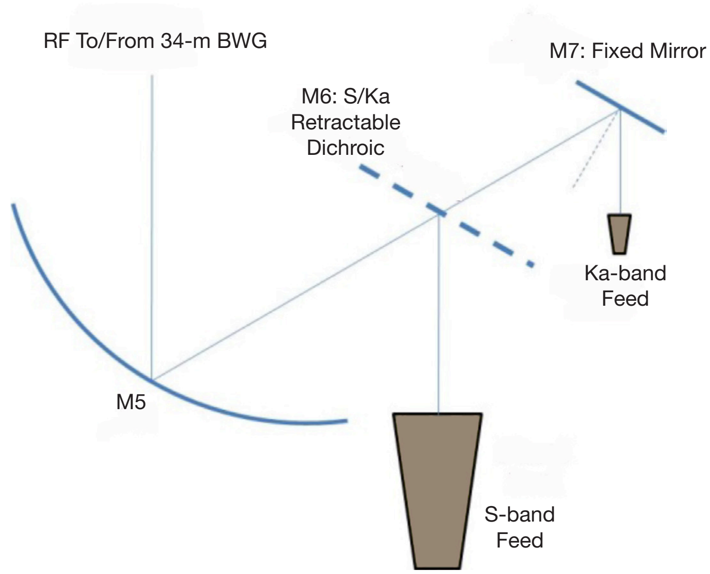


**Figure 1. Part of a DSN 34-m BWG structure employing the S/Ka dichroic plate.**

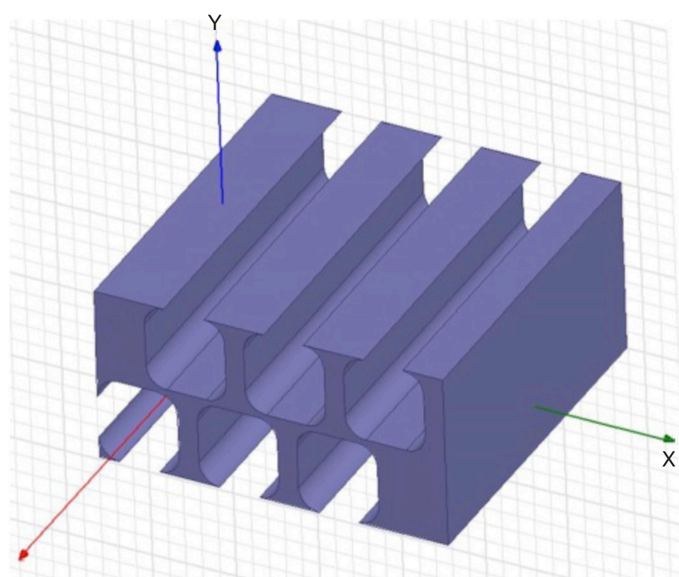


**Figure 2. Dichroic model in HFSS. Only a unit cell is used in the calculations. Drawing is not to scale.**

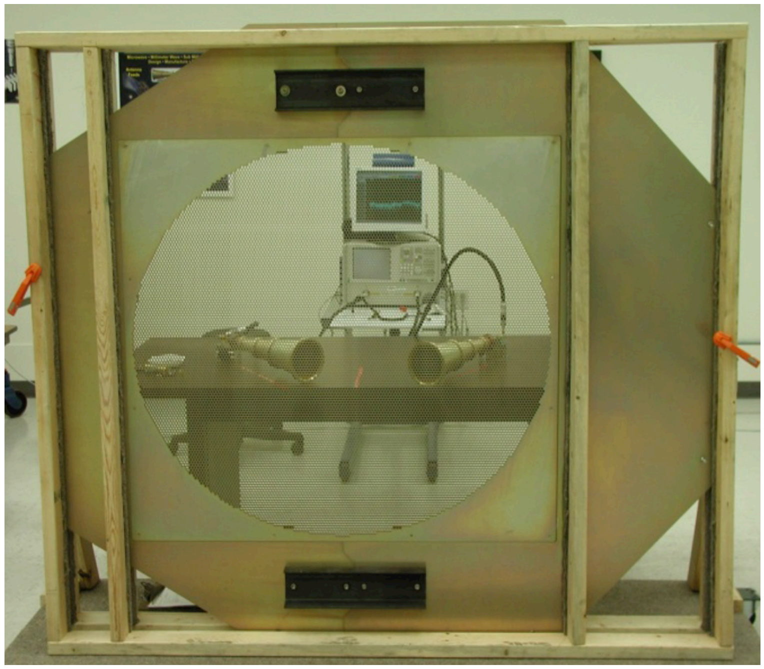

**Figure 3. Manufactured S/Ka dichroic plate and measurement setup used to measure TE and TM reflection coefficients.**

The canonical rectangular waveguide modes employed in [1] cannot be used for rounded waveguide structures. The dichroic is designed using a combined finite-element method (FEM) for arbitrarily shaped guides in conjunction with method of moments and Floquet modes of periodic structures [2]. Other types of FEM techniques such as the High-Frequency Structure Simulator (HFSS)[1] can also be used to design and analyze FSS-type structures of arbitrary shape cross-section. The technique used to design the dichroic plate in this study was later verified using HFSS.

## II. Design Methodology

Waveguide layout configuration for this design somewhat resembles the one presented in [1]. However, the sharp edges of waveguide structures in [1] are replaced by round edges, as shown in Figure 2. A plane wave incident assumption is used. It is also assumed that the dichroic plate acts as an infinite periodic structure with a 30-deg angle of incidence by a plane wave, as shown in Figure 1.

There are four basic parameters in this design, which include height, width and radius of curvature at the edge of the waveguide, and the thickness of the dichroic plate. While the four parameters work together to tune the plate at S-/Ka-bands, height and width of the waveguide are primarily used to tune the plate for transverse electric (TE) and transverse magnetic (TM) transmission/reflection coefficients. Perforation on the dichroic plate is made over an ellipse with major and minor axis of 46 in. × 40 in. Its thickness ensures very

[1] ANSYS Corporation: www.ansys.com/en/Products/Electronics/ANSYS-HFSS

small reflection and adequate transmission at Ka-band. Furthermore, the minimum radius of curvature of round edges was selected to ease manufacturing process for the end-mill machining.

Reflection coefficient requirements are to be better than –15 dB over Ka-band and better than –25 dB at 25.9 GHz (± 0.1 GHz) for JWST downlink operation. The reflection coefficient at S-band (2.10–2.30 GHz) should be about 0.0 dB.

### III. Calculated and Measured Data of the Dichroic Plate

The S/Ka dichroic plate is fabricated at Custom Microwave Inc. (CMI) and is made from a solid piece of aluminum. Reflected TE and TM incident fields on the dichroic plate from a 30-deg incident field are computed using the FEM technique, as described in [2]. Measurement setup is shown in Figure 3 where the reflection coefficients are measured using two horns facing the dichroic plate at 30-deg incident angles. Calculated versus measured TE and TM reflection coefficients are shown in Figures 4 and 5. Measured and calculated results show excellent agreement over Ka-band. S-band reflection coefficient requirements are met and nearly zero dB across the band based on test results at a DSN station.

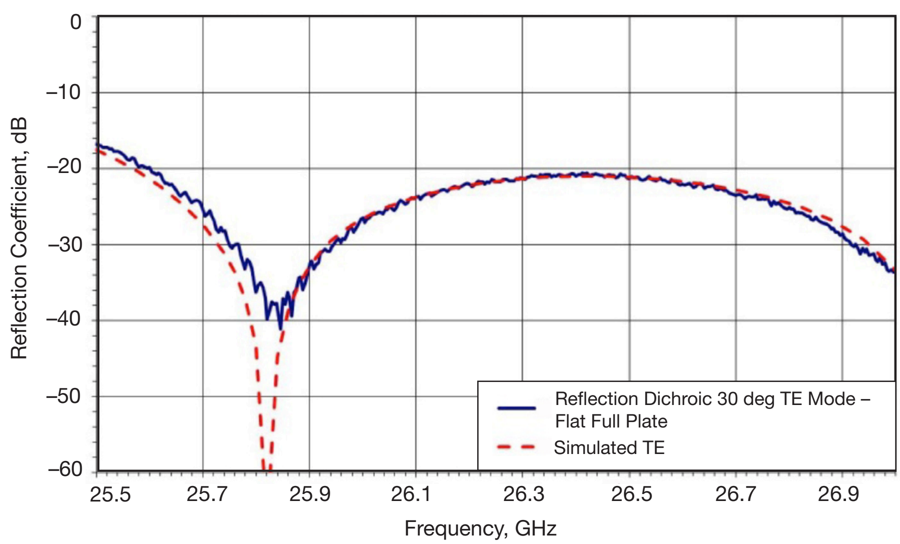


**Figure 4. Part of a DSN 34-m BWG structure employing an S/Ka dichroic plate.**

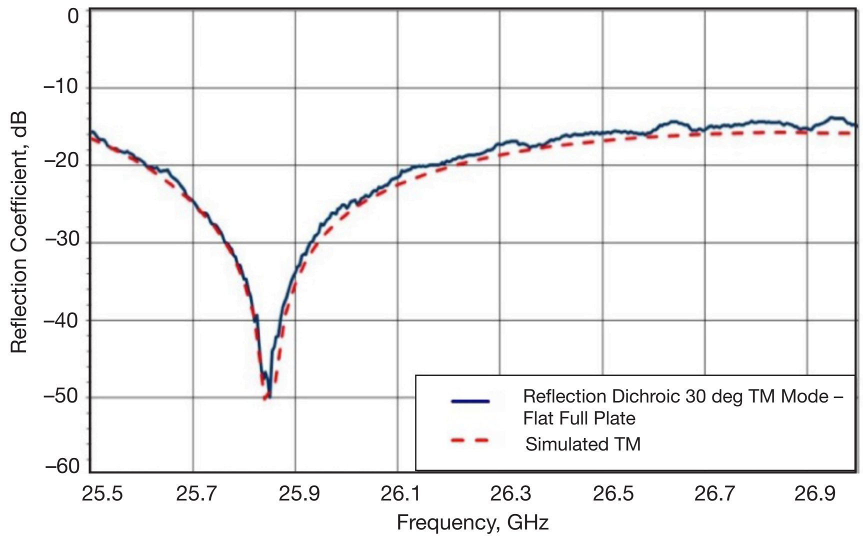


**Figure 5. Part of a DSN 34-m BWG structure employing an S/Ka dichroic plate.**

## IV. Conclusions

The S/Ka dichroic plate is designed with rounded corners in its waveguide structures to avoid the high cost and long fabrication time of the wire EDM process. Excellent agreement between TE and TM reflection coefficients is observed when comparing calculated versus measured results. There is better than 25 dB return loss over the operating band. The dichroic noise temperature contribution is within the subsystem requirement allocated for JWST downlink communication. The dichroic has been successfully installed and is operational at DSS-24, DSS-34, and DSS-54.

## References

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