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12 GHz Radio-Holographic Surface Measurements of the RRI 10.4 m Telescope

Ramesh Balasubramanyam, Suresh Venkatesh, and Sharath B. Raju

Raman Research Institute, Bangalore 560 080, India

Abstract. A modern Q-band low noise amplifier (LNA) front-end is being fitted to the 10.4 m millimeter-wave telescope at the Raman Research Institute (RRI) to support observations in the 40−50 GHz frequency range. To assess the suitability of the surface for this purpose, we measured the deviations of the primary surface from an ideal paraboloid using radio holography. We used the 11.6996 GHz beacon signal from the GSAT3 satellite, a 1.2 m reference antenna, commercial K_u-band Low Noise Block Convereters (LNBC) as the receiver front-ends and a Stanford Research Systems (SRS) lock-in amplifier as the backend. The LNBCs had independent free-running first local oscillators (LO). Yet, we recovered the correlation by using a radiatively injected common tone that served as the second local oscillator. With this setup, we mapped the surface deviations on a 64×64 grid and measured an rms surface deviation of $\sim 350\,\mu$m with a measurement accuracy of $\sim 50\,\mu$m.

1. Introduction

RRI has a mm-wave Leighton telescope, of 10.4 m diameter with 81 hexagonal panels(Sridharan 1993). It is being rejuvenated to undertake Q-band observations at 43 GHz. This requires the surface rms error to be below $\sim 370\,\mu$m in order to have an aperture efficiency better than 50 percent, as given by Ruze's relation: $\eta_{ap} = \eta_0 \; exp{-}(\frac{4\pi\delta}{\lambda})^2$ (Ruze 1966). Radio holographic surface measurement was carried out in 2007 August – Septemper to measure the surface rms error, and to identify panels that may need correction. In this poster paper, we report the details of this experiment, analyse the data, discuss the results and present our conclusions.

2. Experimental Setup

The key idea in radio holography is to measure the complex beam pattern. Its fourier transform yields the aperture plane field (APF) distribution. Surface deviations can be calculated from the phases of the APF (Bracewell 1965) The signal-to-noise ratio (SNR) required to measure the surface deviation to an accuracy of $\delta\,\mu$m over $N \times N$ pixels is proportional to N/δ (Scott & Ryle 1977) For K_u-band (λ = 25 mm), the SNR should be ≥ 1600 to achieve a measurement accuracy of at least 80 μm.

Both the test (10.4 m) and the reference (1.2 m) antennas were fitted with satellite TV low-noise block converters (LNBCs) as front-ends (see Figure 1). A 11.315 GHz reference tone was radiatively fed to both the antennas for use as second LOs to remove the effects of the free-running first LOs in the LNBCs. A tracking phase locked loop (PLL) improves the SNR by locking to the signal from the reference antenna down-converted and filtered to 57.5 MHz. On both the chains, signals are down-converted to below 100 kHz and fed to the test (10.4 m) and reference (1.2 m) inputs of the SRS lock-in amplifier (analog correlator). The correlation amplitudes and phases were digitized with a 12 bit analog-to-digital converter (ADC) and recorded in the control computer every 100 ms.

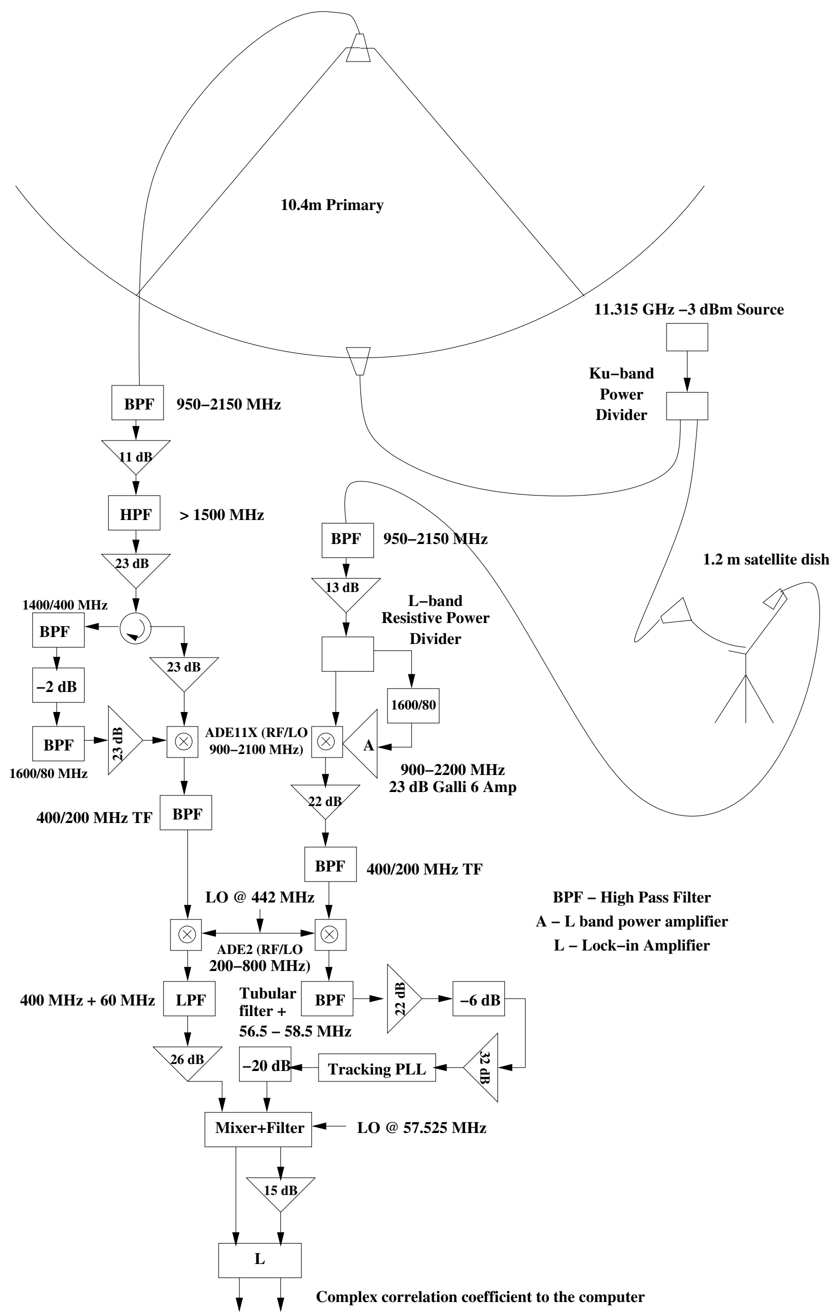

Figure 1. Dual channel holography receiver layout

Software was developed to automatically raster-scan the region of interest. Calibration and scan data from the two position encoders and ADCs were recorded. In addition, satellite drift had to be compensated at regular intervals.

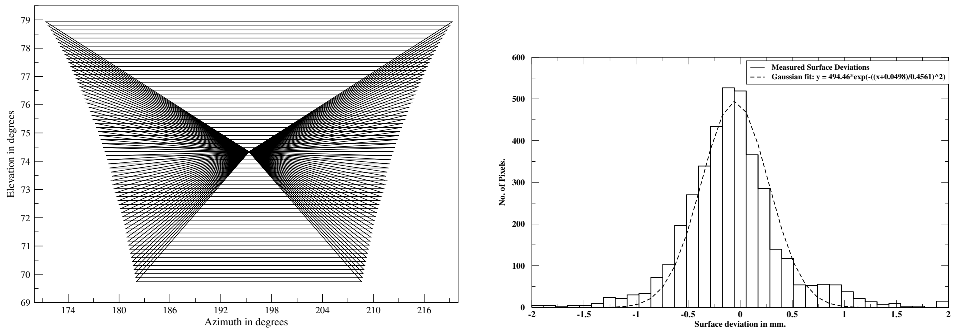

Figure 2. (a) Scheme for raster scan. (b) Histogram of the measured surface deviations.

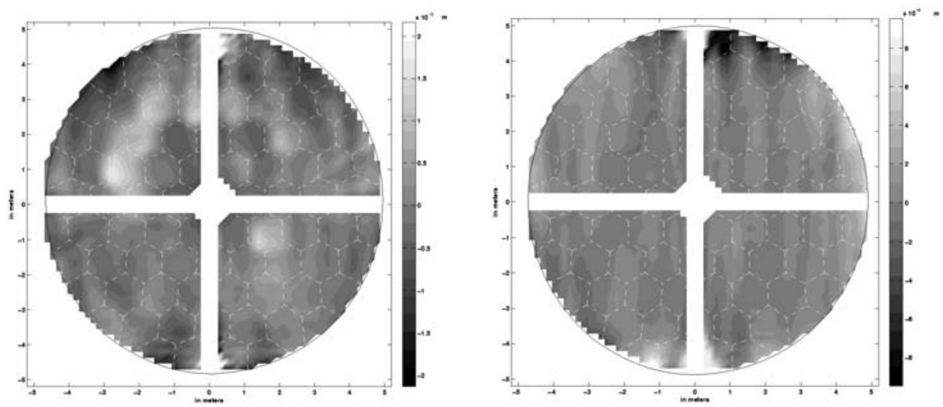

Figure 3. (a) Measured surface deviations. (b) Difference map showing measurement accuracy.

3. Observations

The 11.6996 GHz beacon signal from EDUSAT (Orbital slot: 74°E longitude, translates to El: 74.40° & Az: 195.75°) was observed. The correlation co-efficients between the two antennas were recorded on the fly. The map spans ±4.3° in real space in both azimuth (Az) & elevation (El) about the satellite position as shown in Figure 2(a). The critical sampling at 11.7 GHz is 8.8′ and the measured beam width is 9.6′. Since the number of pixels across the dish is 64 (a map of 64 × 64), a spatial resolution of 16 cm was achieved, which is 1/6th the size of one panel in the dish. Each observation lasted 7−8 hrs which includes 65 Az scans, 11 satellite pointings and 8 to 9 repeats of central block of 5 scans. Four independent observations were carried out, all leading to the same results. All the observations were conducted during night to ensure system stability.

4. Results and Conclusions

The effect of free running local oscillators in LNBC was solved by radiatively injecting a tone. The effect of satellite drifting was removed by pointing to the satellite every 30 minutes. An

SNR > 5000 was achieved by making the receiver chain robust, repeating and co-adding the central block scans & using satellite pointing data for amplitude and phase calibration.

From the measured surface deviations (see Figure 3(a)), the surface rms error is calculated to be $\sim$ 350 μm. It is within $\lambda/16$, implying that Q Band observations are possible. It can also be seen that some panels require correction. Figure 3(b) shows the residual obtained by subtracting two independent surface deviation measurements. The rms of this residual is $\sim$ 70 μm. Therefore, the measurement accuracy is estimated to be $\sim$ 50 μm.

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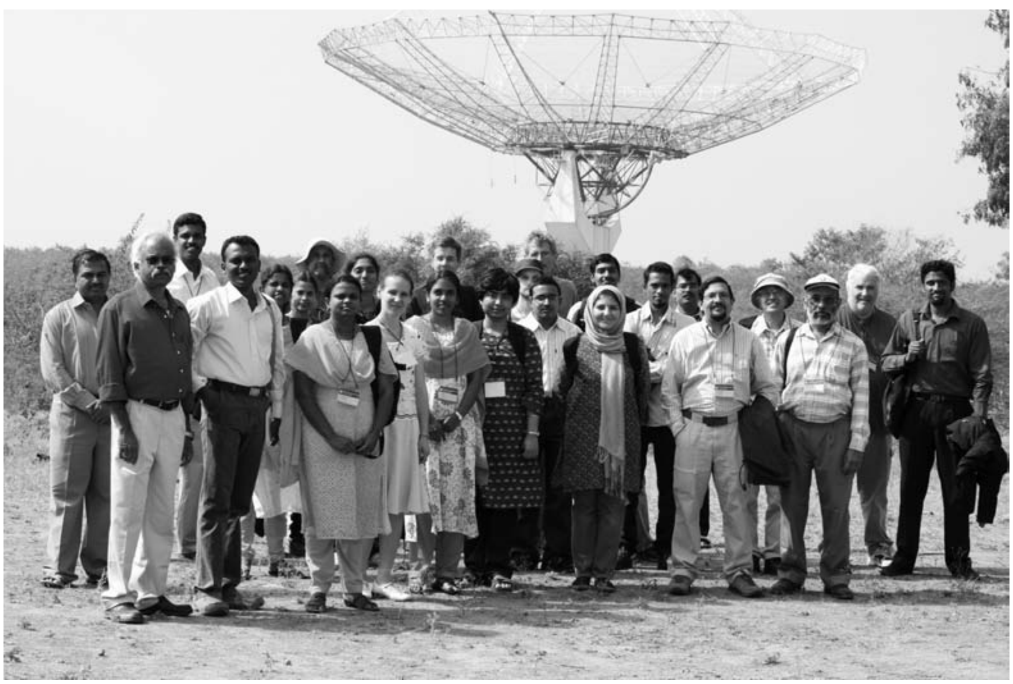

A group photograph at the GMRT