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***Abstract*—We present measured on-dish beam patterns for a room temperature spline-profile quad-ridge flared horn (QRFH) feed designed for the Square Kilometre Array (SKA) Band 1 covering 350-1050 MHz. The feed and LNA package has been mounted on the offset Gregorian SKA precursor prototype telescope, Dish Verification Antenna 1 (DVA-1) located at the Dominion Radio Astrophysical Observatory (DRAO) near Penticton, British Columbia, Canada. Telescope beam pattern cuts are measured by sweeping over the sun and adding corrections for the solar disk size, elevation and aperture efficiency. Sensitivity calculated with measured receiver noise show good agreement with the predicted performance.**

I. Introduction

The Square Kilometre Array (SKA) is an international collaboration to build the world's largest and most sensitivity radio telescope array. The SKA singel-pixel feed programme aims to cover $0.35 - 13.8$ GHz with five different frequency bands through five separate feed packages mounted on each of the offset Gregorian 15 m reflector telescopes. The splined Quad-Ridge Flared Horn (QRFH) feed design for the lowest frequency band $350 - 1050$ MHz [1] defined as Band 1 has due to recent development in Low Noise Amplifiers (LNA) [2] been transferred from a cryogenic to a completely room temperature system [3] with comparable noise performance.

In this paper we present telescope beam pattern measurements using a completely room temperature receiver developed at Onsala Space Observatory for $350-1050$ MHz. The system was installed on the offset Gregorian SKA precursor prototype, Dish Verification Antenna 1 (DVA-1), at the Dominion Radio Astrophysical Observatory (DRAO) near Penticton, British Columbia, Canada. Beam pattern cuts were measured using the sun as source and the results show good agreement with simulation. Measurement of the receiver noise temperature gives confirmation of the feed system feasibility.

II. System Performance

The 3:1 QRFH feed design was designed with spline-defined profiles and optimized for high $A_{\text{eff}}/T_{\text{sys}}$ (sensitivity) on the SKA reflector optics, which consists of a 15 m offset Gregorian dish with a 5 m sub-reflector that has a half subtended angle of $\theta_0 = 58°$. A_{eff} is the effective reflector area and $T_{\text{sys}} = T_{\text{a}} + T_{\text{rec}}$ is the system noise temperature where T_{a} and T_{rec} are the antenna and receiver noise temperatures respectively. To achieve high sensitivity a reasonable trade-off between spill-over and illumination efficiency is required. The feed prototype shows measured input reflection $S_{11} < -10$ dB and $T_{\text{rec}} < 20$ K (Y-factor tests). The room temperature LNAs, designed by Low Noise Factory (LNF) in Sweden, are integrated inside the horn ridges and directly connected to the feeding pins. In Fig. 1 the QRFH can be seen mounted on the DVA-1, which compared to the SKA reflector has a slightly smaller half subtended angle of $\theta_0 = 55°$ and a smaller subreflector without a spill-over shield. The feed aperture efficiency η_{a} simulated on DVA-1 is above 60 % across the band with an average of 71 %, see Fig. 2. At the low end of the band there is over illumination of the dish due to the smaller half subtended angle of DVA-1. This also increases the spill-over noise contribution from the ground. We estimate the receiver performance with a system simulator that combines GRASP physical optics (PO) and physical theory of

Fig. 1. QRFH (top left) installed on DVA-1, seen just below the sub-reflector.

diffraction (PTD) [4]. The $A_{\text{eff}}/T_{\text{sys}}$ is given by a full-sphere integration of the sky and ground noise temperatures weighted with the telescope beam pattern. Below 500 MHz, the sky noise temperature is several times larger than at the high end of the band, which increases T_{a}. The estimated sensitivity for the feed on DVA-1, Fig. 2, averages 2.91 m^2/K over the band for zenith angle $|\theta_p| = 60°$ and 3.54 m^2/K over $650 - 1050$ MHz. There is good agreement in sensitivity calculated with estimated and measured T_{rec}. Only frequencies free from interference during measurement are shown here.

To confirm the simulated beam pattern of the feed - reflector system, the telescope was swept in elevation and azimuth cuts over the sun. Corrections for the sun solid angle (0.5°), the aperture efficiency and elevation axis deformation was applied accordingly. In Fig. 3 the comparison between simulated and measured main beam is shown. At 418 MHz there is compression of the beam due to saturation of the signal chain, this was corrected for at higher frequencies and the result is improved. The cuts were measured at a mean elevation of 43° with a ±8° azimuth sweep (not to be confused with beam pattern azimuth coordinate ϕ in Fig. 3) over the sun with power averaged over the spectral channels, the bandwidth is 50 MHz.

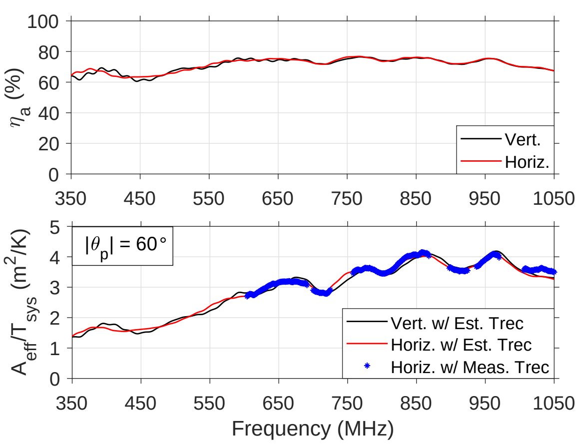
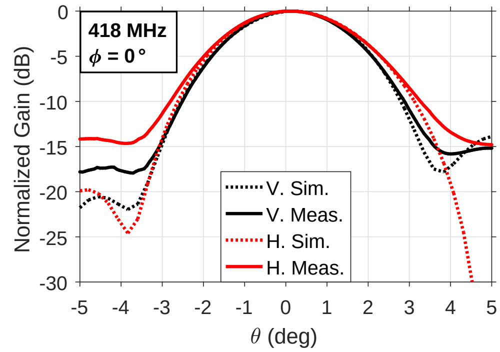
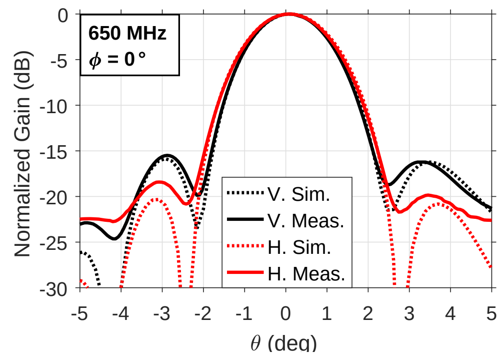


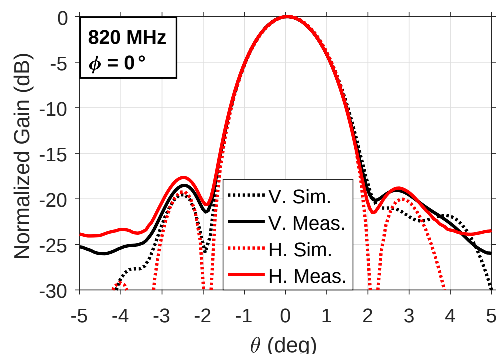
Fig. 2. Simulated aperture efficiency η_{a} (top) and sensitivity $A_{\text{eff}}/T_{\text{sys}}$ (bot.) for the feed on DVA-1 for both polarizations at zenith angle $|\theta_p| = 60°$. Sensitivity with measured T_{rec} is shown as blue dots.



(a)



(b)



(c)

Fig. 3. Measured beam pattern compared to simulated for $\phi = 0°$ on DVA-1, normalized to 0 dB, for both polarizations (V. for Vertical, H. for Horizontal). The sun was used as source and corrections for η_a, elev. axis deformation and the sun solid angle was applied. (a) 418 MHz (b) 650 MHz (c) 820 MHz.

III. Conclusion

A prototype room temperature single pixel feed system for SKA Band 1 over $350 - 1050$ MHz was installed and measured on the DVA-1 telescope. The beam pattern cuts measured by sweeping the sun gives a reasonable agreement with predicted beam cuts and the measured T_{rec} proves the feasibility of the system with good agreement to predicted performance.

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