REPORT 1.5

UHF TV ANTENNA RECONSTITUTION

UHF SAMPLE SITE (XYZ 123_456)

22ND JUNE 2017

1/ EXECUTIVE SUMMARY

Sixarms has been commissioned by Client A to verify the performance of the XYZ 123_456 UHF TV antenna installed at UHF Sample Site. The verification was made using an unmanned aerial vehicle (UAV) based survey system on the 22nd June 2017.

The UHF antenna being surveyed is an existing installed XYZ UHF TV broadcast array antenna. It is an omni-directional array, with the TV services being horizontally polarised. It consists of 80 panels,16 levels with 5 faces. The antenna has an aperture of 18m and is mounted on a mast, with the centre of the array at 194m above ground level.

The verification procedure involved the measurement of the Horizontal Radiation Pattern (HRP) on the main beam and a Vertical Radiation Pattern (VRP) on each of the 5 antenna faces. This report concerns the UHF TV antenna performance.

Measurement Findings:

- Generally, all measurements had good correlation to the designed patterns.
- The measured HRP agrees well with the designed pattern, except for the minor differences in lobe orientation.
- The measured VRPs shows variations of up to 0.5° with the designed pattern. The beamtilt is less than expected on the Western side and more on the Eastern side. This indicates the potential of a physical lean of 0.3 – 0.5° towards the East.
- Maximum ERP values for each of each of the 5 services were measured to be Service1=54.1dBW (Licensed = 50dBW), Service2=55.3dBW (55dBW), Service3=52.3dBW (53.5dBW), Service4=53.1dBW (53.5dBW) and Service5=52.5dBW (53.5dBW). Service1 seems to be the only service that does not measure closely to the licenced ERP taking into consideration the tolerances of this report.

In summary, the antenna has been observed to be operating closely to the designed HRP. A potential physical lean of the antenna to the East is effecting the VRP beamtilts by approximately 0.3° to 0.5°.

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SIXARMS

DOCUMENT REVISION

Version	Date	Revision Details
0.9	27 July 2017	Draft Release for Comment
1.0	7 September 2017	First Release

CONTACTS

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ABBREVIATIONS

AUT Antenna Under Test

DTV/DVB-T Digital Television

ERP Effective Radiated Power

FM Frequency Modulation

GPS Global Positioning System

IMU Inertial Management Unit

ITU International Telecommunication Union

HRP Horizontal Radiation Patter

RF Radio Frequency

UAV Unmanned Aerial Vehicle

VRP Vertical Radiation Pattern

VHF Very High Frequency

2/ INTRODUCTION

Sixarms has developed a method of commissioning broadcast antennas by measuring the radiation pattern from an airborne platform equipped with appropriate field strength, receive antenna, and positional measuring equipment.

This method is an efficient and accurate way to rapidly evaluate the antenna performance in both horizontal and vertical planes, as a high number of sample points can be acquired within a short time frame.

The measurement survey involves the following actions carried out during the flight:

- Field strength data acquisition with a calibrated receive antenna and field strength meter,
- Positional data acquisition of the UAVs location in 6-dimensional space with a GPS and IMU and barometer

The measured field strengths are acquired in a free space situation. The UAV measurement system will have two main objectives to complete once it is airborne. Firstly, to measure the VRP and secondly, to measure the HRP of the antenna (these measurements include the ERP). VRP runs are carried out from a static distance away from the mast in the far field, with an incremental vertical rise from below the antenna to above the antenna to capture the vertical pattern. HRP runs are carried out from a static height in relation to the antenna but at a slow fixed-distance orbit in the far-field to capture the horizontal pattern. The outcome is a complete characterisation and verification of the performance of the antenna being measured. This system is based on the *ITU Recommendation ITU-R SM.2056-1 "Airborne verification of antenna patterns of broadcasting stations".*

The report that follows presents the measurements obtained on site on the 22nd June 2017 and compares them to the supplied design pattern and details any discrepancies or areas of interest.

3/ RESULTS AND PLOTS

The measurement survey was carried out on the 22nd June 2017. In total, 6 complete data sets were collected for each UHF DTV service operating on the TV antenna. This consisted of five VRP measurement runs and one HRP measurement run, all with horizontal polarisation.

The actual flight paths and distances can be found in the Appendices but all flights were chosen to be approximately 600m from the transmission site. As the far-field was calculated at 1.4km from the antenna, a decision was made to make measurements at 600m. A comparison between measurements at 600m and at 1.4km is made to verify that measurements at 600m are acceptable (please see section below *"Verification of VRP vs flight Distance"*). All VRP flights were made between 8 degrees below the horizon and 3 degrees above the horizon.

The following sections outline the VRP and HRP measured plots and results and the plots have been organised according to depression angle (HRP) and azimuth (VRP). Included in the plots are:

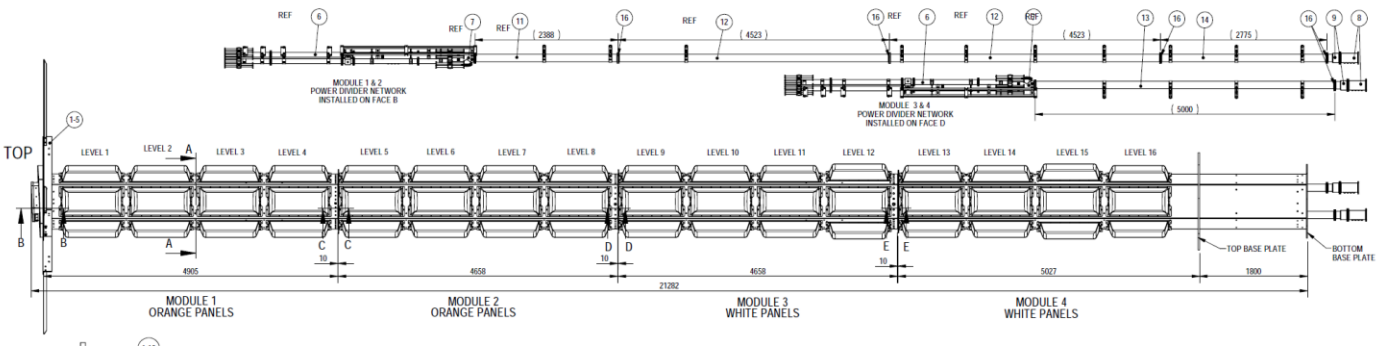
- Normalised plots (E/Emax) and comparison with designed
- ERP (dBW) comparisons (helpful when calculating coverage predictions)

Transmission, reception and uncertainties for the measured antenna can be found in the Appendices.

3/1 XYZ 123_456 Design

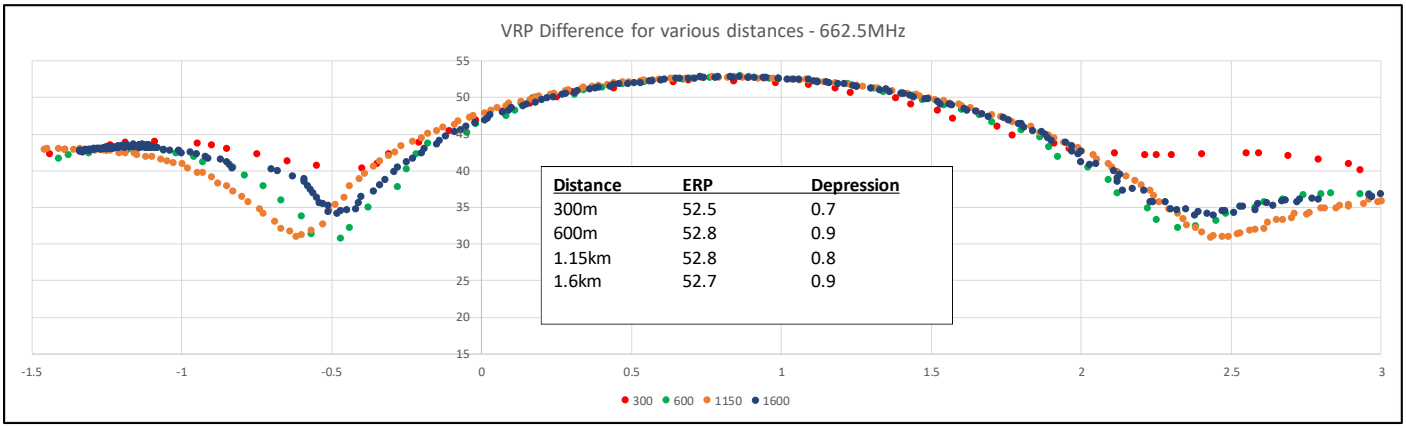
The UHF antenna being surveyed is an XYZ and UHF TV broadcast array (handbook 123_456). It is a omni-directional array capable of operating from 520 - 820MHz. The antenna consists of two halves with a total of 80 panels, 16 levels with 5 faces. The antenna has an aperture of around 18m and is mounted on a tower, with the centre of the array at 194m above ground level.

Handbook pattern data is overlaid with measured data for comparisons (Results Section). Below is a drawing of the actual antenna.



3/2 VERIFICATION OF VRP VS FLIGHT DISTANCE

Ideally, all measurements are taken in the farfield where the farfield is defined as $\frac{2D^2}{\lambda}$ where D = Aperture of the antenna and lambda is the wavelength of the frequency of interest. Measurements are usually taken in the farfield where the E and H components converge to form the antenna radiation pattern. In this instance VRP and HRP measurements were taken at a 600m radius. The farfield was calculated at 1.4km. The plot below shows the differences in ERP and depression angle for a VRP run at 300m, 600m, 1.15km and 1.6km.



It can be realised from the plot that it would be acceptable to perform VRP measurements at 600m with the disclaimer that differences between the 600m VRP and 1.6km VRP may occur at the NULLS of the antenna pattern. The depression angle and ERP seem to be consistent (within the tolerances of the measurement system) over all distance measurements.

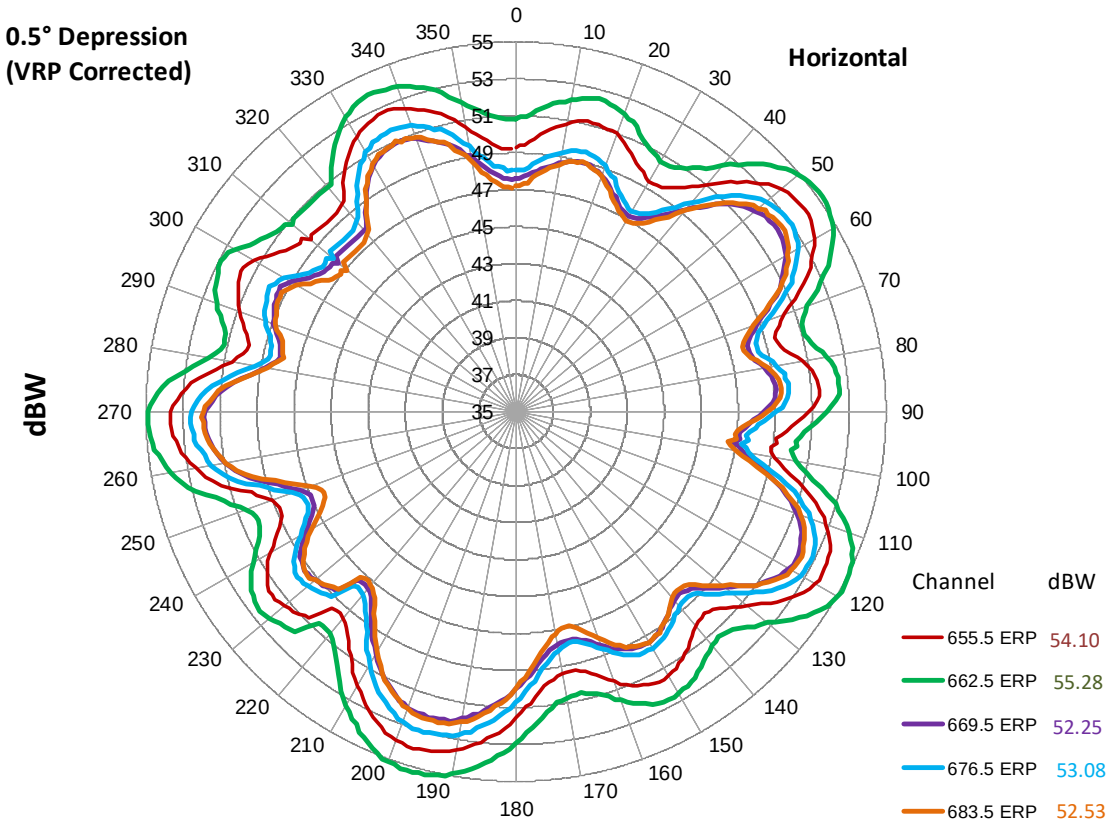
3/3 HORIZONTAL RADIATION PATTERNS

Depression Angle	Plot Type		Service MHz	Results	Plot Number & Page
0.5°	H - Component	Normalised (to Self)	655.5 MHz 662.5 MHz 669.5 MHz 676.5 MHz 683.5 MHz		Plot 1 Page 9 Plot 2 Page 9
		ERP	655.5 MHz 662.5 MHz 669.5 MHz 676.5 MHz 683.5 MHz	54.1 dBW 55.3 dBW 52.3 dBW 53.1 dBW 52.5 dBW	

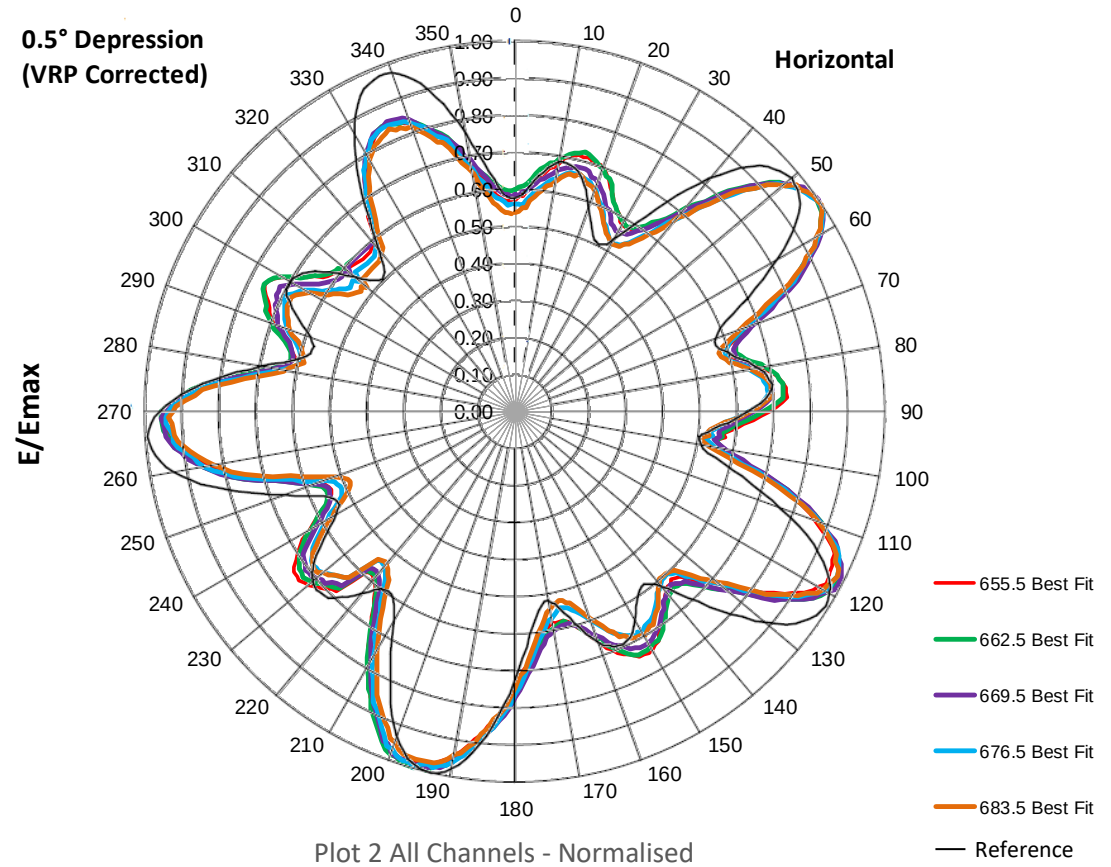
3/4 VERTICAL RADIATION PATTERNS

Azimuth	Plot Type		Service	Results (BeamTilt/ERP)	Plot Number & Page
13° FACE 13	H - Component	Normalised (to self)	655.5 MHz 662.5 MHz 669.5 MHz 676.5 MHz 683.5 MHz	0.6° 0.6° 0.7° 0.7° 0.7°	Plot 3 Page 10
		ERP	655.5 MHz 662.5 MHz 669.5 MHz 676.5 MHz 683.5 MHz	51.5 dBW 52.7 dBW 49.2 dBW 49.7 dBW 42.2 dBW	Plot 4 Page 10
85° FACE 85	H - Component	Normalised (to self)	655.5 MHz 662.5 MHz 669.5 MHz 676.5 MHz 683.5 MHz	0.9° 0.9° 0.9° 0.9° 0.9°	Plot 5 Page 11
		ERP	655.5 MHz 662.5 MHz 669.5 MHz 676.5 MHz 683.5 MHz	51.6 dBW 52.7 dBW 49.3 dBW 50.0 dBW 49.6 dBW	Plot 6 Page 11
157° FACE 157	H - Component	Normalised (to self)	655.5 MHz 662.5 MHz 669.5 MHz 676.5 MHz 683.5 MHz	0.5° 0.5° 0.6° 0.5° 0.6°	Plot 7 Page 12
		ERP	655.5 MHz 662.5 MHz 669.5 MHz 676.5 MHz 683.5 MHz	51.5 dBW 52.7 dBW 49.6 dBW 50.0 dBW 49.5 dBW	Plot 8 Page 12
229° FACE 229	H - Component	Normalised (to self)	655.5 MHz 662.5 MHz 669.5 MHz 676.5 MHz 683.5 MHz	0.2° 0.1° 0.1° 0.3° 0.2°	Plot 9 Page 13
		ERP	655.5 MHz 662.5 MHz 669.5 MHz 676.5 MHz 683.5 MHz	51.2 dBW 52.3 dBW 40.1 dBW 49.4 dBW 49.0 dBW	Plot 10 Page 13
301° FACE 301	H - Component	Normalised (to self)	655.5 MHz 662.5 MHz 669.5 MHz 676.5 MHz 683.5 MHz	0.2° 0.1° 0.2° 0.2° 0.2°	Plot 11 Page 14
		ERP	655.5 MHz 662.5 MHz 669.5 MHz 676.5 MHz 683.5 MHz	51.0 dBW 52.4 dBW 48.9 dBW 49.3 dBW 48.9 dBW	Plot 12 Page 14

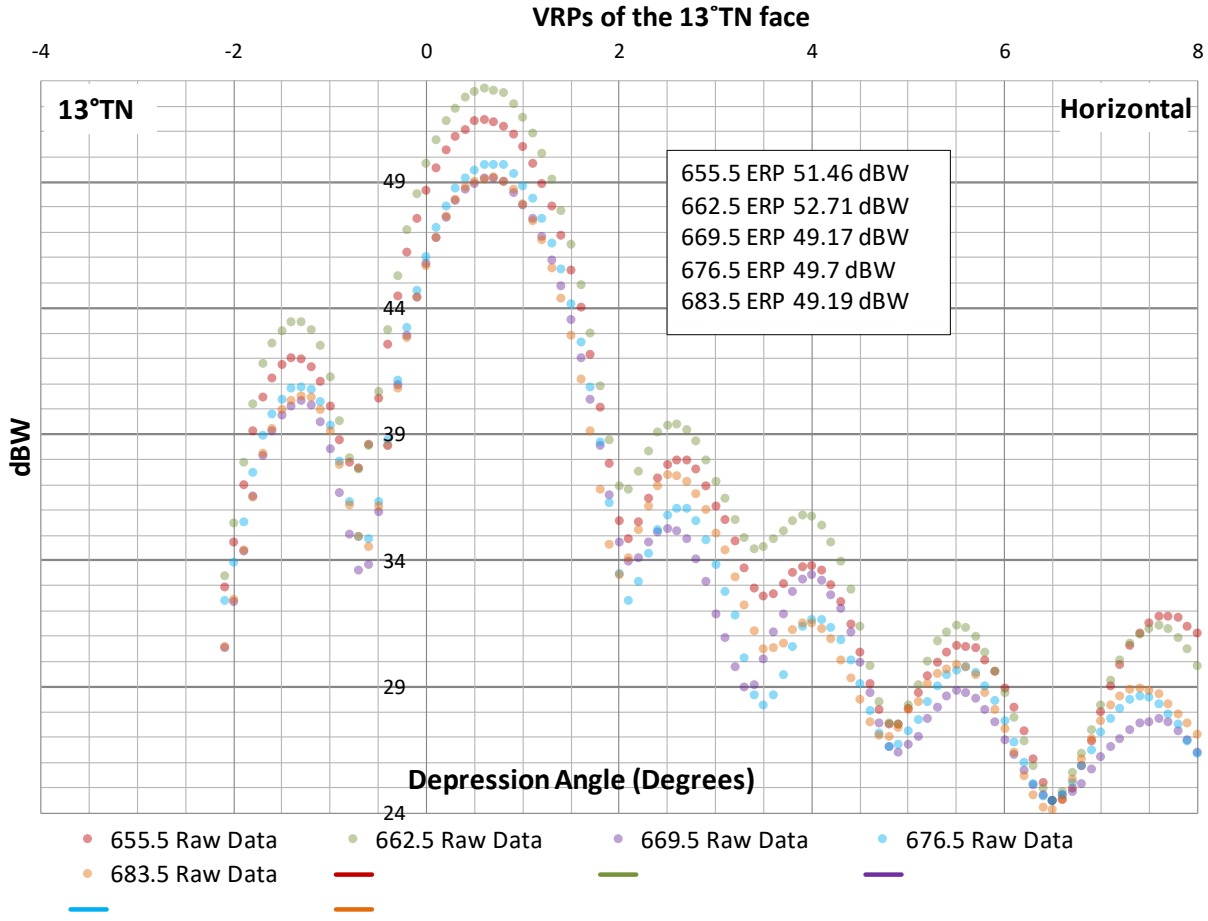
HRPs at 0.5° Below the Horizon



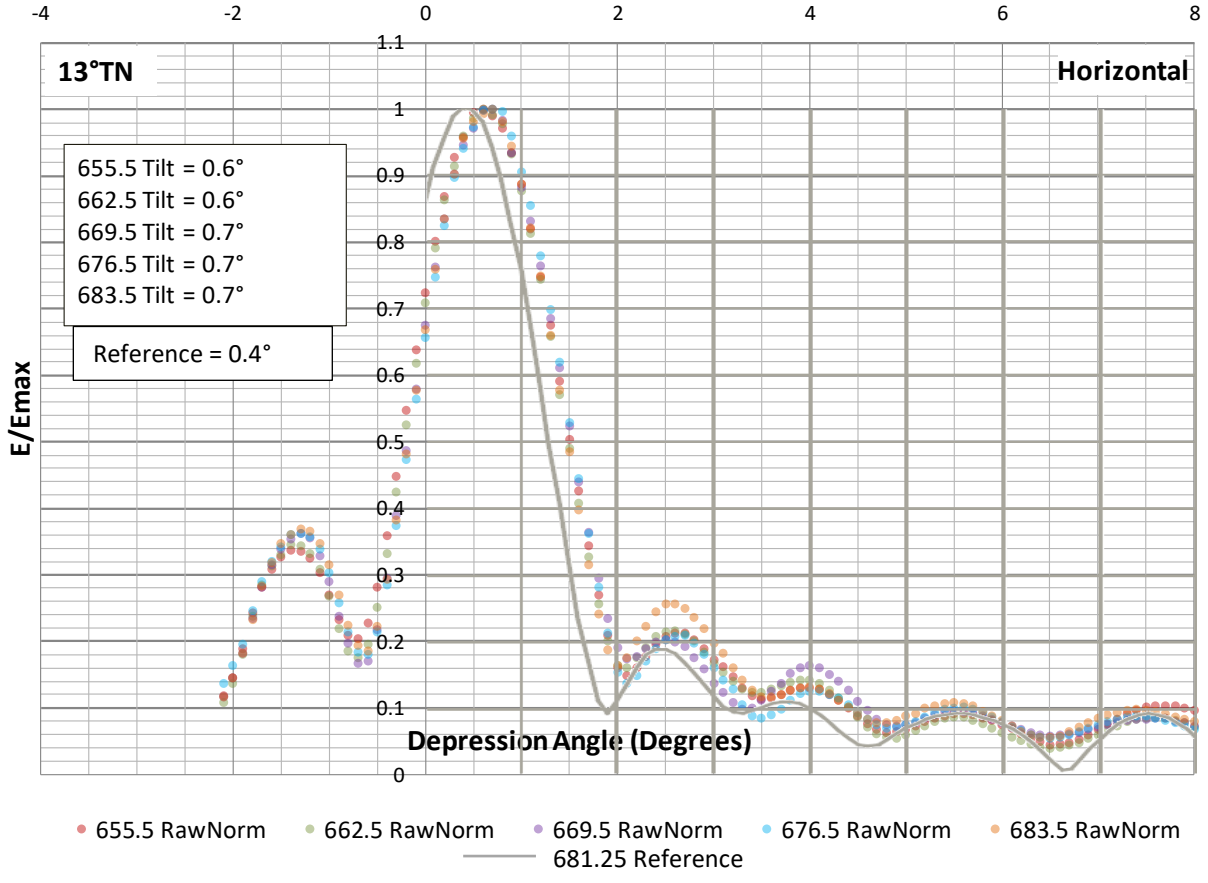
Plot 1: All Channels ERP (dBW)



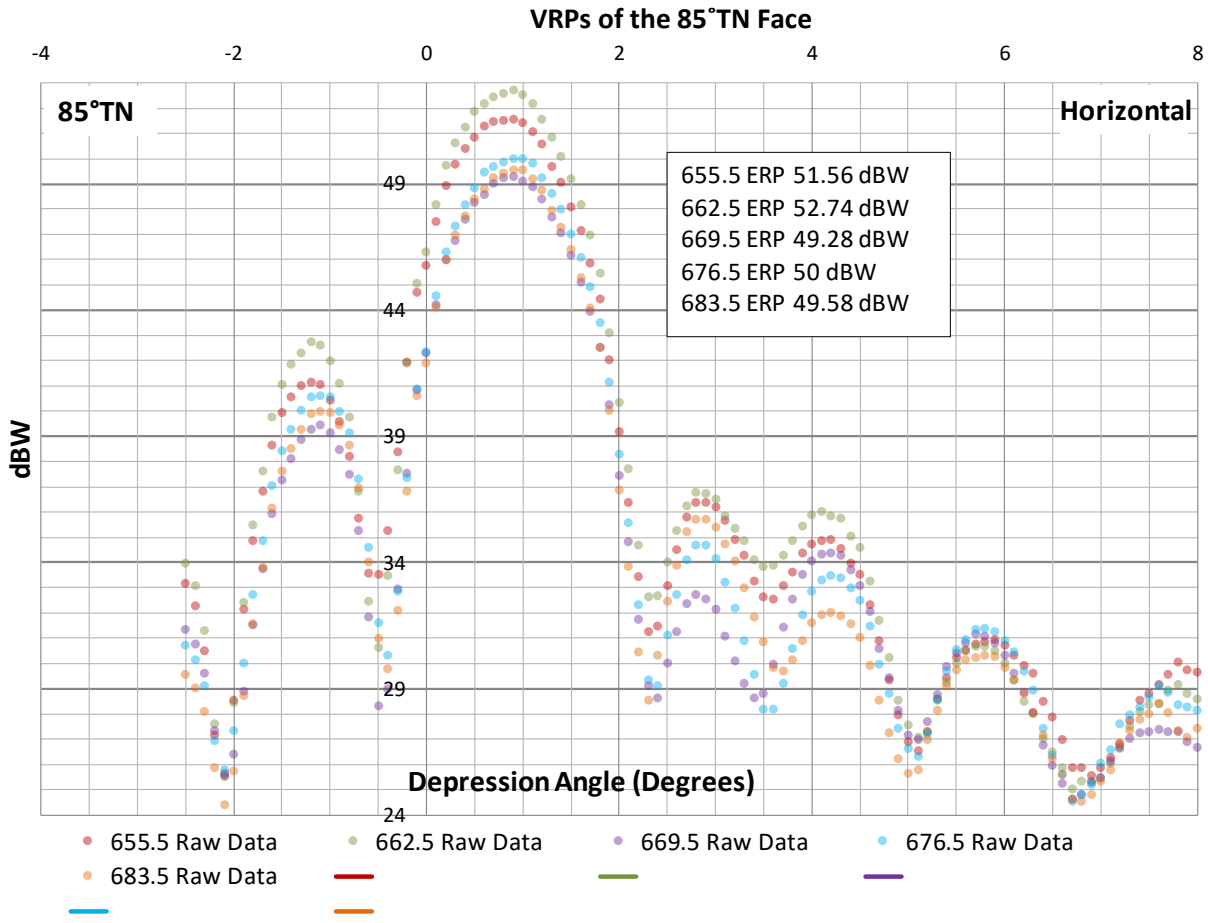
Plot 2 All Channels - Normalised



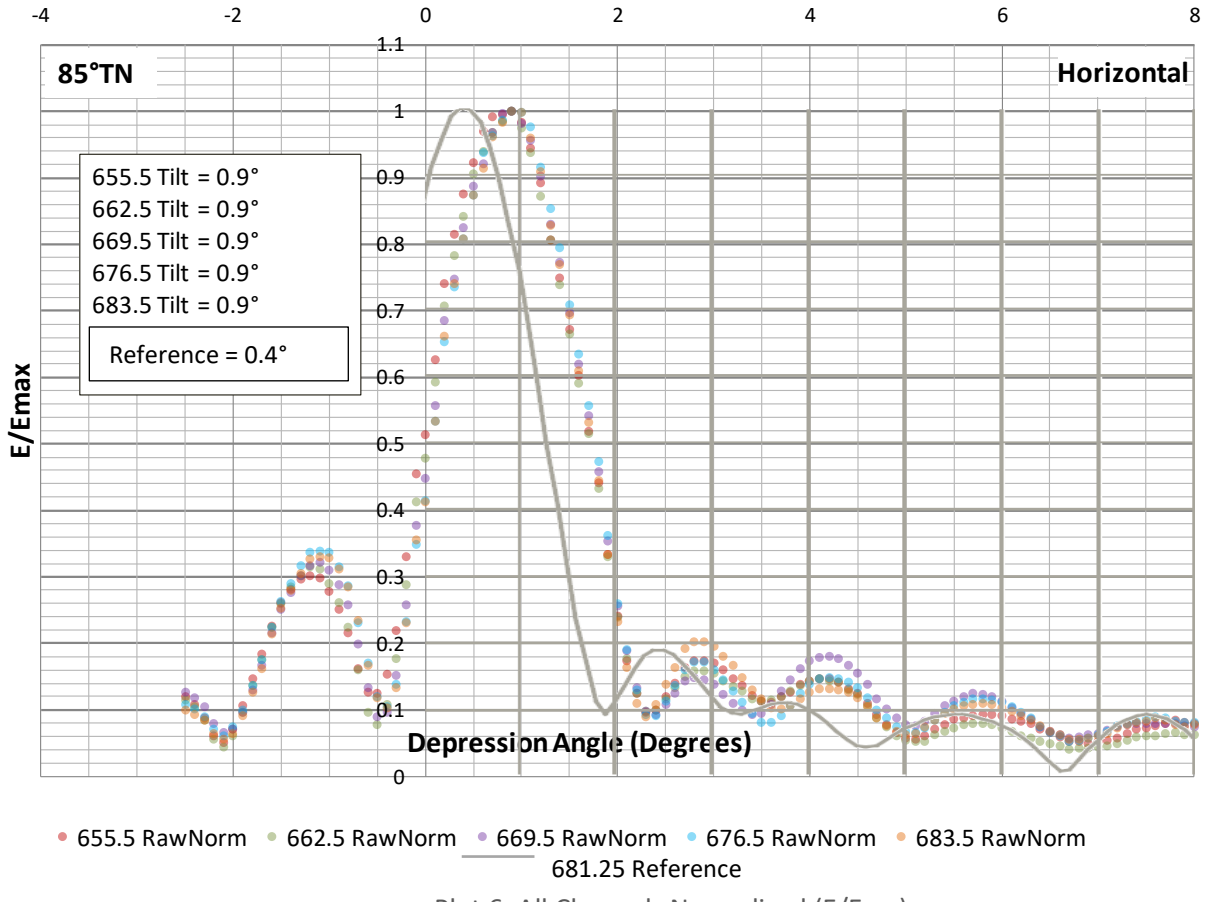
Plot 3: All Channels ERP (dBW)



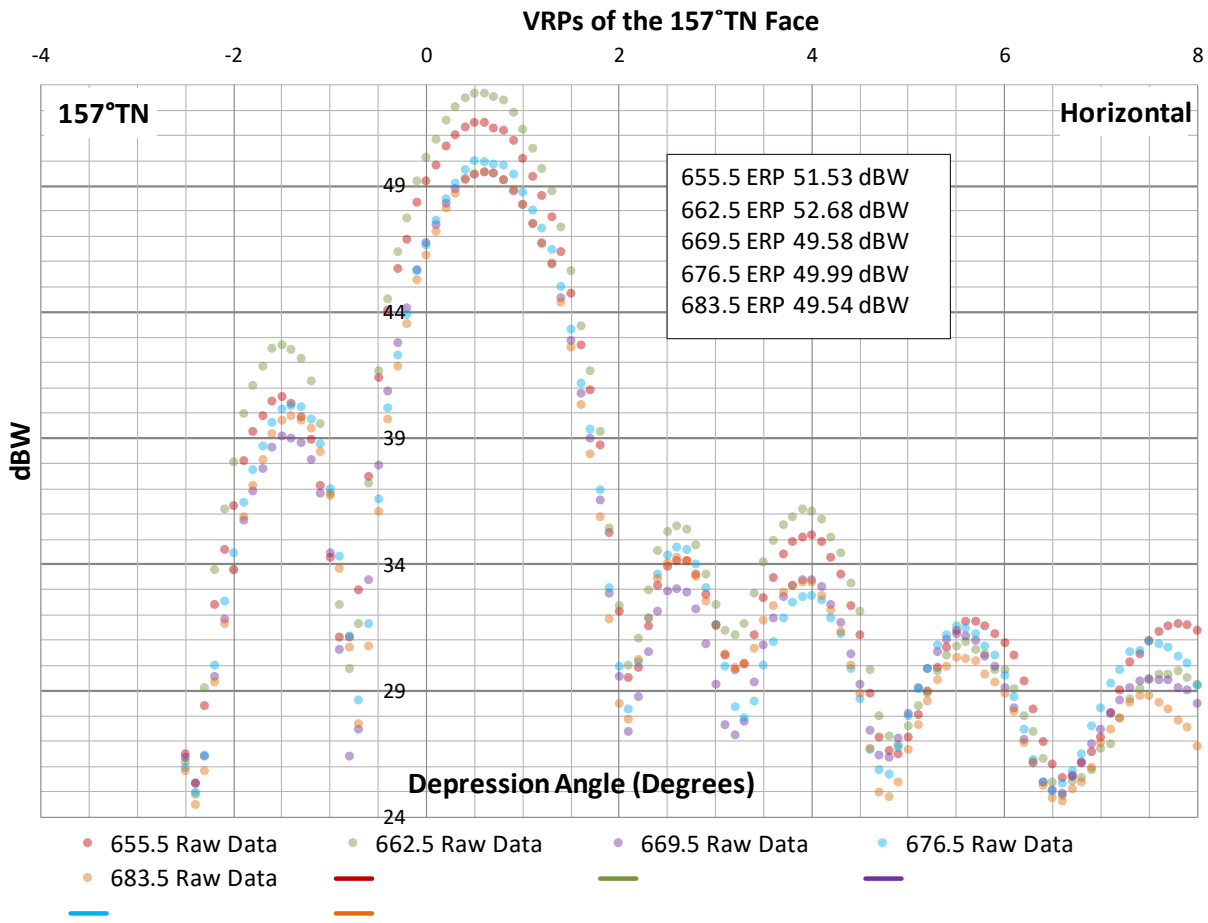
Plot 4: All Channels Normalised (E/E_{MAX})



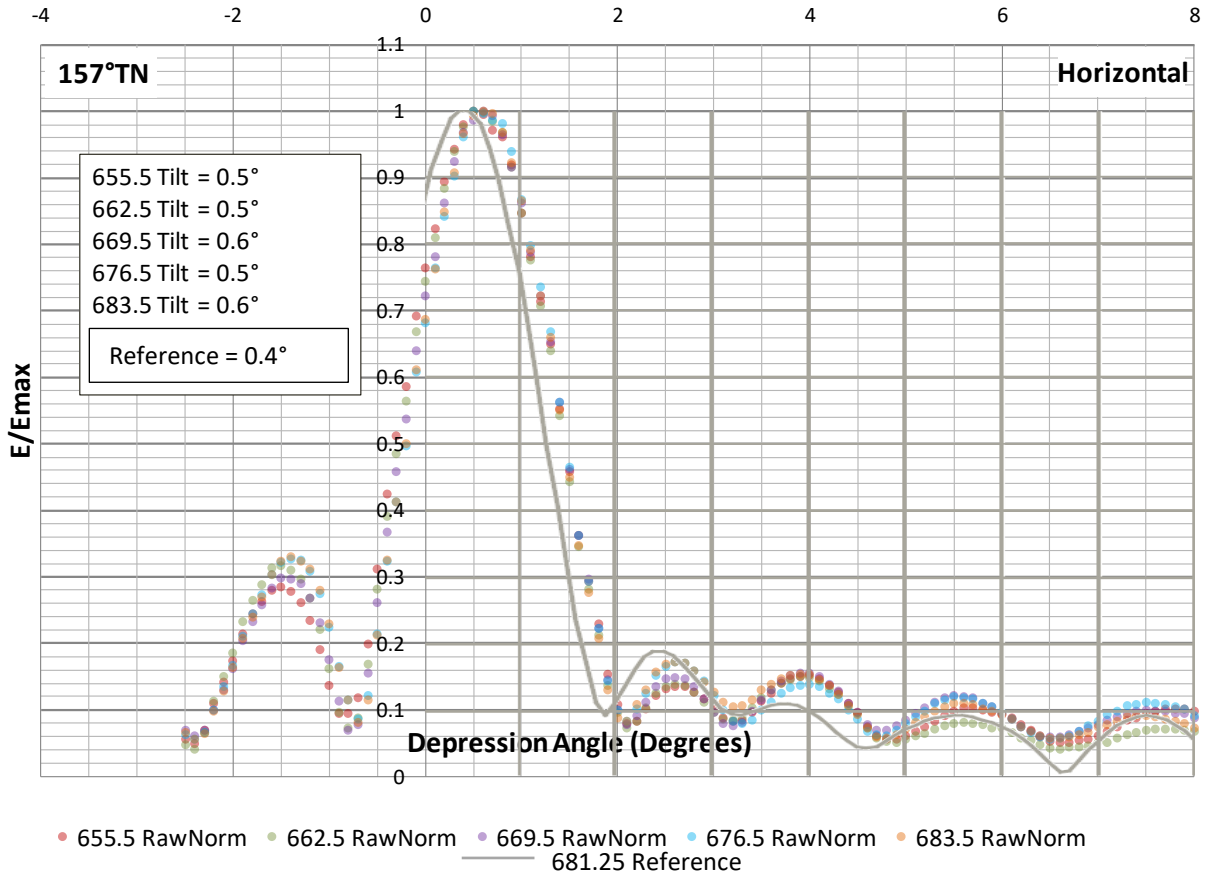
Plot 5: All Channels ERP (dBW)



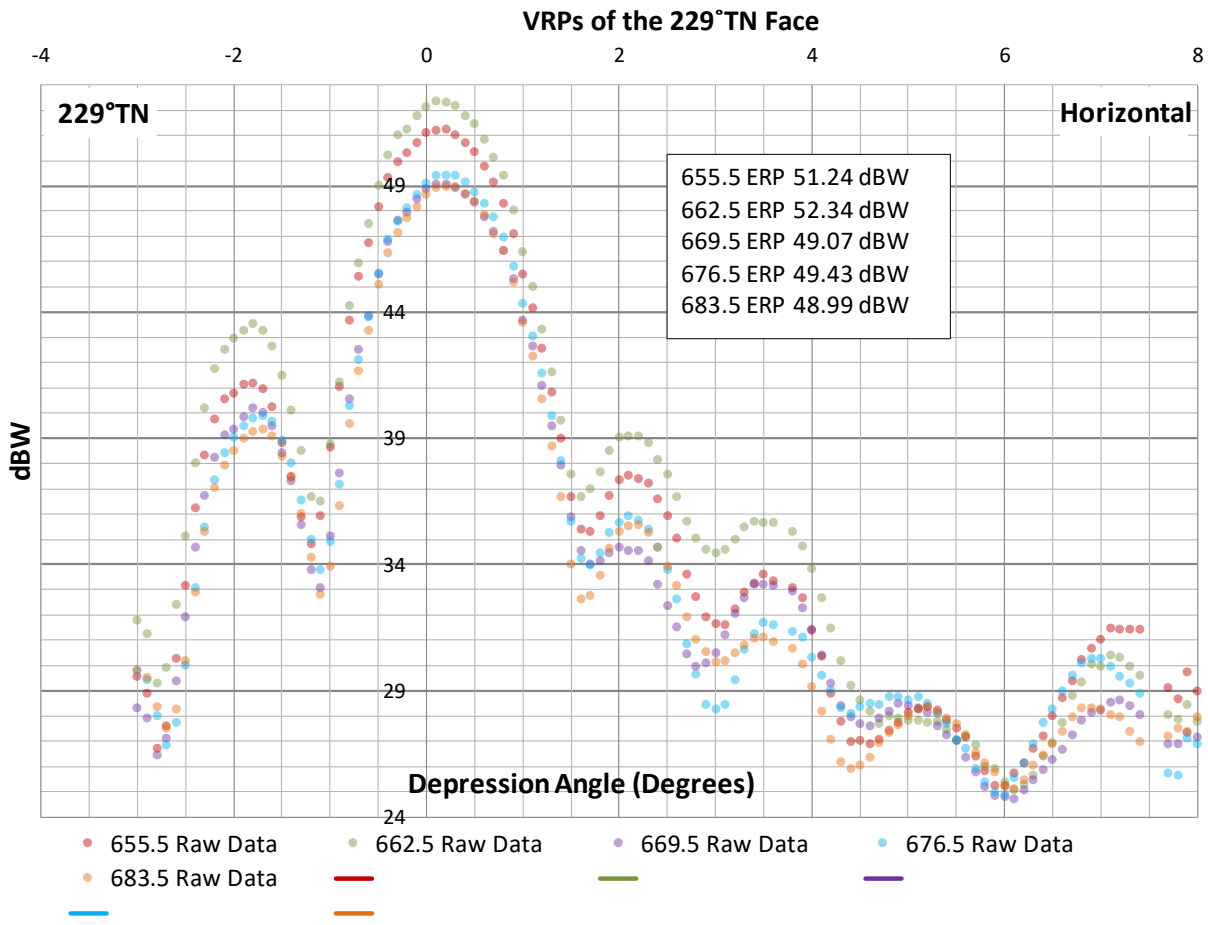
Plot 6: All Channels Normalised (E/E_{MAX})



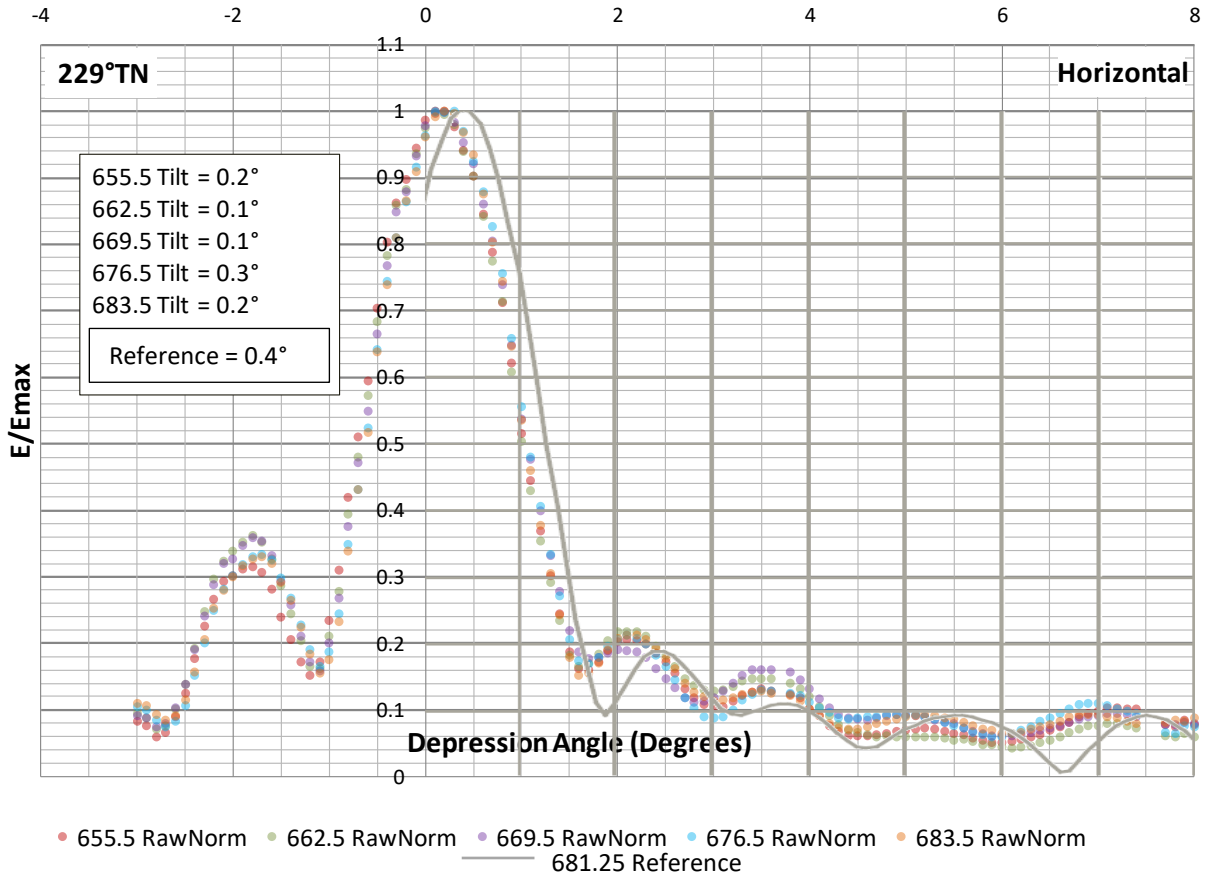
Plot 7: All Channels ERP (dBW)



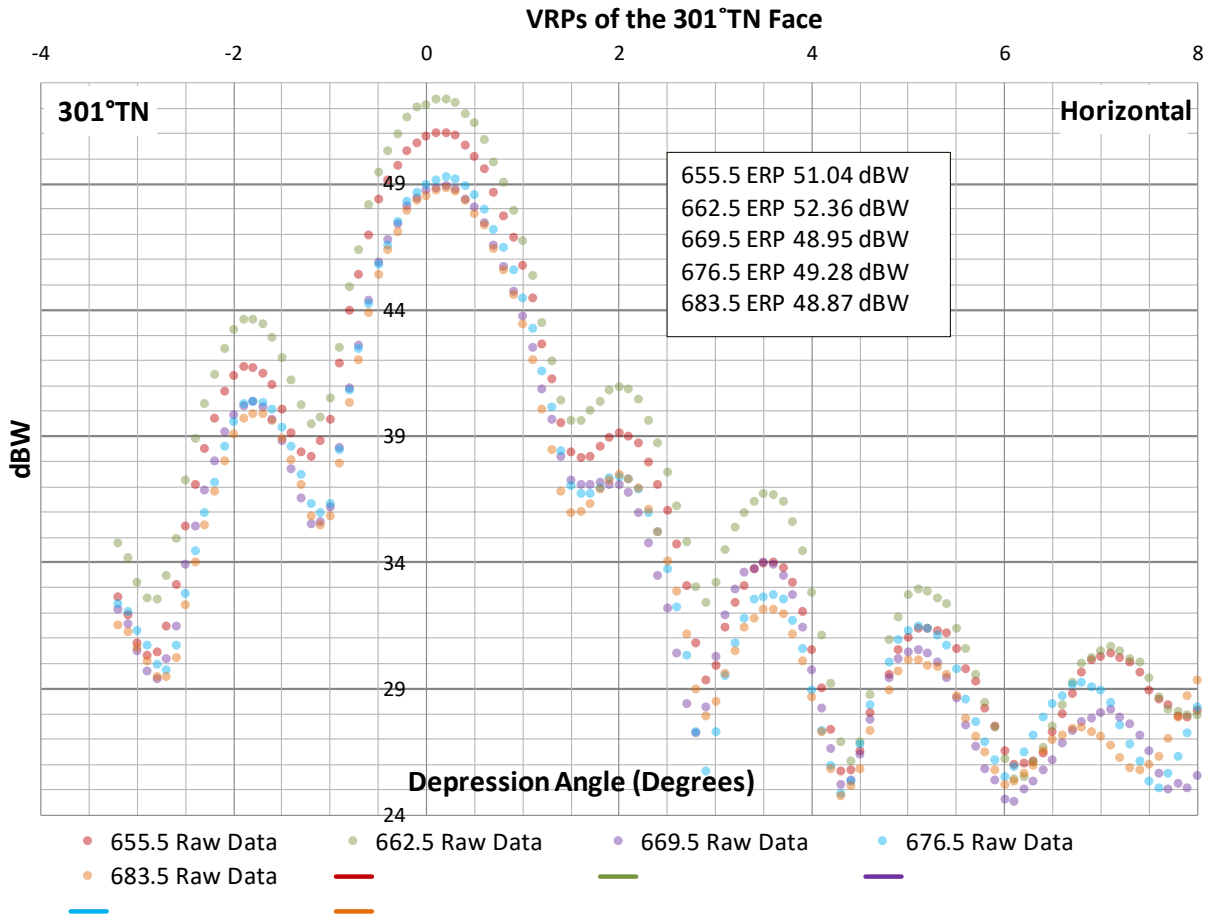
Plot 8: All Channels Normalised (E/E_{MAX})



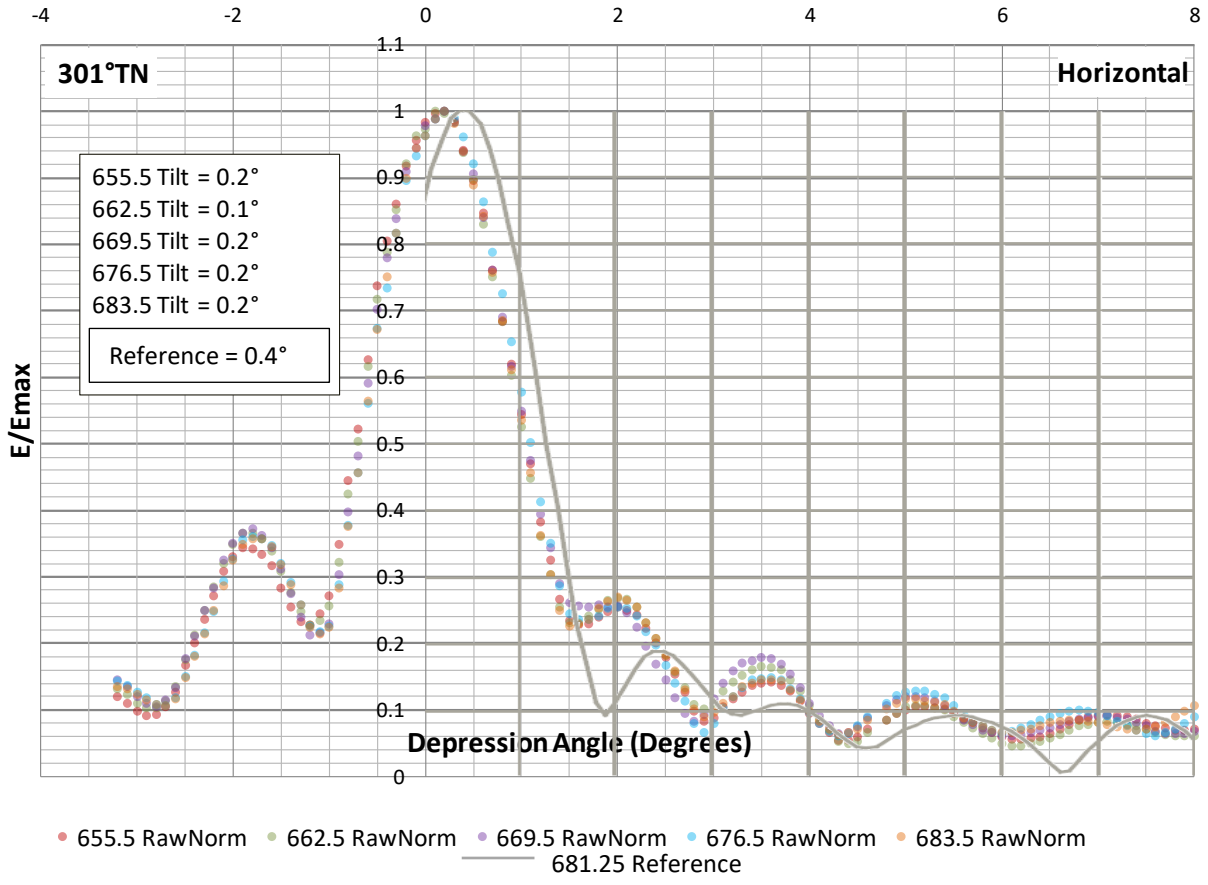
Plot 9: All Channels ERP (dBW)



Plot 10: All Channels Normalised (E/E_{MAX})



Plot 11: All Channels ERP (dBW)



Plot 12: All Channels Normalised (E/E_{MAX})

4/ CONCLUSIONS

The following conclusions can be drawn from the UHF Sample Site antenna measurement survey for all channels measured:

- Generally, all measurements had good correlation to the designed patterns.
- The measured HRP agrees well with the designed pattern, except for the minor differences in lobe orientation.
- The measured VRPs shows variations of up to 0.5° with the designed pattern. The beamtilt is less than expected on the Western side and more on the Eastern side. This indicates the potential of a physical lean of 0.3 – 0.5° towards the East.
- Maximum ERP values for each of each of the 5 services were measured to be Service1=54.1dBW (Licensed = 50dBW), Service2=55.3dBW (55dBW), Service3=52.3dBW (53.5dBW), Service4=53.1dBW (53.5dBW) and Service5=52.5dBW (53.5dBW). Service1 seems to be the only service that does not measure closely to the licenced ERP taking into consideration the tolerances of this report.

The antenna has been observed to be operating closely to the designed HRP. A potential physical lean of the antenna to the East is effecting the VRP beamtilts.

APPENDIX 1: TRANSMISSION PARAMETERS

The following details and parameters were used in calculations in this report:

SITE DETAILS

Site (City)	Site Grid Reference Lat, Lon, (WGS84)	Service		Mast Base AHD[1] (metres)	Antenna Electrical Centre RL (metres)	Antenna Details Panel Faces
		CH	Freq. (MHZ)			
UHF Sample Site	[redacted]	46 47 48 49 50	655.5 662.5 669.5 676.5 683.5	98	194	Face 13°TN Face 85°TN Face 157°TN Face 229°TN Face 301°TN

[1] Australian Height Datum

ERP CALCULATION DETAILS

Service	Antenna Gain (dBd)	Antenna Factor (dB)	Cable Loss (dB)	Attenuation Loss (dB)	Other Loss (dB)	Final Cal Factor (dB)
655.50 MHz	5.21	24.40	0.30	29.70	5.70	54.88
662.50 MHz	5.41	24.49	0.30	29.70	5.70	54.78
669.50 MHz	4.96	24.58	0.30	29.70	5.70	55.32
676.50 MHz	5.13	24.67	0.30	29.70	5.70	55.24
683.50 MHz	5.56	24.76	0.30	29.70	5.70	54.90

APPENDIX 2: EQUIPMENT AND FLIGHT PARAMETERS

The following equipment was used during the antenna reconstitution process as well as the actual flight details and measurement tolerances.

EQUIPMENT USED

	Serial	Calibration/Verification Date
Unmanned Aerial Vehicle	#Franky	N/A
Receiver System	#41690130	06/01/2017
Antenna System	#ZCG LPY600-AL	12/03/2016
1m LCU195 Cable	#LCU195-1m	10/6/2016
Attenuation	#1237 &#0839	10/6/2016

UHF TV Measurement System

ACTUAL FLIGHT PROFILES

The following flight profiles were used:

Type	Azimuth	Distance from Site	Depression Angle
VRP	13°	600m	8 to -3
	85°	600m	8 to -3
	157°	600m	8 to -3
	229°	600m	8 to -3
	301°	600m	8 to -3
HRP	Full	600m	0.5°

Partial HRP 1

Partial HRP 2

VRP - 13ºTN

VRP - 85ºTN

VRP - 157º & 229ºTN

VRP - 301ºTN

Actual Flight Paths (mapped in Google Earth) -HRP and all VRPs – True North towards upper page

VALID SAMPLE TOLERANCES

No measurements outside the tolerances listed below were used in the pattern calculations.

Parameter	Tolerance
UAV Azimuth	±10°
UAV Pitch	±5°
UAV Roll	±5°
Depression Angle	±0.5°
Distance	±2.0m
Height	±1.0m

APPENDIX 3: UNCERTAINTY CALCULATIONS

The system model is indicated below. In this model, all sensitivity coefficients of the influence quantities are equal to 1. The common unit is the dB variation of the received field strength.

$$\Delta f = g_1 + g_2 + \ldots + g_N \qquad (1)$$

where: Δf is the total dB variation of the fields due to uncertainty in and correction of the influence quantities, g_i. g_1, g_2, … g_N are the corrections and uncertainties in the influence quantities expressed as dB variations.

ABSOLUTE

For Absolute measurements, positional accuracy is estimated to vary with a triangular distribution with an uncertainty of 0.5dB. Scattering effects from nearby objects has been assumed to be varying in a symmetric rectangular distribution with a span of 1.0dB. The Spectrum Analyser has a standard uncertainty with a normal symmetry of 1.5dB.. The feeder loss has a standard rectangular distribution with an uncertainty of 0.2dB (from Calibrated Scalar Analyser). The antenna azimuth alignment has is a triangular distribution with an uncertainty of 0.5dB. The variation in antenna gain over the channels of interest is estimated to vary in a symmetric rectangular distribution with a span of 0.5dB.

Source of uncertainty	Unit	Uncertainty				
		Probability distribution	Semi span *a or σ*	Divisor *d*	$u_i = a/d$	u_i^2
Positional Accuracy	dB	Triangular	0.5	√6	0.204	0.042
Scattering Effects/Layering	dB	Rectangular	0.5	√3	0.577	0.333
Spectrum Analyser	dB	Normal	1.5	2	0.750	0.563
Feeder Loss	dB	Rectangular	0.2	√3	0.115	0.013
Azimuth Alignment	dB	Triangular	0.5	√6	0.204	0.042
Antenna Gain	dB	Rectangular	0.5	√3	0.115	0.013
SUMS						1.006
Combined standard uncertainty, uc = √Σ(ui²)						1.003
Coverage factor, k						2 (95% CI)
Expanded Uncertainty, U = k × uc						**±2.0 dB**

RELATIVE

For Relative measurements, positional accuracy is estimated to vary with a triangular distribution with an uncertainty of 0.5dB. Scattering effects from nearby objects has been assumed to be varying in a symmetric rectangular distribution with a span of 1.0dB. The Spectrum Analyser variation has a standard uncertainty with a normal symmetry of 0.2dB.. The feeder loss variation has a standard rectangular distribution with an uncertainty of 0.05dB. The antenna azimuth alignment has is a triangular distribution with an uncertainty of 0.5dB. The variation in antenna gain over a complete FM Band is estimated to vary in a symmetric rectangular distribution with a span of 0.2dB.

Source of uncertainty	Unit	Uncertainty				
		Probability distribution	Semi span *a or σ*	Divisor *d*	$u_i = a/d$	u_i^2
Positional Accuracy	dB	Triangular	0.5	√6	0.204	0.042
Scattering Effects	dB	Rectangular	1	√3	0.577	0.333
Spectrum Analyser Var	dB	Normal	0.2	2	0.100	0.010
Feeder Loss Variation	dB	Rectangular	0.05	√3	0.029	0.001
Azimuth Alignment	dB	Triangular	0.5	√6	0.204	0.042
Antenna Gain Variation	dB	Rectangular	0.2	√3	0.115	0.013
SUMS						0.441
Combined standard uncertainty, uc = √Σ(ui²)						0.664
Coverage factor, k						2 (95% CI)
Expanded Uncertainty, U = k × uc						**±1. 3 dB**