ngVLA Antenna Memo #8

Efficiency Loss and Pointing Offsets due to Feed Offsets on the ngVLA Reference Design Antenna

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July 1, 2020

Abstract

This note presents feed offsets from the secondary focus and resulting beam pointing offsets for an efficiency loss of 0.3% referenced to the on-axis efficiency at 16.5 GHz and 40.5 GHz using the ngVLA Reference Design optics [1]. This threshold was selected based on the ngVLA Calibration Requirements [2]. The analysis demonstrates that efficiency loss will constrain the specification of the feed indexer in the z_f-axis, while the pointing error will constrain the specification in the y_f-axis. Constraining the pointing error due to band switching and positioner precision to 1" and the efficiency loss to 0.3% at 116 GHz, would require indexer precision of ± 63 um in the y_f-axis and ± 192 um in the z_f-axis, respectively.

1. Introduction

This note presents feed offsets from the secondary focus and resulting beam pointing offsets for an efficiency loss of 0.3% referenced to the on-axis efficiency at 16.5 GHz and 40.5 GHz using the ngVLA Reference Design Optics [1]. The 0.3% threshold was selected based on the ngVLA Calibration Requirements [2]. CAL0205 requires limiting the change in the forward gain to 0.3% at 8 GHz to support the system dynamic range. While greater tolerances are permitted at high frequency, we have used this threshold at both analyzed frequency points in this analysis. The efficiency and beam pointing were computed using GRASP. The antenna model is shown in Figure 1. The location of the primary, the secondary and the feed are referenced to a global coordinate system (x, y and z). The coordinate system for the primary and the secondary are in the plane of the rim of the respective reflectors. All dimensions are in meters. The angle beta is the rotation angle in the symmetric plane of the reflectors.

2. Simulations

Simulated patterns of an axially corrugated horn are used at Ku-band. Calculations were done in the 12.5 to 20.5 GHz range. The feed offsets are in five directions $\pm x_f$, y_f and $\pm z_f$ as shown in Figure 1. Table 1 shows results at 16.5 GHz. The feed offset distances are in mm and λ, and beam pointing offset is in arc-minutes and HPBWs. On axis efficiency is 87.6554% and HPBW is 3.8825 arc-minutes as computed in GRASP.

Table 2 shows feed and pointing offsets, for 0.3% efficiency loss at 40.5 GHz. The efficiency at zero offset is 90.9697% and HPBW is 1.5646 arc-minutes. In this calculation the feed pattern is approximated by a Gaussian beam with a taper of -16 dB at the edge of the subreflector.

3. Summary

The results seem to point out that the feed position error should be less than 0.3λ in the transverse directions and less than 0.1λ in the axial direction for efficiency loss less than 0.3%. For the given offsets in the transverse directions, the pointing offset is approximately 0.35HPBW. The pointing coefficient relating to the feed position is 0.27 arc-min/mm.

The analysis demonstrates that efficiency loss will constrain the specification of the feed indexer in the z_f-axis, while the pointing error will constrain the specification in the y_f-axis. Constraining the pointing error due to band switching to 1" and the efficiency loss to 0.3% at 116 GHz, would require indexer precision of ± 63 um in the y_f-axis and ± 192 um in the z_f-axis, respectively.

The author acknowledges R. Selina for his contributions to the summary and for other edits and P. Ward for formatting the document.

References:

[1] L. Baker, "Analysis of ngVLA Design #6 With Ideal and Actual Feed," Document # 020.25.01.00.00-0001-REP ngVLA Optical Reference Design, January 2017.

[2] C. Hales, "Calibration Requirements," Document # 020.22.00.00.00-0001-REQ, June 2020.

Table 1: Feed Offsets & Pointing Offsets at 16.5 GHz.

Offset direction	Feed offset (d)		Pointing offset (θ)		Efficiency %	Efficiency Ratio	θ/d (arc-min/mm)
	mm	d/λ	Arc-min	θ/HPBW			
y_f	5.0	0.2752	1.38	0.3554	87.3753	0.9968	0.276
x_f	4.5	0.2477	1.2	0.3091	87.3632	0.9967	0.248
$-x_f$	5.5	0.3027	1.5	0.3863	87.3834	0.9969	0.273
z_f	0.9	0.0495	0	0	87.3793	0.9969	
$-z_f$	2.74	0.1508	0	0	87.3954	0.9970	

Table 2: Feed Offsets and Pointing Offsets at 40.5 GHz.

Offset direction	Feed offset (d)		Pointing offset (θ)		Efficiency %	Efficiency Ratio	θ/d (arc-min/mm)
	mm	d/λ	Arc-min	θ/HPBW			
y_f	2.037	0.2752	0.54	0.3451	90.6706	0.9967	0.265
x_f	1.480	0.2000	0.42	0.2684	90.7165	0.9972	0.284
$-x_f$	2.400	0.3242	0.63	0.4026	90.6852	0.9969	0.263
z_f	0.55	0.0743	0	0	90.6915	0.9969	
$-z_f$	0.7	0.0946	0	0	90.6811	0.9968	

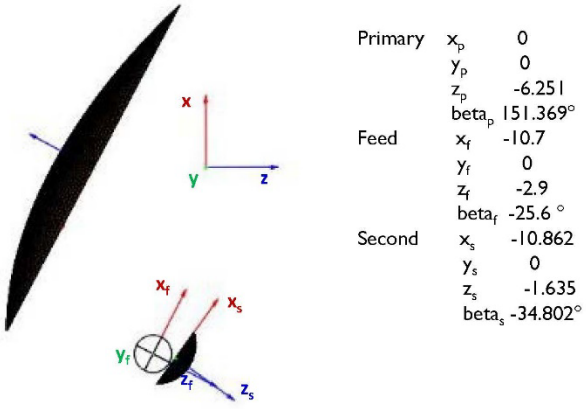

Figure 1. GRASP model of the ngVLA antenna.