L-Band and X-Band Antenna Design and Development for NeXtRAD

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Outline

Introduction

NeXtRAD

In short, NeXtRAD is an evolution of NetRAD, a netted radar system which operates in the S-Band.

NeXtRAD improves upon the RF capabilities of NetRAD by:

- Fully Polaremetric (HH, HV, VV, VH)
- Multiband (X- and L-Band)
- Wireless networked nodes for large baseline separation

NeXtRAD

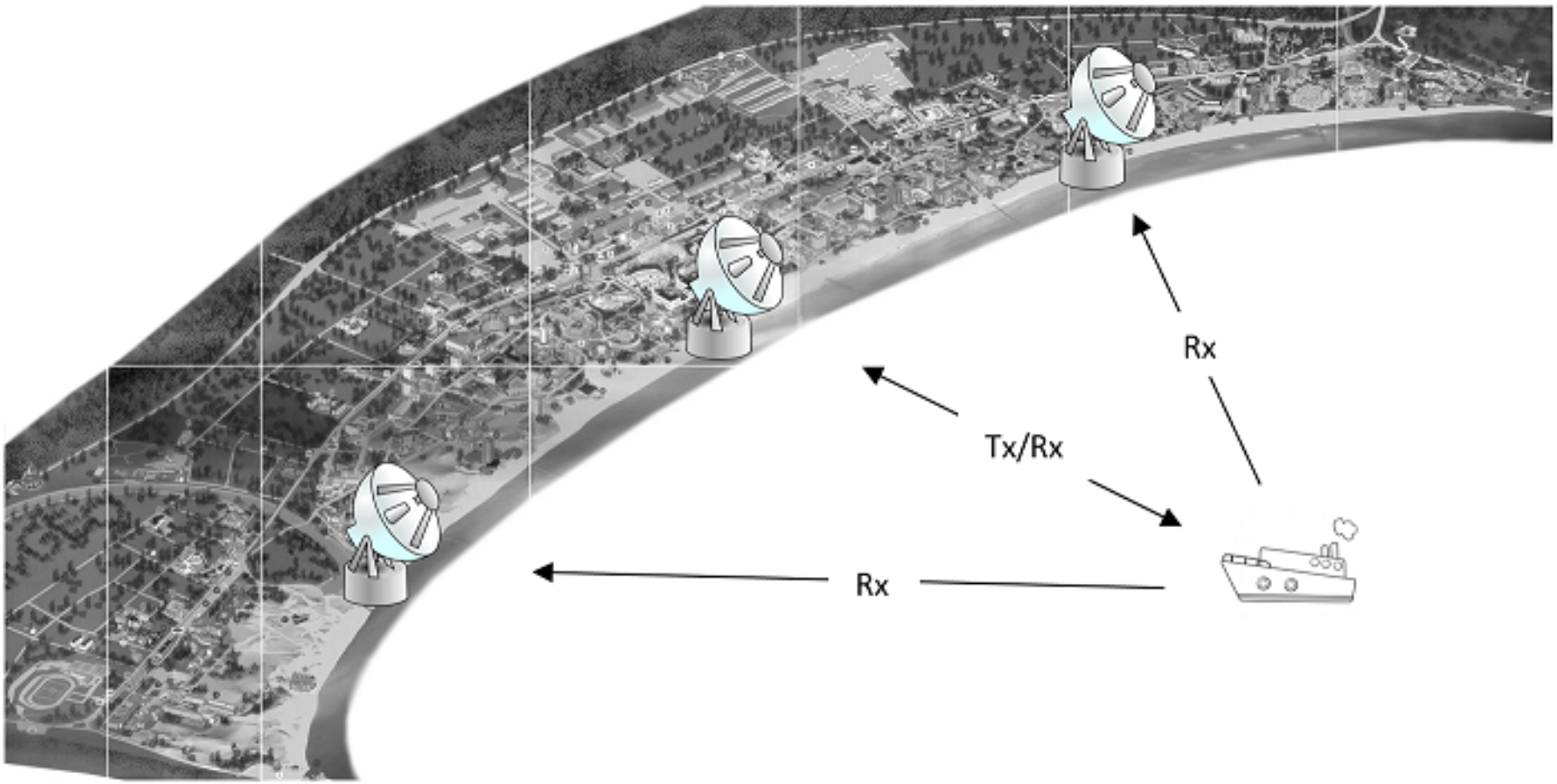

Figure: Basic NeXtRAD node geometry

Application Requirements

L- and X-Band Antenna Requirements

- Dual polarised (Horizontal and Vertical)
- L-Band centre frequency $f_0 = 1.3$ GHz
- X-Band centre frequency $f_0 = 8.5$ GHz
- Minimum 50 MHz bandwidth (X- and L-Band)
- 10° azimuth HPBW (X- and L-Band)
- 1.5 kW (L-Band) and 400 W (X-Band) peak power handling capabilities
- Be able to be mounted on a standard tripod and withstand harsh environmental conditions such as strong winds

L-Band Antenna Design

L-Band Coaxial to Waveguide Launcher Design

- Freespace Wavelength:

$$\lambda_0 = c/f = \frac{3 \times 10^8 \text{ m/s}}{1.3 \times 10^9 \text{Hz}} = 230.8 \text{ mm}$$

- Probe Length:

$$L_{probe} = \frac{\lambda_0}{4} = \frac{C}{4 \times f_0} = 57.7 \text{ mm}$$

- Waveguide Wavelength:

$$\lambda_g = \frac{\lambda_0}{\sqrt{1 - (\frac{\lambda_0}{1.705 \times D})^2}} \approx 360 \text{ mm}$$

- Backshort Distance:

$$L_{backshort} = \frac{\lambda_g}{4} \approx 90 \text{ mm}$$

Coaxial to Waveguide Transition Design

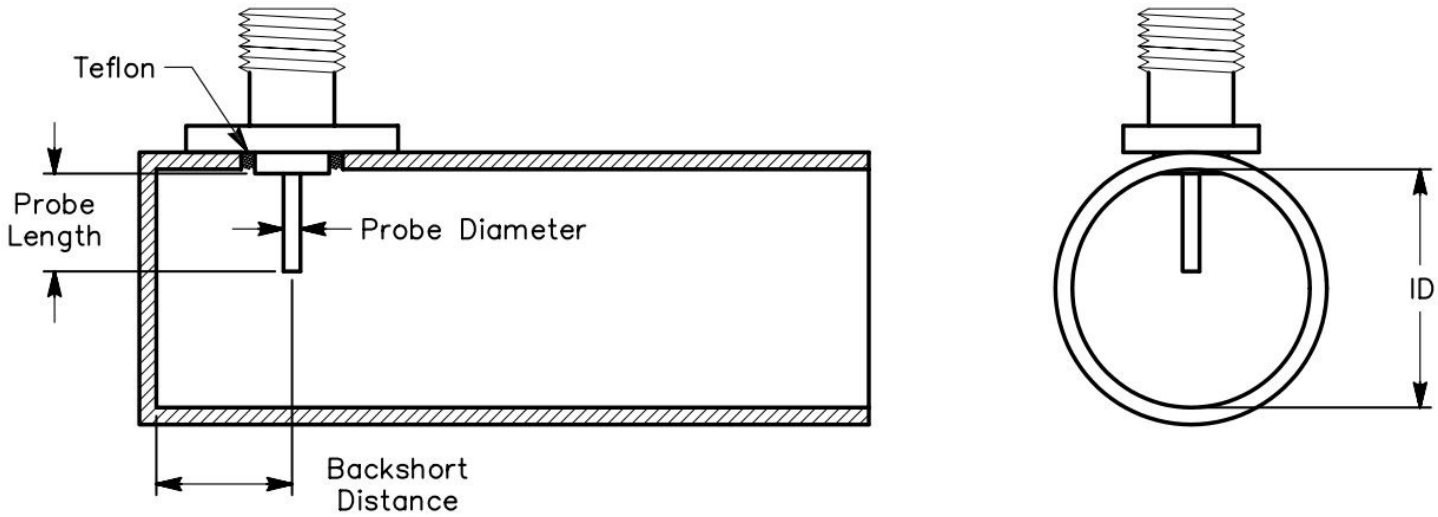

Figure: Coaxial to waveguide transition.

L-Band Truncated Reflector Antenna

Required Specification	Simulated Parameter
Diameter	1440 mm
Height	744 mm
Depth	290.3 mm
Focal Point	446 mm
f/D ratio	0.31
Parabolic Equation	$y = (5.60 \times 10^{-4})x^2$
HPBW (Azimuth)	H-Pol : 10.7° V-Pol : 10.0°
HPBW (Elevation)	H-Pol : 16.4°
	V-Pol : 16.6°
SLL (Azimuth)	H-Pol : 20.3 dB V-Pol : 16.9 dB
SLL (Elevation)	H-Pol : 15.1 dB V-Pol : 15.0 dB
F/B ratio	H-Pol : 24.7 dB
	V-Pol : 30.7 dB

Prototype L-Band Antenna Dimensions

Simulated Results of Modified Pre-fabricated Antenna

Parameter	Simulated Design
Diameter	1350 mm
Height	600 mm
Depth	370 mm
Focal Point	307.85 mm
f/D ratio	0.23
Parabolic Equation	$y = (8.16 \times 10^{-4})x^2$
HPBW (Az)	H-Pol - 13.9° V-Pol - 12.1°
HPBW (El)	H-Pol - 19.7° V-Pol - 20.5°
SLL (Az)	H-Pol - 17.4 dB V-Pol - 17.4 dB
SLL (El)	H-Pol - 16.3 dB V-Pol - 15.2 dB
F/B ratio	25 dB

L-Band Antenna Prototype

Figure: L-Band antenna prototype with dual polarised circular waveguide feed

Optimised Feed Parameters

- Due to feed blockage, physical adjustments were made to restore specified performance.
- The probe was moved forward inside the waveguide by 43.3 mm to restore required performance.

Parameter	**Standalone Feed**	**Antenna with Feed**
Probe Length	57.7 mm	56.9 mm
Backshort Length	90.0 mm	133.3 mm

Dish with Feed S-Parameter Measurements

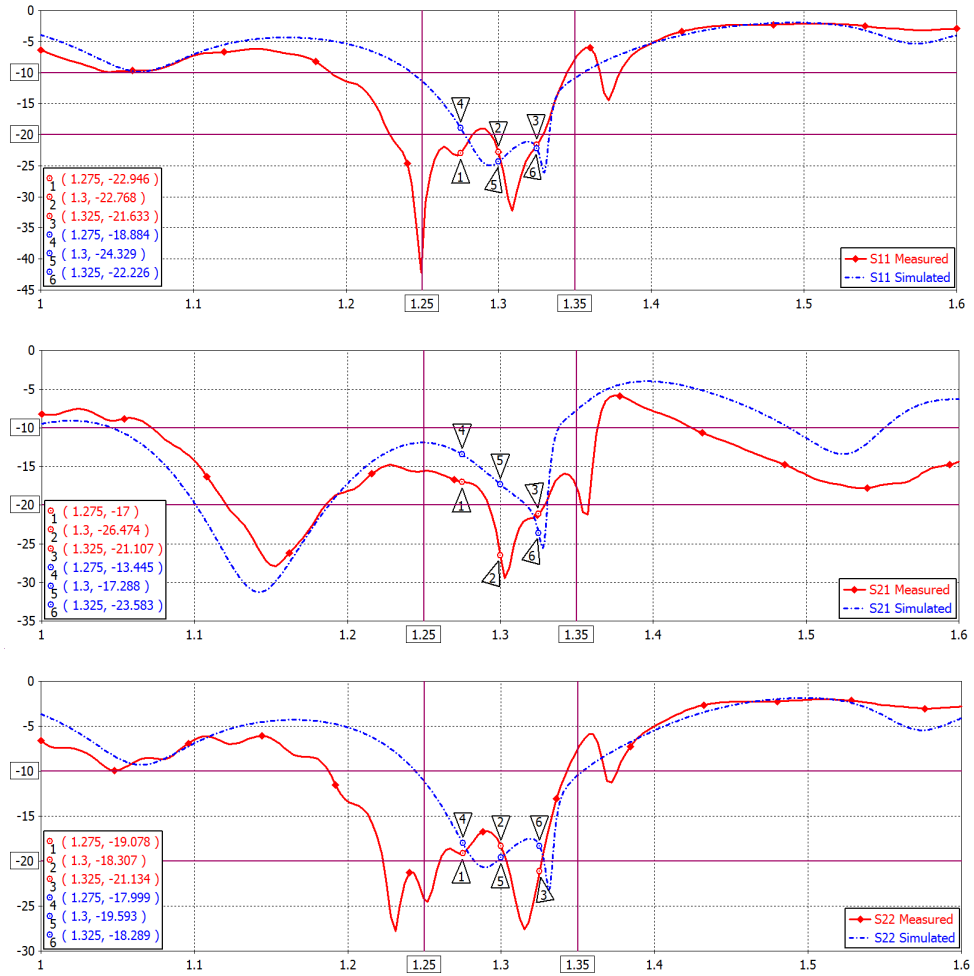

Figure: Simulated (blue) vs. Measured (red) S11 (top) S21 (middle) S22 (bottom) parameters for optimised feed placed at the dish focal point.

L-Band Antenna Results

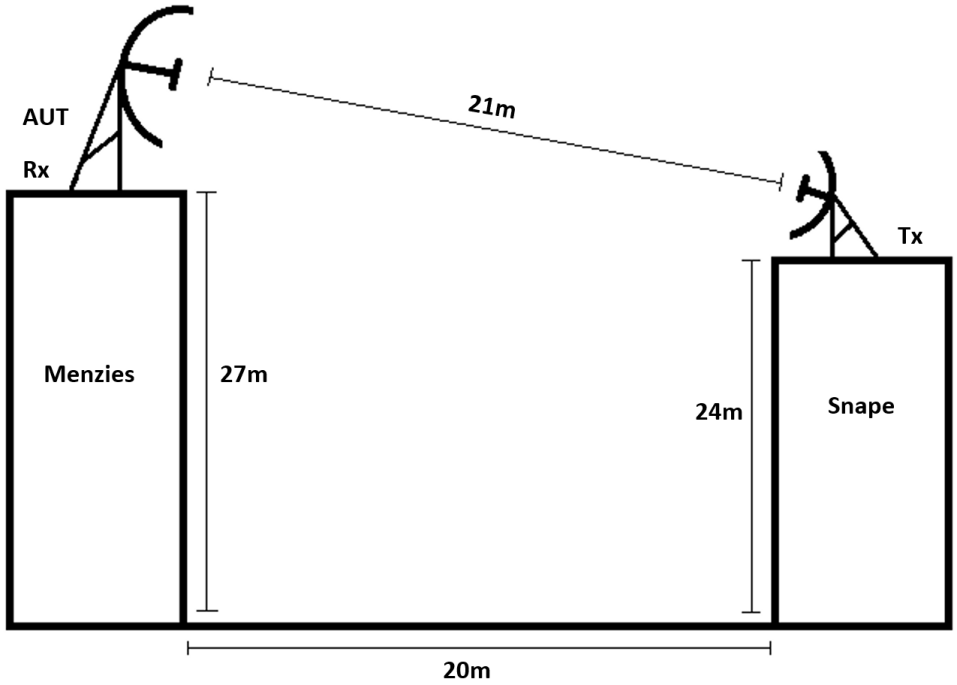

Figure: Testing setup on the roof of the Menzies and Snape buildings at UCT.

Beam Pattern Results for H-Pol

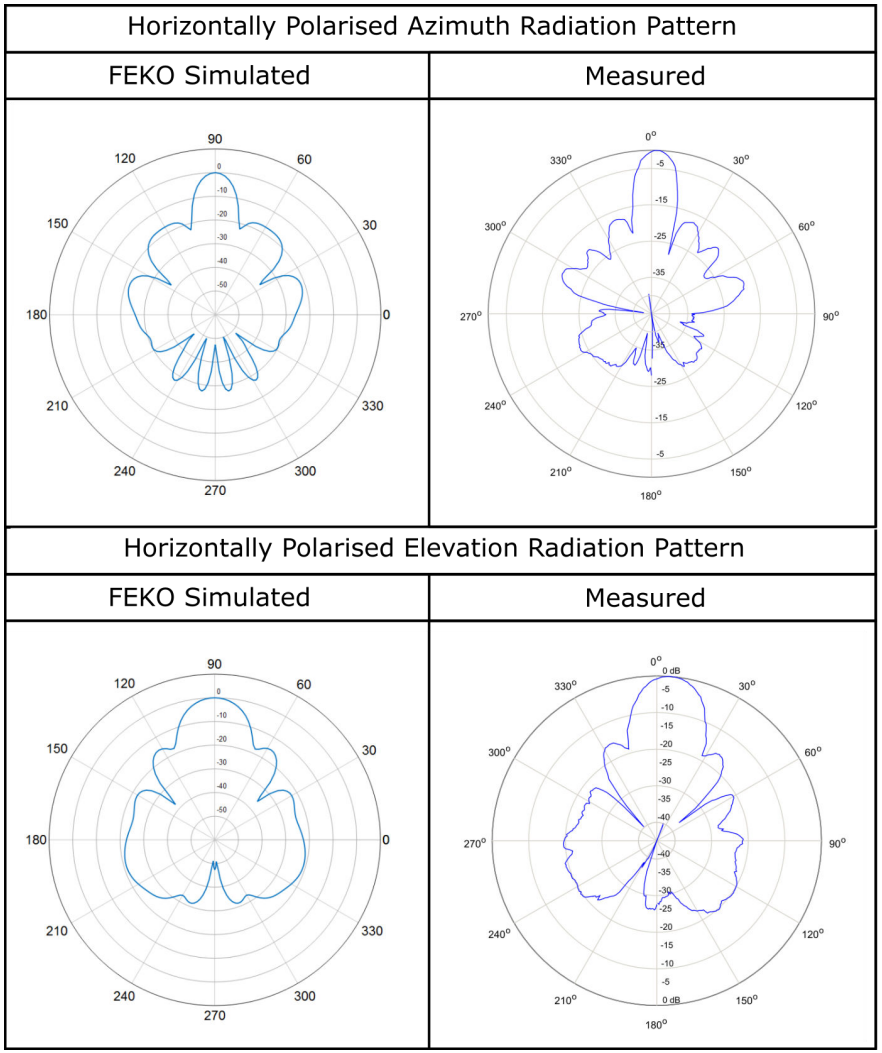

Figure: Horizontally polarised azimuth (Top) and elevation (Bottom) beam pattern. (Left) Simulated (Right) Measured.

Beam Pattern Results for V-Pol

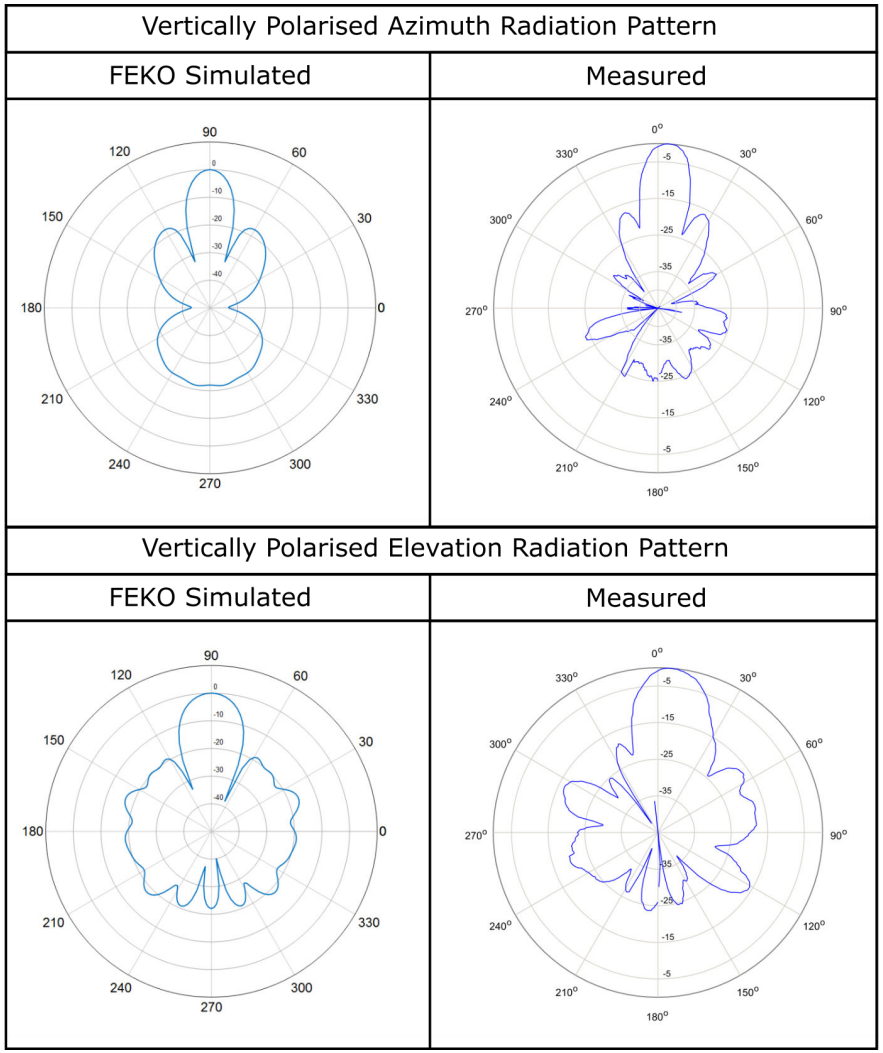

Figure: Vertically polarised azimuth (Top) and elevation (Bottom) beam pattern. (Left) Simulated (Right) Measured.

Summary of L-Band Prototype Antenna Performance

	Horizontal Polarisation			Vertical Polarisation		
	FEKO	**CST**	**Measured**	**FEKO**	**CST**	**Measured**
Az HPBW	12.1°	12.2°	12.4°	13.9°	14.2°	13.9°
El HPBW	20.5°	20.4°	20.0°	19.7°	19.5°	19.6°
Az SLL	-17.3 dB	-17.0 dB	-17.4 dB	-17.4 dB	-17.2 dB	-16.4 dB
El SLL	-15.2 dB	-15.2 dB	-15.7 dB	-16.3 dB	-16.9 dB	-15.8 dB

L-Band Prototype Antenna Summary

It has been shown that:

- The measured results of the built prototype match the simulated results as expected
- A truncated parabolic dish antenna can meet all the application requirements
- Circular waveguides perform better than square waveguides when dual polarising using orthogonal probes [1]
- Feed blockage is of major concern with electrically small prime focus dish antennas ($D \leq 10\lambda_0$) [2]

X-Band Antenna Design

X-Band Coaxial to Waveguide Feed Design

X-Band Free-space wavelength for 8.5 GHz:

$$\lambda_\circ = \frac{c}{f_\circ} = \frac{3 \times 10^8 \text{ m/s}}{8.5 \times 10^9 \text{ Hz}} = 35.29 \text{ mm}$$

Waveguide diameter (l_g) chosen from aluminium water pipe is 28 mm. Cutoff wavelength:

$$\lambda_{c(\text{TE11})} = 1.706 \times l_g = 47.77 \text{ mm}$$

Cutoff frequency is calculated to be 6.28 GHz. Length of the probe and backshort:

$$L_{\text{probe}} = \frac{\lambda_\circ}{4} = 8.82 \text{ mm}$$

$$L_{\text{backshort}} = \frac{\lambda_g}{4} = 13.09 \text{ mm}$$

X-Band Horn Antenna

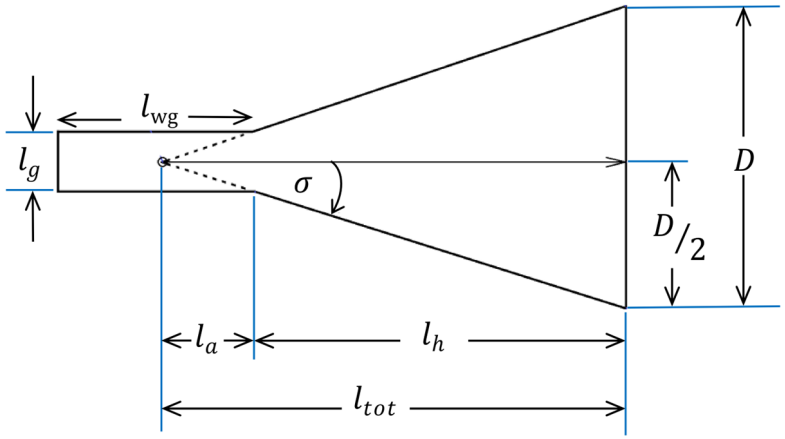

Figure: Side view of a horn antenna.

Diameter of the antenna aperture:

$$D = \frac{70\lambda_\circ}{\theta} = 247.03 \text{ mm}$$

Length of the horn from waveguide to aperture:

$$l_h = \frac{D^2}{3\lambda_\circ}\left(1 - \frac{l_g}{D}\right) = 511.14 \text{ mm}$$

X-Band Prototype Antenna

Figure: X-Band conical horn antenna prototype with the dual polarised waveguide feed.

X-Band Antenna Results

Menzies Building Rooftop

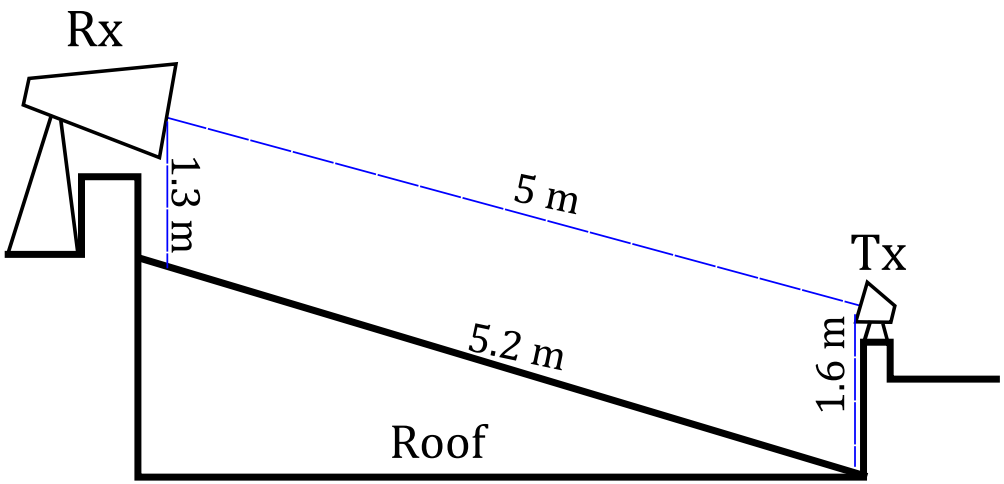

Figure: Antenna configuration at Menzies Building rooftop.

Simulated X-Band Antenna S-Parameters

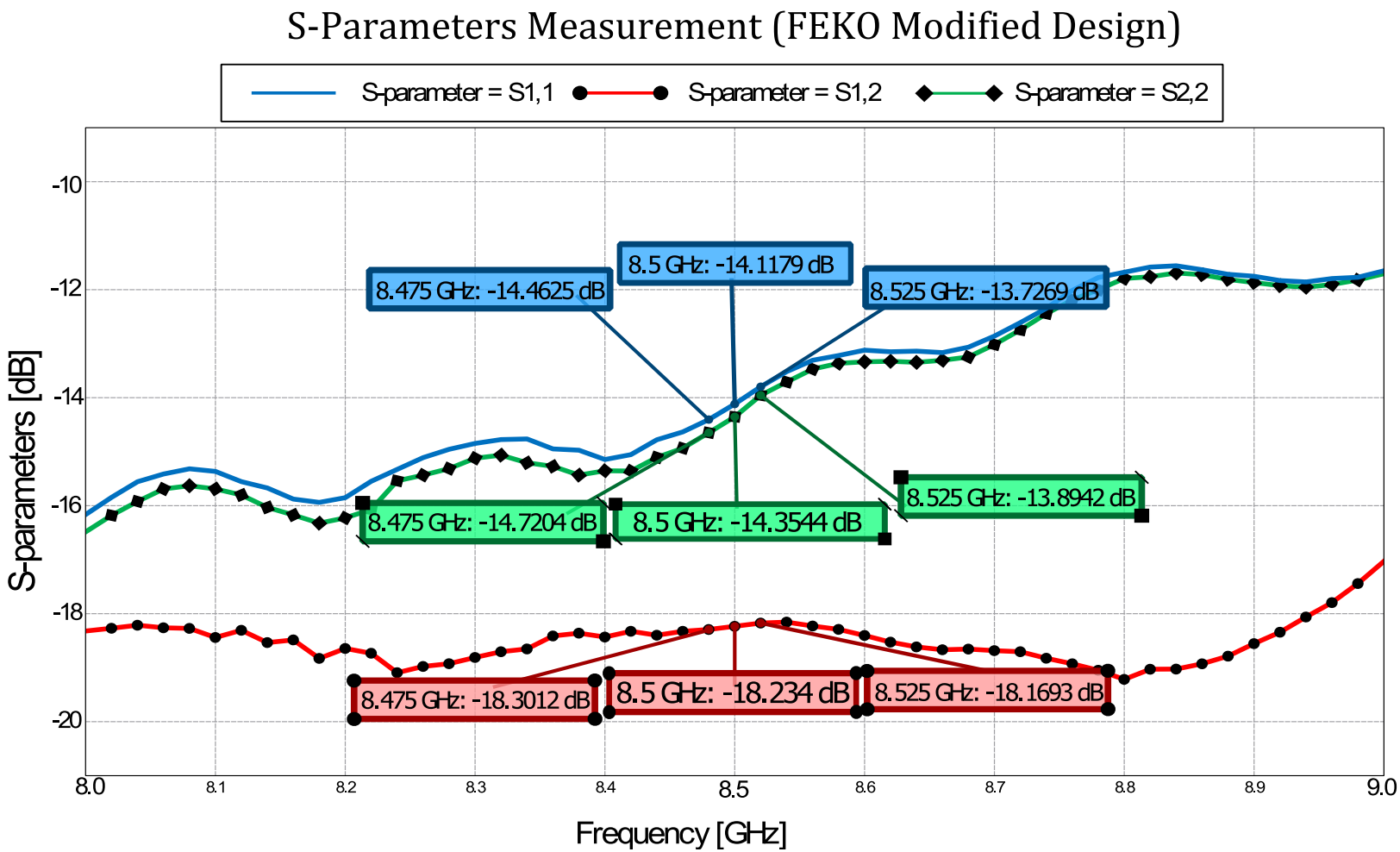

Figure: Simulated S-parameter results for X-Band horn antenna. S11 (blue), S12 (red) and S22 (green) are shown.

Measured X-Band Antenna S-Parameters

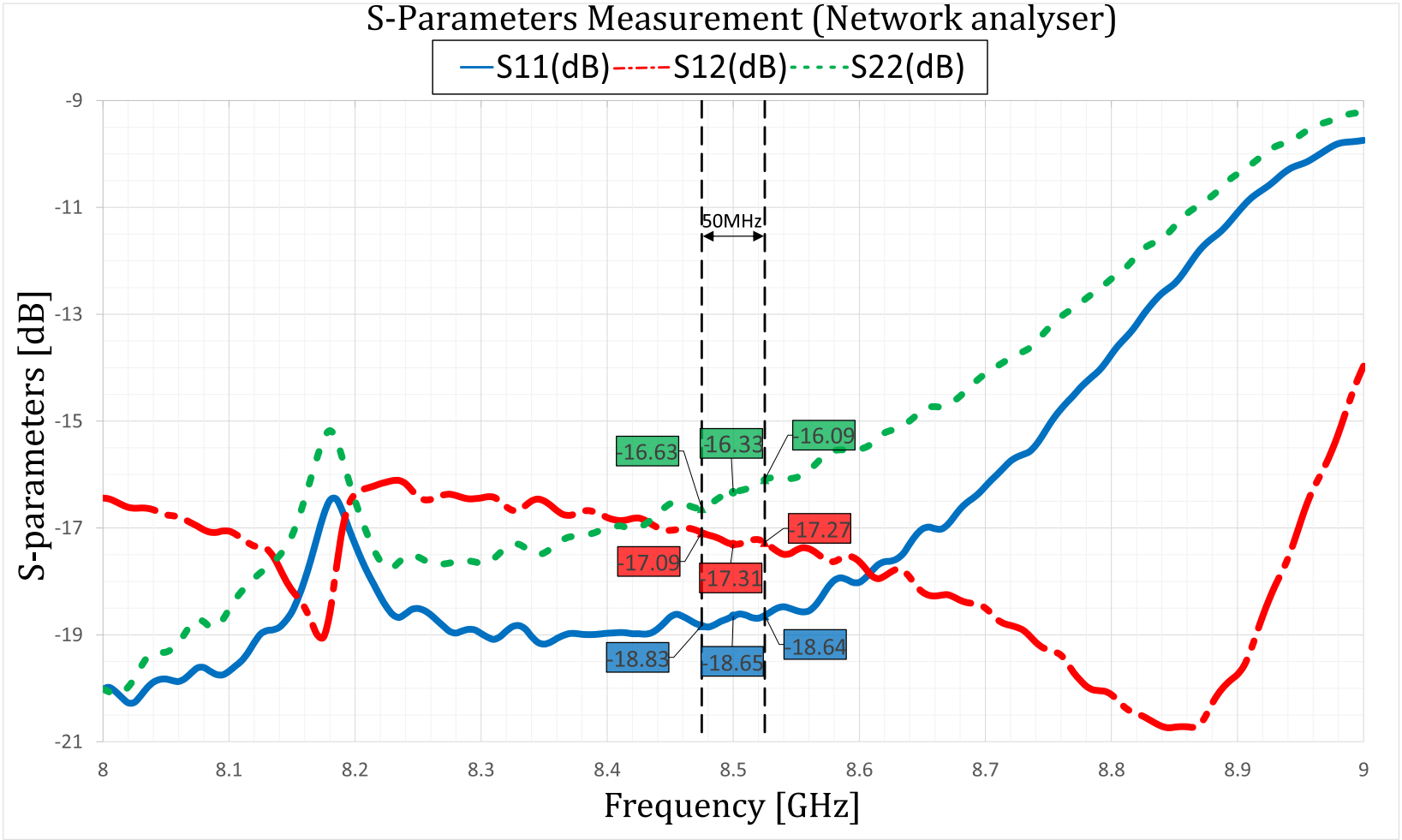

Figure: Measured S-parameter results for X-Band horn antenna. S11 (blue), S12 (red) and S22 (green) are shown.

Simulated X-Band Antenna Radiation Patterns

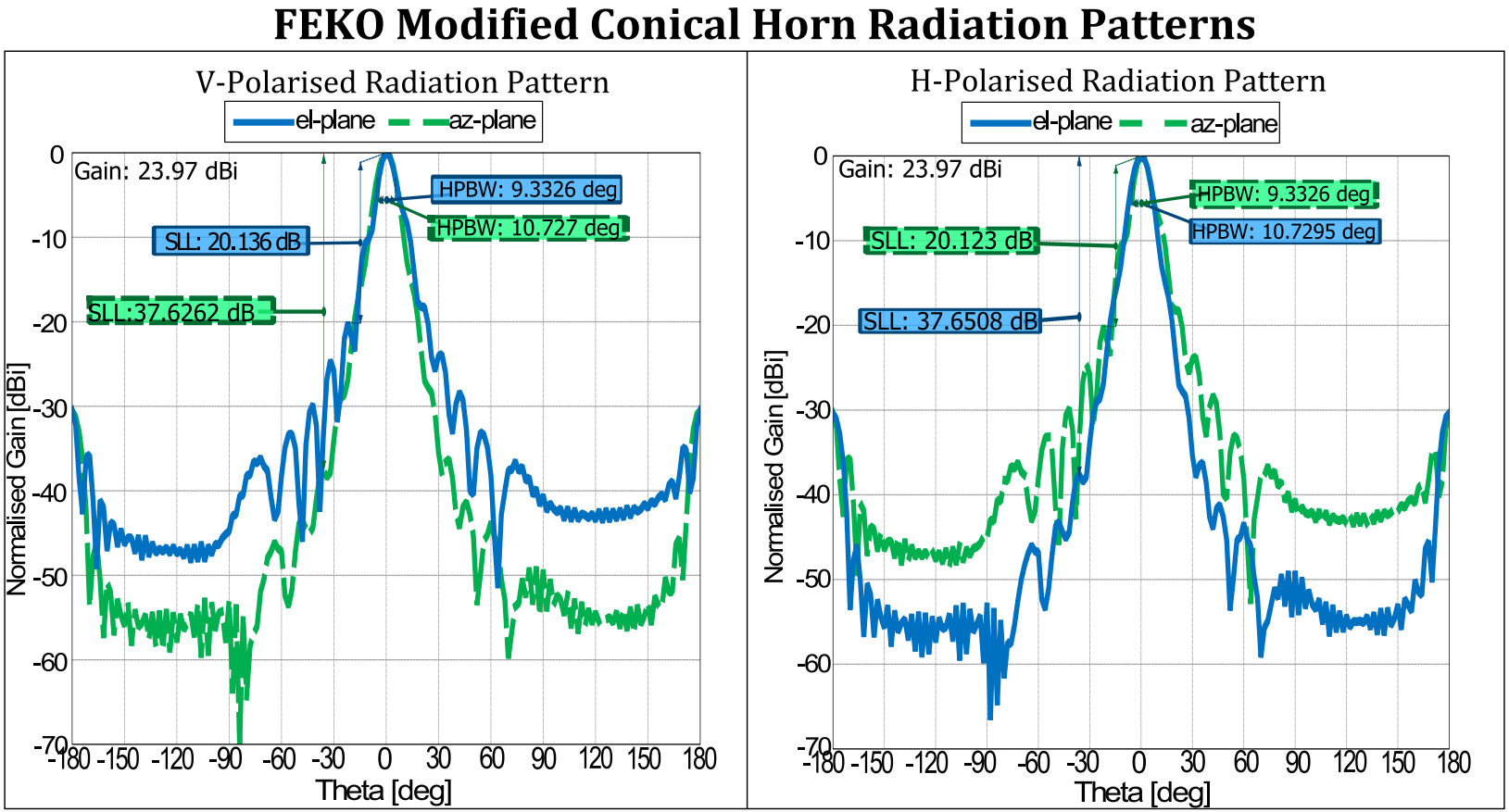

Figure: Simulated X-Band antenna radiation patterns. Azimuth plane (green) and elevation plane(blue) for both V-pol (left) and H-pol (right).

Measured X-Band Antenna Radiation Patterns

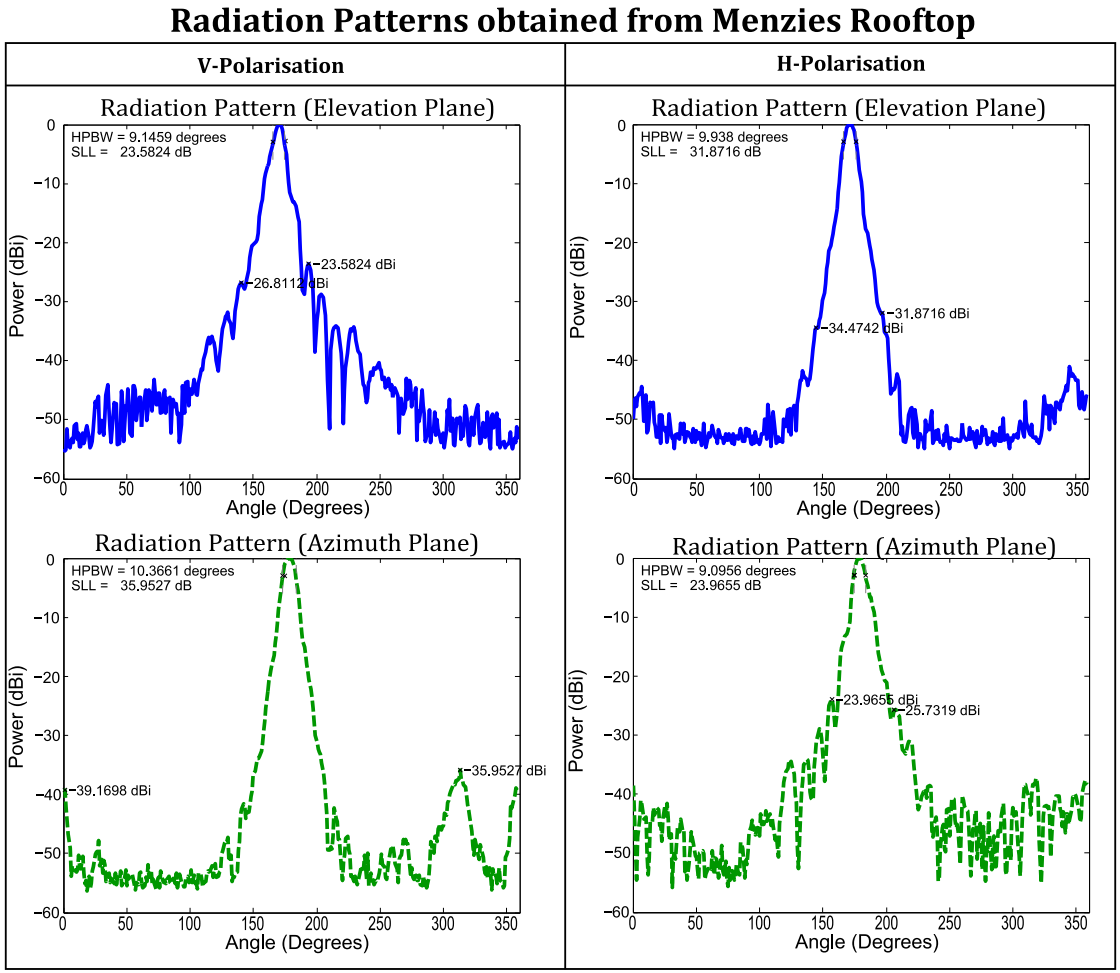

Figure: Measured X-Band antenna radiation patterns. Azimuth plane (green) and elevation plane(blue) for both V-pol (left) and H-pol (right).

Summary of X-Band Antenna Prototype Performance

	Horizontal Pol		Vertical Pol	
	Simulated	**Measured**	**Simulated**	**Measured**
Az HPBW	9.3°	9.1°	10.7°	10.4°
El HPBW	10.7°	10.0°	9.3°	9.2°
Az SLL	-20.1 dB	-23.8 dB	-37.6 dB	-35.9 dB
El SLL	-37.7 dB	-31.9 dB	-20.1 dB	-23.6 dB

X-Band Prototype Antenna Summary

It has been shown that:

- Conical horn and circular waveguide met all the NeXtRAD's antenna specifications.
- Manageable in size and portable.
- Dual polarisation has been successfully implemented.
- Approximately 10° azimuth HPBW achieved in both polarisations.
- FEKO shows accuracy.

Conclusions and Future Work

- The simulated results shown a close agreement to the measured results for both L- and X-Band prototypes.
- The measured L-Band prototype has an azimuth HPBW of 12.4°and 13.9°when horizontally and vertically polarised respectively.
- The measured X-Band prototype has an azimuth HPBW of 10.7°when both horizontally and vertically polarised.
- With improved manufacturing, the optimal L-Band antenna can be produced to provide almost exactly 10° azimuth HPBW as was simulated.
- It has been shown that both antennas meet the requirements and are suitable for use in NeXtRAD.

References I


S. Paine, "Design and Implementation of Dual Polarised L-Band Antenna with 10 Degree Azimuth Beamwidth," University of Cape Town, Cape Town, Tech. Rep., 2014.


P. Wade, "Parabolic Dish Feeds," 1998, accessed: October 13, 2016. [Online]. Available: http://www.w1ghz.org/antbook/chap11.pdf

Thank you!