LOW NOISE MICROWAVE RECEIVING SYSTEMS ON A 64 m ANTENNA

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Abstract

The performance capability at S-, X- and K-band of the NASA/JPL 64 m Cassegrain antenna at Goldstone, California, is reviewed. The multiple feed system allows X- and K-band atmospheric research studies to be conducted simultaneously with mission directed S-band spacecraft tracking. A description of the antenna system and its multiple operation is followed by gain and efficiency comparisons at the three frequencies. The total operating system temperature, and its frequency dependence, is presented and discussed.

Antenna gain and efficiency, and zenith system operating temperature are summarized, at S- and X-band respectively, by 62 dB, 63%, 16K; and 72 dB, 52%, 24K. Preliminary measurements for K-band are 76 dB, 39%, 29K.

Introduction

A recently installed multiple feed system on the NASA/JPL 64 m Advanced Antenna System, located at Goldstone, California, provides a significant operational and research facility. Centimeter wave atmospheric studies are being conducted simultaneously with mission directed S-band spacecraft tracking. Experience with this equipment and measurements of gain and system temperature are discussed for S-, X- and K-band frequencies.

Multiple Feed System

Figure 1 is a photograph of the 64 m Cassegrain antenna, fitted with an asymmetric subreflector capable of continuous rotation about the focal axis with five precision indexed operating positions. One feed horn is located at each position of the secondary focus corresponding to each indexed operating position of the subreflector. The feed horns are shown in Figure 2. The two cones in the foreground contain separate S-band systems and these provide special performance characteristics (such as diplexed polarization diversity or ultra low noise receive only) for certain spacecraft tracking missions.

The three remaining secondary foci are all contained within the third feedcone, which is fitted with X- and K-band radiometers, together with associated reference horns. The X-band main and reference horns and the K-band main horn are positioned at the three indexed subreflector positions. The location of the K-band reference horn is deliberately not on an indexed position.

Perfect microwave optics are obtained only on a single system at a time, depending on the rotational setting of the subreflector. Each system, as it is focussed in turn, results in the identical axial boresight. Defocussed feeds, either intentionally not aligned with the secondary foci, or the reference horns, are operated simultaneously. While the boresight angles are different, the main beam efficiency remains high (for the small boresight shifts experienced). Thus these beams are useful for many purposes, such as atmospheric radiometry or background reference temperature measurements.

Gain and Efficiency

The gain and efficiency at S-band have previously been measured using a standard horn and cw techniques with the transmitter of the Surveyor spacecraft on the Earth's moon. The results are 61.6 dB (with a 3σ tolerance of ± 0.4 dB) and 63%. At X- and K-bands commonly accepted radio source calibrations have been used with an established accuracy in the order of ± 1 dB. The results are 72.3 dB and 52% at 8 GHz and 76.2 dB and 40% at 15 GHz, at 45° elevation.

Figure 3 shows system efficiency as a function of elevation angle for the three frequencies. The two higher frequencies allow an accurate measure of the precision of the reflecting surface pair. The results are shown at the top of Figure 3. They are approximately 1.1 mm RMS at 45° elevation and 1.5 mm RMS at 15° and 75°.

System Operating Noise Temperatures

The tricone structure shown in Figure 2 contains five traveling wave maser front-ends. Each S-band cone has a maser, with a third maser available for switching into either cone by remotely controlled waveguide switches. The X- and K-band radiometers each have a traveling wave maser front-end in the third cone. The K-band maser is fitted with a superconducting magnet.

Typical equivalent noise temperatures of the three S-band masers are 4 to 6K. Those of the X- and K-band masers are 7K and 10K, respectively.

The total system operating noise temperatures, T_{op}, at zenith, at 2 GHz, 8 GHz, and 15 GHz, are 15.9K, 24K and 29K, respectively. The S-band system temperature refers to the receive only mode.

The tricone structure contains three continuous wave S-band transmitters: 400 KW and 20 KW at 2115 MHz for spacecraft command and ranging, and 400 KW at 2388 MHz for radar astronomy research. For diplexed operation the S-band system temperature is typically 23.5K due to the extra complexity and dissipative loss of the waveguide path between the maser and the horn. Each of the above noise temperatures refers to the particular system when it is correctly focussed with the subreflector.

Figure 4 shows the elevation dependence in clear weather of system temperature at the three frequencies.

Conclusion

The 64 m antenna, fitted with a multiple feed tricone, functions as a high gain, low noise ground system at three frequencies. Experience and data are being gained with this large aperture (D/λ) in conjunction with low noise technology.

Atmospheric research studies are being performed at the three frequencies independent of, and simultaneously with, mission directed S-band spacecraft tracking. These studies are contributing information on weather dependent functions, as well as allowing research on the measurement and prediction of weather effects, principally rain and cloud cover, on the quality of earth-space microwave links as a function of frequency.

Acknowledgment

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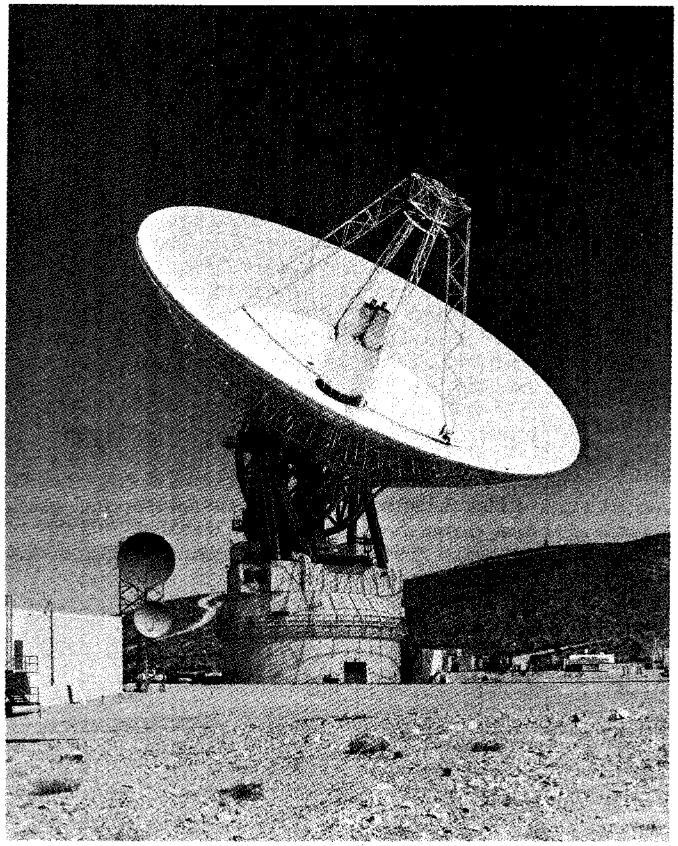

FIG. 1. THE NASA/JPL 64 m ANTENNA AT GOLDSTONE, CALIFORNIA.

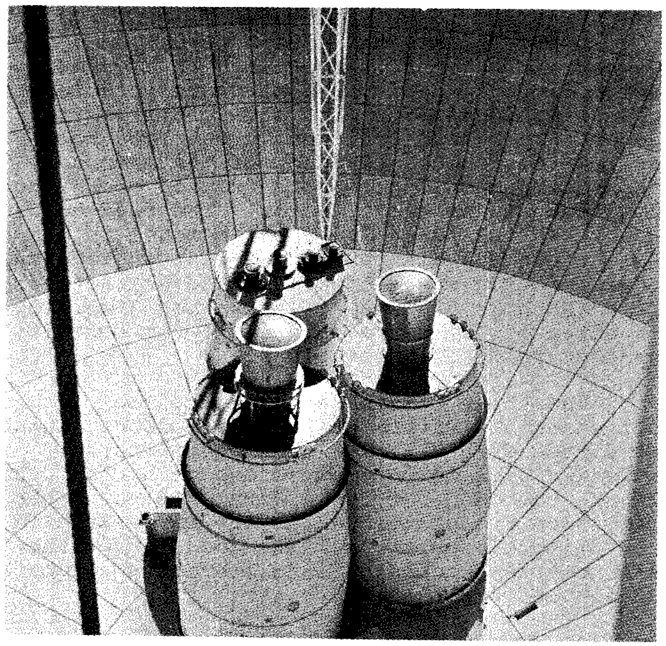

FIG. 2. THE TRICONE ON THE 64 m ANTENNA.

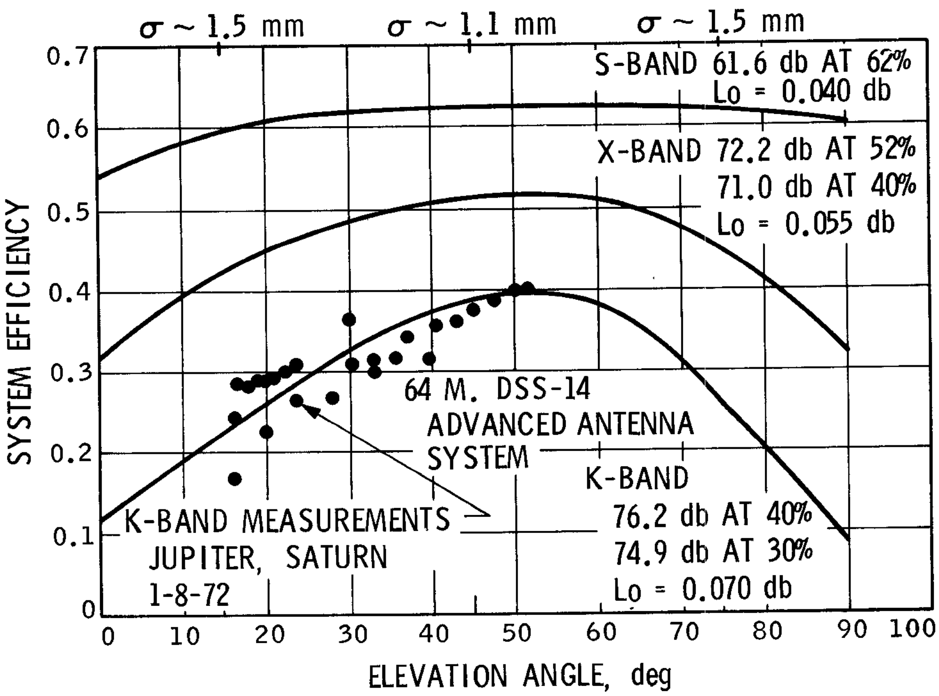

FIG. 3. SYSTEM EFFICIENCY AS A FUNCTION OF ELEVATION ANGLE.

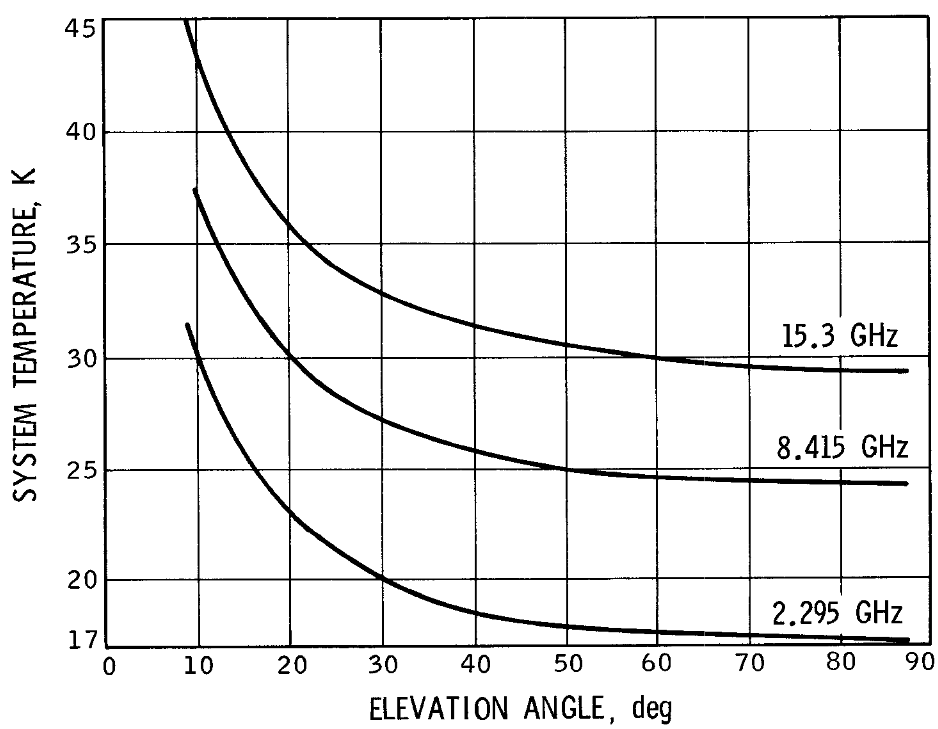

FIG. 4. SYSTEM TEMPERATURE AS A FUNCTION OF ELEVATION ANGLE.

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