Performance of DSS 13 26-m Antenna at X-Band

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The X-band low-noise antenna (XLA) measurement feedcone was operated on the DSS 13 26-m antenna at Goldstone, California, during June 1975 to evaluate, primarily, the overall system efficiency. Radio sources were selected, commonly accepted values of flux density established, and measurements completed, and some conclusions are drawn. The antenna system presently suffers from poor pointing stability. On the other hand, the previously welded and rebolted main reflector has remained quite stable over a period of approximately 5 years.

I. Introduction

The DSS 13 26-m antenna was operated at 8450 MHz during June 1975 for the purpose of overall antenna system evaluation. The antenna reflector portion had previously been operated at X-band during June 1967 and October 1968 with an early feedcone system (Refs. 1,2). During the intervening time, the antenna structure has undergone many changes, necessitating the current set of measurements. To evaluate the antenna performance, the X-band low-noise antenna (XLA) measurement feedcone was installed, and radio metric observations of selected radio sources were performed using a noise-adding radiometer. The antenna parameters evaluated were axial focus of the subreflector, beam pointing characteristics, beamwidth, operating system temperatures, and overall system efficiency.

II. Selected Radio Sources

The performance characteristics of the antenna system were evaluated using 3C123, 3C273, 3C274 (Virgo A), DR 21, and the planets Venus and Jupiter. The important radio source characteristics assumed are listed in Table 1. The primary factors affecting the selection of a radio source to be used for antenna calibrations are accuracy of flux density, distribution of flux, source angular size, and source positions. The source 3C274 (Virgo A) was used to evaluate the gain of the system to be consistent with and comparable to previous work. The sources 3C123, DR 21, Venus, and Jupiter were used for both efficiency and pointing evaluations. The source 3C273 was also used for pointing evaluation, but the variability of its flux density makes it a poor standard for efficiency measurements. The use of more than one source for antenna performance evaluation gives a more complete and consistent calibration of the performance.

III. Antenna Performance

A. Antenna Feed System

The antenna feed system with the XLA feedcone is a low-noise system. The overall operating system temperature at zenith (T_{op}) was approximately 21 K. The operating system temperature as a function of elevation angle, including atmospheric loss and antenna spillover, is presented in Fig. 1. The antenna polarization was set to right circular. By using the drift curve technique, the half-power beamwidth was measured to be 0.1 deg or about 6 arc minutes, as expected.

B. Pointing

The pointing characteristics of the antenna were evaluated using the technique of boresighting about the half-power points of the main beam. The measured elevation offsets as a function of elevation angle are presented in Fig. 2. The mean elevation offset is ($+0.014 \pm 0.013$) deg ($1\ \sigma$). Assuming the main beam shape is gaussian, the ±0.013-deg uncertainty results in approximately 0.2 dB ($1\ \sigma$) gain loss. The corresponding measured azimuth offsets as a function of azimuth angle are presented in Fig. 3. The mean azimuth offset is ($+0.122 \pm 0.019$) deg ($1\ \sigma$). Again assuming the gaussian beam shape, the ±0.019-deg uncertainty results in approximately 0.4 dB ($1\ \sigma$) gain loss. As an example of the effect of this level of poor pointing, assume the boresight errors were, in each axis, at the $1\ \sigma$ levels of $+0.013$ and $+0.019$ deg previously mentioned. The resulting error would be 0.023 deg, and the corresponding gain loss is approximately 0.6 dB. Random pointing errors of ±0.020 deg would result in 0.5 dB of gain loss and are common, as seen in Fig. 2 and 3. This performance is considered unacceptable in the context of a high-performance X-band reflector antenna. During a windy period of 50–80 km/h (30–50 mph) gusts, observations of the planet Venus were attempted. The antenna-mounted television camera enabled the visual observations of the antenna pointing performance. Momentary pointing errors of ±0.050-deg peaks (−3 dB loss excursions) were observed during large wind gusts, implying that the entire antenna framework was being moved.

C. Axial Focus

To examine the main reflector focal length as a function of elevation angle, the antenna is set to track a radio source while the subreflector is slewed in the axial direction. The optimum position is displayed by the analog output of the noise-adding radiometer at a particular elevation angle. Performing this test at various elevation angles during a track, the function can be determined. After performing this procedure for the DSS 13 26-m antenna, the optimum indicated control room position was determined not to be elevation-dependent. The indicated control room position of 320 deg is valid for all elevations. The measured data are presented in Fig. 4. This result indicates that the focal length stability of the antenna is excellent. The bolting and welding of the main reflector backup structure and other improvements done previously are apparently still tight. Previous measurements, described in Ref. 3, have indicated large changes in the axial focus which are a clear symptom of very flexible antenna radial ribs. Fortunately, this effect has been completely corrected.

D. System Efficiency

System efficiency is defined as the antenna efficiency including the atmosphere loss as measured at the input flange of the maser amplifier. To examine the system efficiency, the technique of ON/OFF source system temperature measurements was utilized. This technique measures system temperature with and without the noise contribution from the radio source. By calculating the change in system temperature (ΔT_a) caused by the radio source and by knowing the flux density of the radio source, the system efficiency can be determined. The system efficiency vs. elevation angle data are presented in Fig. 5, with a second-order curve fitted to the data. From the fitted curve, the peak efficiency is 43% at 44-deg elevation angle. The poor pointing of the antenna is the primary cause of the large scatter in the efficiency. A change to the antenna system which could contribute to the decrease in mean efficiency is the fully welded subreflector, including the S-band vertex plate. This vertex plate was removed from the antenna for the measurements described in Ref. 2 but could not be removed for this series of tests. Some combination of the welding distortion and the effect of the vertex plate which modifies the aperture illumination has reduced the system efficiency from 50.3% (October 1968) to 43% (this reporting). This decrease in efficiency corresponds to 0.7 dB of gain loss.

IV. Conclusion

In the period between the measurements of October 1968 to the measurements of June 1975, the system efficiency has decreased from 50.3 to 43%. The axial focal length stability of the antenna remains unchanged; that is, the antenna need not be refocused as a function of elevation angle. The most serious problem of operating the DSS 13 26-m antenna at the shorter wavelength is clearly the overall pointing stability of the system. Such changes in the antenna pointing as described by Figs. 2 and 3 degrade the total performance of the antenna system. This degraded performance would be operationally experienced for many missions where boresighting is infrequently done, if at all. As was stated in Ref. 2, there remains a problem in pointing ability of the 26-m antenna which seriously hampers future work at the shorter wavelengths.

References

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2. Norman, R. A., "Efficient Antenna Systems: X-Band Gain Measurements, 85 ft Antenna," in *The Deep Space Network*, JPL Space Programs Summary 37-55, Vol. II, pp. 47–49, Jan. 31, 1969.
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Table 1. Radio source characteristics

Source	S 8450 MHz	Source size	Source structure	Size correction factor	Spectral index at 8450 MHz
3C123	10 f.u.	Two points	Close double sep. 13 arc sec	1.017	−0.94
3C273	21 f.u. Variable	Point	—	1.00	—
3C274 (Virgo A)	42 f.u.	40 × 20 arc sec	Core halo	1.13	−0.85
DR 21	20 f.u.	20 arc sec	Gaussian	1.00	−0.13 (Ref. 4)
Venus	18 f.u.	Semi diam 11.43 arc sec	Planet (disk at 660 K)	1.00	—
Jupiter	13 f.u.	Semi diam 17.30 × 18.51 arc sec	Planet (disk at 230 K)	1.00	

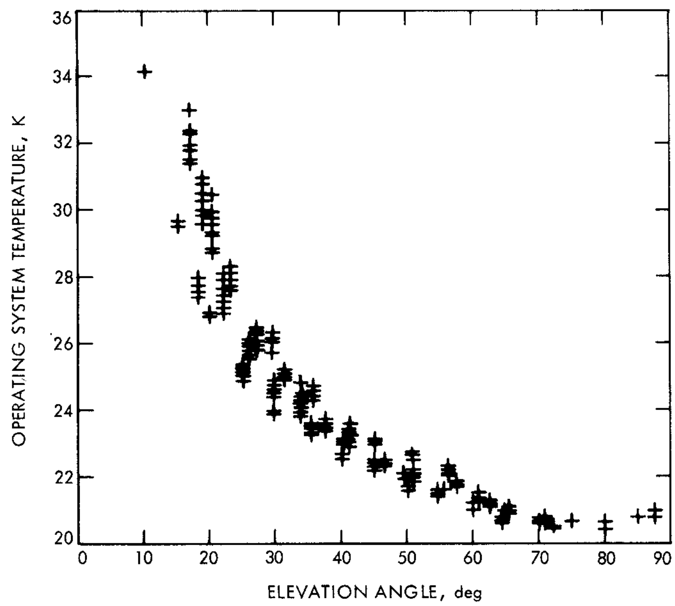

Fig. 1. Operating system temperature as a function of elevation angle, XLA feedcone, DSS 13

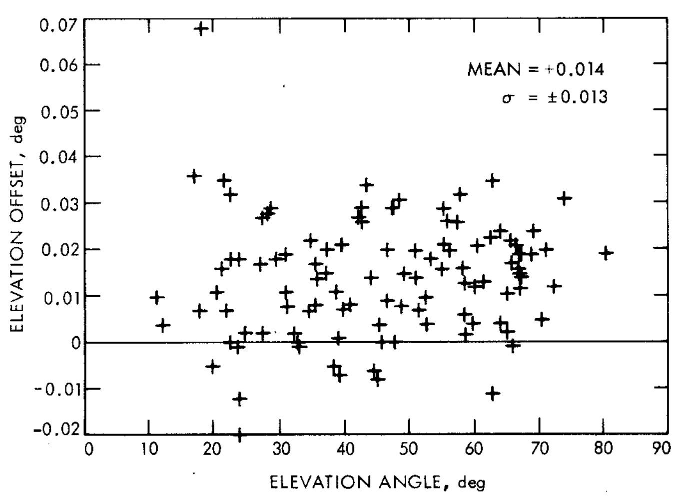

Fig. 2. Elevation offsets as a function of elevation angle, XLA feedcone, DSS 13

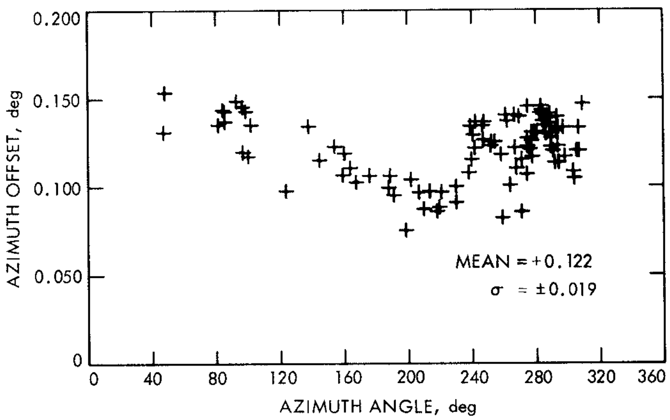

Fig. 3. Azimuth offsets as a function of azimuth, XLA feedcone, DSS 13

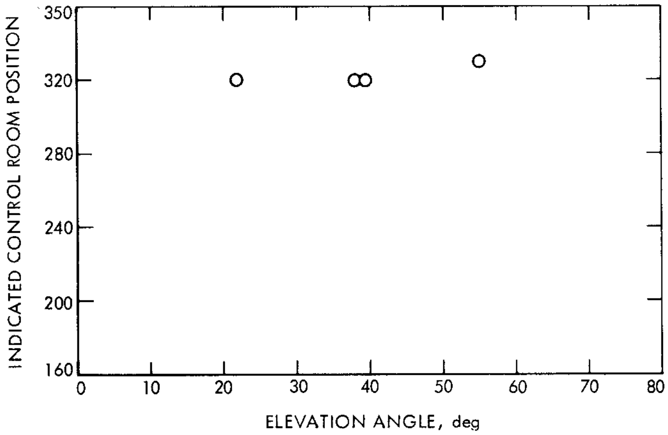

Fig. 4. Axial focus as a function of elevation angle, XLA feedcone, DSS 13

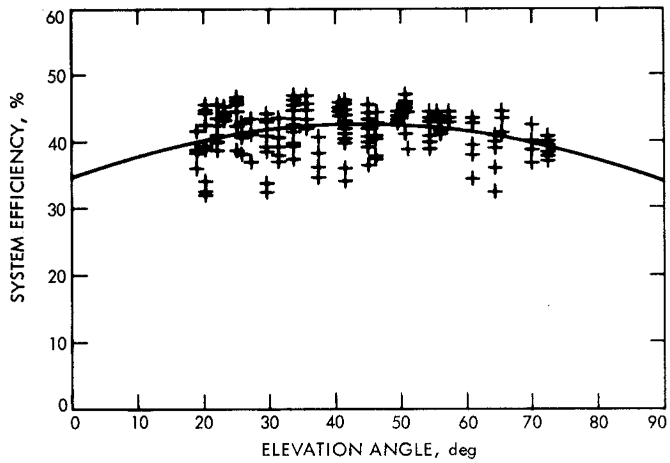

Fig. 5. System efficiency as a function of elevation angle, XLA feedcone, DSS 13