12 METER MILLIMETER WAVE TELESCOPE
MEMO No. 237

Holographic Measurement of the 12m surface

Preliminary Report

Holographic measurements of the surface of the 12m dish have been carried out at a frequency of 38 GHz. This memo briefly describes the observations, the analysis methods and the comparison of the final results with mechanical measurements carried out with the dish in the same state of adjustment.

Observations were carried out during August and September 1983. The signal source used was the Lincoln Laboratories satellite LES-8, which has a steerable 1m paraboloid available at 38 GHz. The receiver system, specially designed and constructed by NRAO, consists of a focus package containing two separate receivers, with a feed assembly at each end. At the sky end a lens corrected feed horn is used to provide a reference signal from the satellite. At the other end a scalar conical feed illuminates the main dish. A digital backend correlates the signals from the main and reference receivers over a 10 kHz bandwidth and provides real and imaginary parts of the correlated signal at 100 ms intervals to the data logging computer of the 12m telescope. This then carries out further integration as required on individual data points. Working from an empheris provided by Lincoln Labs, the telescope is driven in a raster scan of grid points about the current position of the satellite. Positional information is updated at the beginning of each row of the raster scan by performing a 'five point' scan to determine any departures from the emphemeris. Significant drifting in position generally occurs gradually over a period of a few hours, so by updating telescope offsets used every row (~10 mins) the data points do not have to be regridded before Fourier transforming. At the end of each row the telescope is brought back to the satellite position so that the current amplitude of the signal from the satellite, which can vary due to atmospheric attenuation and also changes in the pointing of the satellite antenna, which is updated every 20 mins, can be monitored. This measurement also yields changes in the relative phase between signals received at the two feeds. Such changes occur principally because of temperature induced changes in the length of the feed legs. These can be removed by using the instrumental phase measured on the central position to 'wind back' the measured phases along the corresponding scan. This technique is possible because at the same time that the feed leg lengths change, the dish deforms in such a way as to keep in an approximately paraboloidal shape with focus at the new feed position (see R. Howard, 1983). Such changes in focal length are transparent to the holographic system except for the effect of changing the instrumental phase, which can be compensated for as described above. Further corrections made at this stage are (i) compensation for amplitude and phase errors in the hardware 90^{o} phase shifter used to obtain the imaginary component of the correlated signal. (These can be deduced from measurements at the central position)

(ii) correction of the relative phase for the change in the projected path length between the two feed positions as the telescope is moved backwards and forwards about the on-axis position, and (iii) correction for the intrinsic amplitude and phase response of the reference horn.

After these corrections have been applied the data is Fourier transformed. A mixed radix complex FFT is used, so that there is no restriction to using grids with side length given by a power of two. The aperture plane phase data is then fitted for an arbitrary three dimensional displacement of the main feed position away from the best fit focus position. This removes phase gradients and curvatures across the aperture plane due either to a genuine focus error or to residual mispointing occurring in the central regions of the map. To first order the fitting process also allows for the effects of the phase response pattern of the feed itself, which is known to have a maximum amplitude of 10° and to first order will simulate the effects of an axial defocussing. However, once an accurate measurement has been made of the response pattern of the main feed this can be subtracted from the phase data before fitting.

The conversion of the phase data to surface deformations over the dish completes the reduction of the holographic data. The orientation of the aperture plane maps relative to the actual surface of the dish and the sense (increasing or decreasing path length) of the phase data, are known a priori via a vector voltmeter reading with the telescope on source. This means that external calibration of the results, for example by placing reflectors or absorbers on the dish surface, is not necessary. In order to display the data most effectively, the amplitude and surface deformation maps are converted into AIPS map files which allow the AIPS TV graphics facilities to be used upon them. The data gathered from the mechanical reference jig method (Findlay & Payne, 1983) can also be displayed in this form, enabling a direct comparison between the two sets of results to be made. Such a comparison yields the following:-

(i) The mechanical and holographic maps agree extremely well over about $^4/_5$ of the dish surface.

(ii) In regions of disagreement there is a radial dependence of the error which coincides with the edge balls upon which the measuring jig is rested having changed position relative to their initial calibrated positions.

(iii) Agreement between different holographic maps made with the dish in the same state of adjustment is extremely good. From this comparison an rms on individual holographic maps of better than 35 μm can be deduced. Furthermore for maps made over different elevation ranges, a gravitational component of deformation appears to be present, which is in agreement with theoretical structural calculations (Lee King, 1982).

In conjunction with the mechanical measuring system therefore, the holographic measurements are of sufficient quality and accuracy to enable the setting of the 12m surface to be carried out to a final target rms accuracy of ~70μm. In addition to this, the data from either the holographic or mechanical maps can be used to predict the aperture efficiency of the dish at the working frequencies. An extended version of the fitting programme has been written which accurately calculates these efficiencies using numerical integration over the transformed data points and with an amplitude distribution specified either as an azimuthally symmetric feed pattern in dB or taken directly from the holographic data. Aperture blockage is correctly taken account of in the calculations. At a later stage this program will also provide extrapolated polar diagrams of the antenna response at the working frequencies. These calculations are envisaged as a useful diagnostic and calibration tool in setting up and continuing to maintain the surface and feed systems of the antenna.

References

Findlay, J. & Payne, J., 1983, IEE Conference Publication No. 219, pp. 55-59, April 1983.

Howard, R., 1983. 12 m Memorandum No. 231, August 26, 1983.

King, L., 1982. 12 m Memorandum No. 204, November 30, 1982.

12/19/83

Note by John W. Findlay:

The above preliminary report was written by Dr. A. N. Lasenby. We plan to repeat mechanical and holographic measurements of the 12-meter in March 1984. Dr. Lasenby had not seen my Memo No. 236 when he wrote this, so that his comment that the edge-balls may have moved must, for the present, be treated with caution.