MEASUREMENT OF THE NOISE IMPROVEMENT OF A 34-METER CASSEGRAIN ANTENNA RETROFITTED WITH A LOW-BACKSCATTERING STRUT

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A. Introduction

Large axially-symmetric ground-based dual-reflector antennas are used in a variety of applications simultaneously requiring very high gain and very low noise (e.g., satellite communications, radio astronomy, deep-space communications, and radar). In these systems, reducing the noise by 10 % is equivalent to increasing the antenna gain by roughly 0.5 dB. Since the early days of radio-astronomy this fact has continuously driven efforts to reduce the noise of front-end low-noise amplifiers—a major noise contributor. As the performance of the front-end amplifiers improved, the relative importance of the noise generated by the surrounding warm ground increased, causing the antenna noise to become a major factor in the overall system sensitivity.

Since large ground-based reflectors have been around for several decades, the various electrical and mechanical parameters affecting their performance have received considerable attention and are generally well understood. However, the impact of the subreflector supporting struts on the antenna noise performance remains a source of uncertainty. The reason for this stems from the usually large electrical dimensions involved, which precludes the accurate modeling of the various strut-scattering mechanisms. For the particular antennas used on NASA's Deep Space Network, which have been designed to minimize all noise sources, several studies have typically reported measured noise temperatures between 2 and 3 K (at $\sim$ 8.45 GHz, antenna pointing at zenith), attributed to the struts and other unknown effects (see for example [1] and [2]). With this in mind, an effort has recently been conducted to determine optimal strut shapes to reduce the associated noise contribution [3].

In this work the results of [3] are used to implement a low back-scattering cross section on a single strut of the Jet Propulsion Laboratory Deep Space Station 13 (DSS-13) antenna—a research and development 34-meter diameter deep-space communication beam-waveguide shaped Cassegrain antenna, located in Goldstone, California. The antenna and associated noise measurements are briefly discussed below, and the improvement on the system noise temperature presented.

B. Strut Characteristics of the DSS-13 Antenna

The main characteristics of the DSS-13 antenna are thoroughly discussed in [4], together with predicted and measured electrical performances. Hence, only the aspects relevant to the strut noise are discussed here. The antenna has three equally spaced struts making an angle $\theta_c = 28.6°$ with the boresight direction. Figure 1 depicts the DSS-13 antenna, with its two lower struts shown. At 0° elevation, only one strut is at the antenna top half—inverted-Y tripod configuration. Figure 2 shows a close-up view of a strut, together with the simplified cross-section model used

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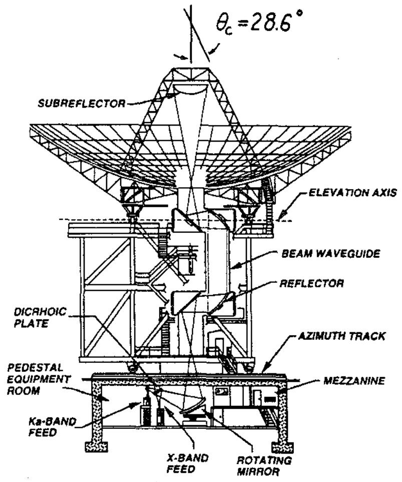

Fig. 1 – DSS-13 antenna geometry.

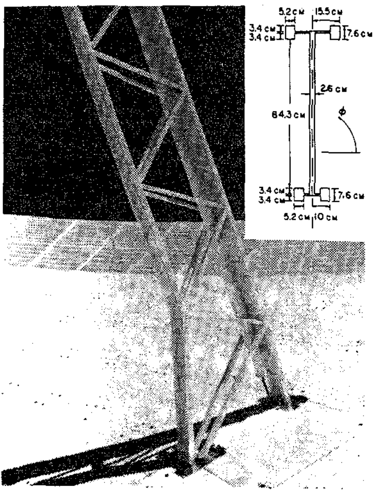

Fig. 2 – DSS-13 antenna strut.

to determine its scattering characteristics. Since the calculation of the scattering produced by the actual truss strut is a formidable task, a constant cross section is assumed to render the geometry more amenable to numerical computations. This is justified since numerical simulations have shown that most of the strut-noise contribution comes from the backscattering of the strut leading edge (edge closer to the main-reflector axis), which is being accurately modeled.

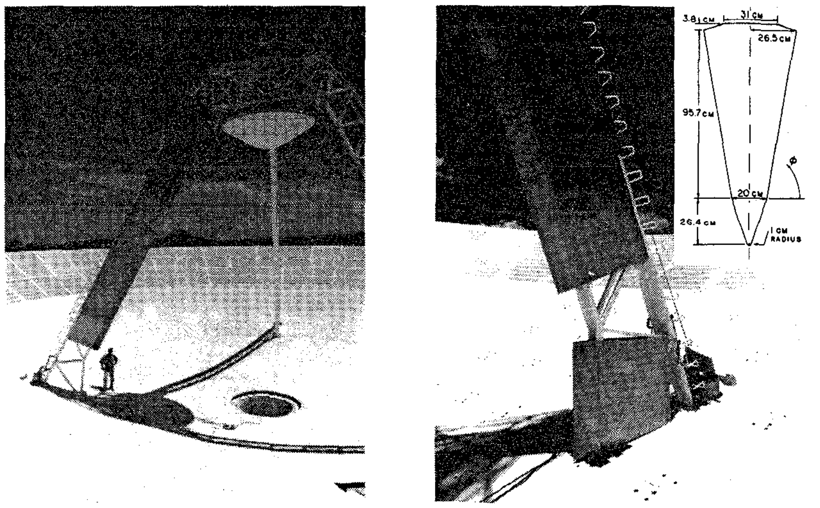

Fig. 3 – DSS-13 antenna top strut during installation of the covers.

The low-backscattering strut was implemented by covering the existing top strut with a folded aluminum panel. The shape of the cover was determined to minimize the energy scattered towards ground [3]. Figure 3 depicts the ~ 12 meter long strut just before covering its last section. The corresponding scattering characteristics of the original and covered struts, illuminated by a circularly polarized plane wave emanating from the main reflector, is shown in Fig. 4. Clearly the covered strut eliminates, for all practical purposes, the energy scattered towards ground.

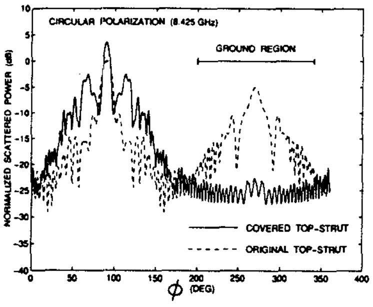

Fig. 4 – DSS-13 antenna strut plane wave scattering behavior.

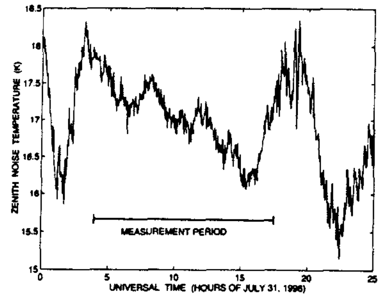

Fig. 5 – 31.4 GHz atmospheric plus cosmic background noise temperature.

C. Measurements and Results

Two pairs of antenna noise temperature measurements were performed with and without the covers installed on the top strut, at various elevation angles, during the July 31, 1996 cloudless evening. The employed radiometric system, as well as its accuracy, is detailed in [5]. Starting from zenith, the antenna was sequentially parked at six representative elevation angles to measure the system noise temperature T_{op}. To assure maximum accuracy, the radiometer was fully recalibrated at each elevation angle. Two frequencies were used, 8.425 GHz and 32 GHz, although the 32 GHz results were subsequently discarded due to insufficient accuracy. Since more than five hours elapsed between two same-elevation with- and without-cover measurements, the variations of the atmospheric attenuation had to be calibrated out. This was accomplished using a water vapor radiometer (WVR), completely independent of the DSS-13 antenna, which measured the atmospheric noise temperature T_{wvr} due to water vapor absorption at 31.4 GHz (including cosmic background). The WVR results are shown in Fig. 5. T_{wvr} was then converted to 8.425 GHz, averaged over the measurement time interval, and subtracted from the measured T_{op} to eliminate the atmospheric plus cosmic noise background contributions. This left only the desired antenna system noise temperature without and with the covers, Ta_{woc} and Ta_{wic}, respectively. This procedure yielded the results of Tab. 1, where ΔT is the strut-noise improvement.

D. Conclusion

The measurements performed show that covering the the top strut of the DSS-13 antenna lowers the zenith noise temperature by 0.2 K. This improvement sharply rises to 0.45 K around a 50° elevation and continues to increase as the antenna elevation

Elevation (deg)	Ta_{woc} (K)	Ta_{wic} (K)	$\Delta T = Ta_{woc} - Ta_{wic}$ (K)
90.000	37.705	37.508	0.20 ± 0.05
70.000	37.614	37.378	0.24 ± 0.01
50.000	37.617	37.167	0.45 ± 0.03
30.000	37.701	37.107	0.59 ± 0.06
19.470	37.848	36.985	0.86 ± 0.08
11.540	37.887	36.791	1.10 ± 0.15

Tab. 1 – DSS-13 antenna strut noise temperature improvement.

decreases. At an elevation of 11.54° the improvement reaches 1.10 K. The fact that the top-strut scattering cone starts to illuminate the warm ground at a 57.2° elevation provides a possible explanation for this behavior [3]. Since examination of the strut-scattering mechanisms indicate that covering all struts with the antenna pointing at zenith effectively removes the strut noise contribution, the measured $3 \times 0.2 = 0.6$ K value is then considerably less than the 2 K to 3 K attributed in the literature to the subreflector support and other unknown effects [1],[2]. At the time of this writing possible additional sources of noise, to explain the previously reported measured 2 K to 3 K values, are under investigation.

E. Acknowledgement

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