Holography, Raster Scan, and Stability Measurements of the NASA-JPL Deep Space Network Antennas

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I. Introduction

The NASA JPL Deep Space Network (DSN) of large reflector antennas are subject to continuos demands for improving signal reception sensitivity, increase transmitted power, dynamic 'range, navigation accuracy, and frequency stability. In addition, "once-in-a-lifetime science opportunities have increasing demand of the DSN performance reliability. The increase of the antenna operational frequencies to X-band (8.45 -GHz) and Ka-band (32-GHz), coupled with higher performance demands by new missions ex. the Cassini spacecraft and the gravity wave detection experiment, have created a demand for a new and integrated antenna performance and calibration instrument. This new instrument will acquire all the data necessary to derive high precision (and high resolution where applicable) antenna gain, pointing, panel and subreflector alignment, and antenna stability, as well as calibration of radio sources. To this end, the new instrument is capable of processing wide-band, noise like, natural radio source signals as well as narrow-band, satellite's continuos wave (C W) beacon and pilot tone signals.

In this paper the architecture of the instrument and its specification are described as well as some latest measurement results demonstrating its capabilities.

II RF Performance Calibration System.

The architecture of the RF Performance Calibration System (the instrument), share a common data acquisition and processing computer hardware and software controlling two different (co located) receivers. The total power radiometer (TPR) receiver is utilized for the reception of the radio source signals while the two channel amplitude and phase receiver (microwave antenna holography receiver- MAHST) for the reception of satellite's CW beacon and pilot tone signals. The data from the TPR is used to derive: the antenna efficiency versus elevation function, antenna pointing versus elevation model, beam pattern, antenna noise temperature, radio source calibration, and low resolution aberration suitable for phase retrieval holography. The data from the MAHST is used to derive the panel alignment screw adjustment, subreflector alignment, gravity deformation maps, directivity, and beam pattern. In addition, the combined instrument have been (and could be) used for other advanced measurements for ex. deformable surface calibration for compensation of reflector gravity distortion, and tipping curves utilized for the measurement of stealth strut performance.

The data acquisition is developed around menu driven user friendly software provided by LabView.

III High Resolution High Precision Holographic Maps.

On June 28, 1996 the new instrument was used for the measurement of the newly built 34-meter beamwaveguide (BWG) DSN antenna in Goldstone California, designated DSS-25. Measurements were made from the cassergrain F 1 focus utilizing beacon signals from GSTAR-4 satellite observed at the nominal elevation angle of 47 degrees. Gravity and performance measurement at low elevation angle were studied from measurement of beacon signals from Intelsat-307 satellite observed at the nominal angle of 12.7 degrees. At 47.0 degrees elevation, the normal rms surface error of the DSS-25 as set by the theodolite was 0.4 mm (the best ever in the DSN). After applying the holography derived panel setting, the normal rms surface error was reduce to 0.25 mm. At 32 GHz (Ka-band), the improved performance due to panel setting is estimated to be 0.76 dB. This is equivalent to increasing the effective collecting area of the antenna by 102 m^2 at Ka-band. The antenna rms surface error at 12.6 degrees. elevation is 0.50 mm, and mostly characterized by astigmatism due to gravity deformation as expected.

The subreflector position was set at 47.0 and 12.6 degrees. elevations from F 1. Relative to its nominal position, the following corrections were made at 47.0 deg elevation: X=-O. 1", y=-.21 2", z=+.40". At 12.6 degrees. elevation, the subreflector position is y=+0.2" and z=+.33".

The accuracy of the high resolution maps in the above measurements was 0.07 mm rms, and the panel setting derivation accuracy is 0.0175 mm (17.5-micron) rms.

IV Fractional Frequency Stability of a 34-meter antenna

The instrument provides a real time display of the fractional frequency stability, Alan deviation of the antenna mechanical subsystem. The need for antennas with high frequency stability 10^{-15}, is required for the gravity wave detection experiment that will utilize the Cassini spacecraft. The utilization of a reference antenna located near the antenna under test in the measurement, eliminate the signal fluctuations in the common path to the satellite, enabling the determination of the stability of the antenna under test. From the measurements, the stability, Alan deviation of DSS-25 was found to be 2.6x 10-'s for tau= 1024 see, which satisfy the requirements for the Cassini gravity wave experiment.