REPORT 1.1

TV ANTENNA RECONSTITUTION

SAMPLE SITE (TV). 3 MARCH 2017.

1/ EXECUTIVE SUMMARY

Sixarms has been commissioned by the Client to verify the performance of the New VHF FM antenna installed at the Sample Site. The verification was made using an unmanned aerial vehicle (UAV) based survey system on the 3rd March 2017.

The FM antenna being surveyed is a newly installed ABC FM broadcast array antenna. It is an omni-directional array, with the VHF FM services being circularly polarised (i.e. Vertical and Horizontal). It consists of 16 panels, 4 levels with 4 faces FM antenna. The antenna has an aperture of 13.6m and is mounted on a mast, with the centre of the array at 88m 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 4 antenna faces for both the vertical and horizontal components of the circularly polarised antenna. This report concerns the FM antenna performance.

Measurement Findings:

1) The HRP's (both V&H components) are generally omnidirectional in nature. Minor differences in peaks and nulls were observed and are within the tolerances of this report.

2) The VRP's (both V&H components) did not differ significantly from the design. Variations in measured beamtilts versus designed beamtilts had less than 1dB effect on ERP values.

3) Combined V&H measured maximum ERP values (taking uncertainties into consideration) are within Regulator licenced ERP values.

In summary, there appears to be no significant differences between the design and what has been measured. No further investigation is needed.

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DOCUMENT REVISION

Version	Date	Revision Details
1.0	3 March 2017	Initial 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 3rd March 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 3rd March 2017. In total, 5 complete data sets were collected for each VHF DTV service operating on the TV antenna. This consisted of four vertical measurement runs and one horizontal measurement run, all in the horizontal polarisation.

The actual flight paths and distances can be found in the Appendices but all flights were chosen to be approximately 370m from the transmission site to allow for measurements to be taken in the far-field and to mitigate ground reflections. However, some measurements experienced minor fluctuations in their values. This is due to other structures as well as ground reflections within the vicinity of the measurement location. These fluctuations had minimal effect on the accuracy of the plots. All vertical flights were made between 13 degrees below the horizon and 12 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:

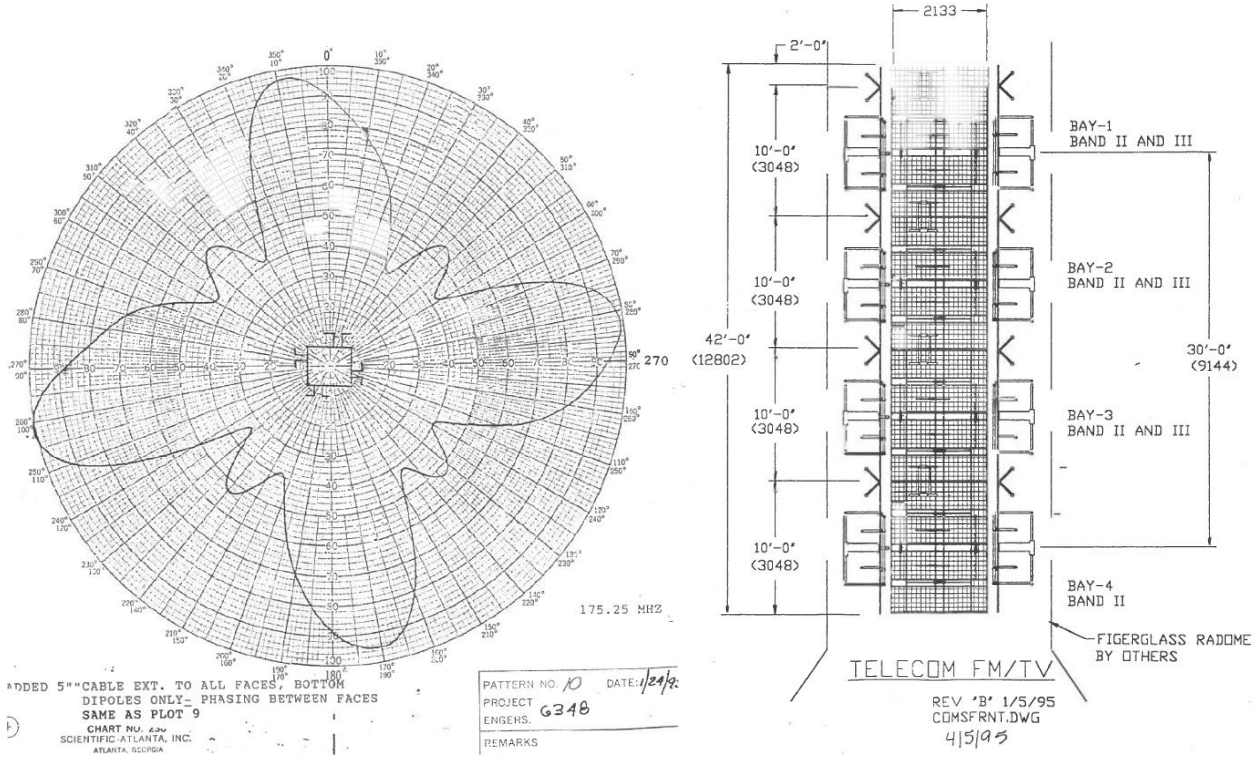
- Normalised plots (E/Emax) and comparison with designed
- ERP (dBW) comparisons (helpful when calculating coverage predictions)

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

3/1 VHF TV ANTENNA AND DESIGN PLOTS

The VHF antenna being surveyed is an interleaved XYZ FM and TV broadcast array. It is a omni-directional array operating from 88-108MHz and 170MHz-200MHz. Each separate antenna consists of 16 panels, 4 levels with 6 faces. The antenna has an aperture of 12.8m and is mounted on a tower, with the centre of the array at 104.1m above ground level.

The original pattern for 175.25MHz is shown below, but electronic formats (provided by the client) at 177.5MHz were used as comparison against the measured data.



3/2 HORIZONTAL RADIATION PATTERNS

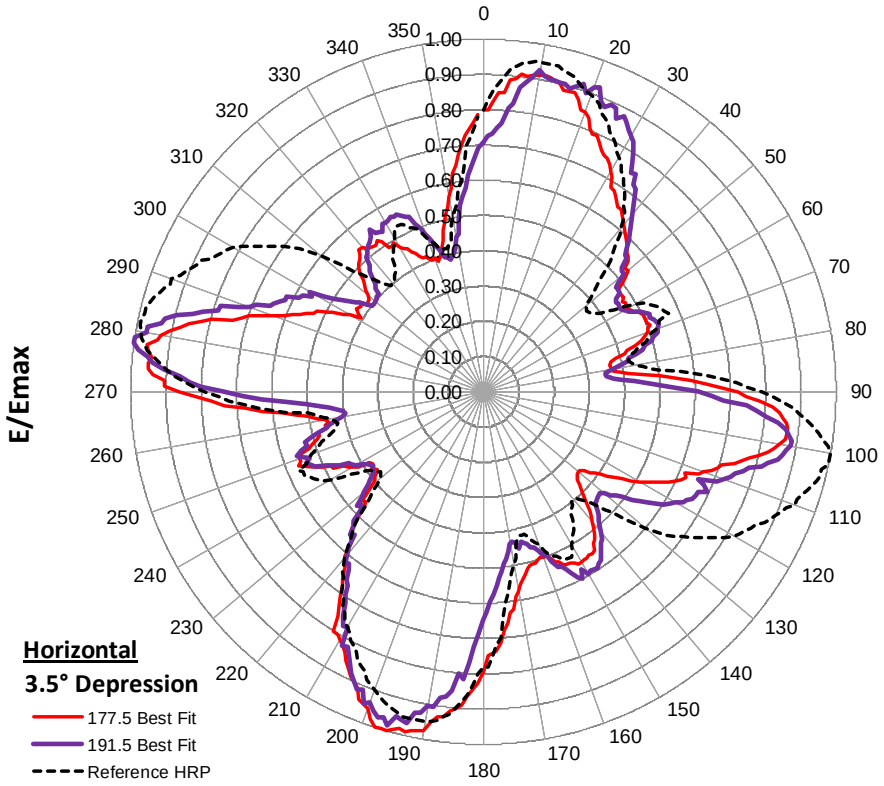
Depression Angle	Plot Type		Service MHz	Results	Plot Number & Page
3.5°	H - Pol	Normalised (to Self)	177.5 MHz 191.5 MHz		Plot 1 Page 8 Plot 2 Page 8
		ERP	177.5 MHz 191.5 MHz	49.5 dBW 48.0 dBW	

3/3 VERTICAL RADIATION PATTERNS

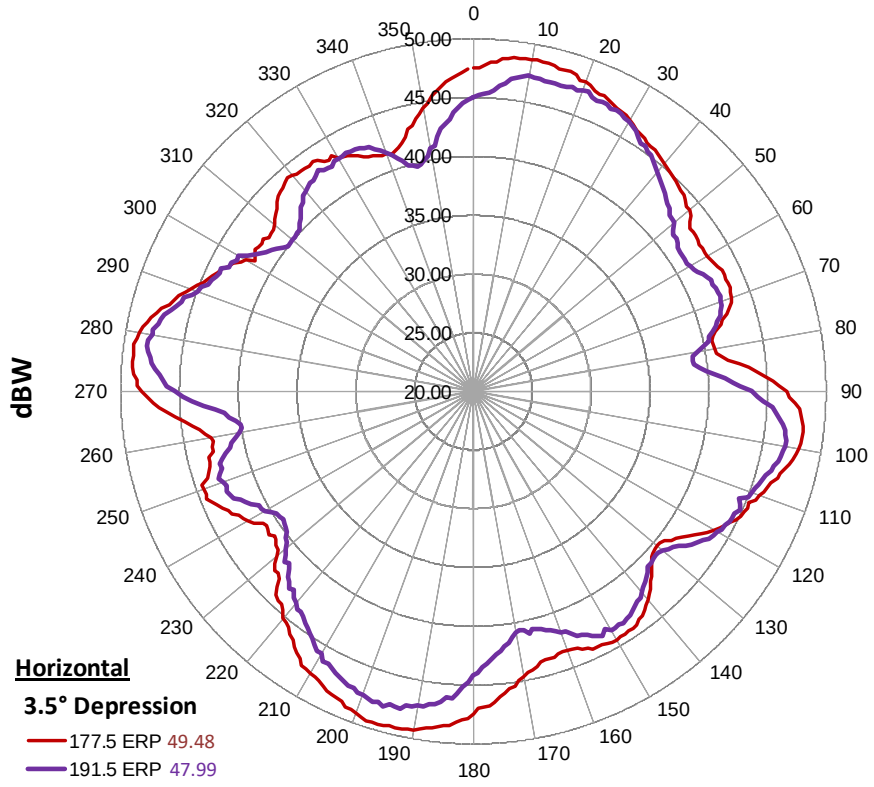
Azimuth	Plot Type		Service	Results (BeamTilt/ERP)	Plot Number & Page
21° FACE A	H-Pol	Normalised (to self)	177.5 MHz 191.5 MHz	3.1° 4.0°	Plot 3 Page 9 Plot 4 Page 9
		ERP	177.5 MHz 191.5 MHz	47.3 dBW 46.7 dBW	
111° FACE B	H-Pol	Normalised (to self)	177.5 MHz 191.5 MHz	3.3° 3.2°	Plot 5 Page 10 Plot 6 Page 10
		ERP	177.5 MHz 191.5 MHz	47.7 dBW 46.6 dBW	
201° FACE C	H-Pol	Normalised (to self)	177.5 MHz 191.5 MHz	2.7° 3.9°	Plot 7 Page 11 Plot 8 Page 11
		ERP	177.5 MHz 191.5 MHz	48.4 dBW 46.6 dBW	
291° FACE D	H-Pol	Normalised (to self)	177.5 MHz 191.5 MHz	2.6° 2.5°	Plot 9 Page 12 Plot 10 Page 12
		ERP	177.5 MHz 191.5 MHz	47.5 dBW 46.7 dBW	

No Smoothing has been applied to the data.

Horizontal Radiation Patterns

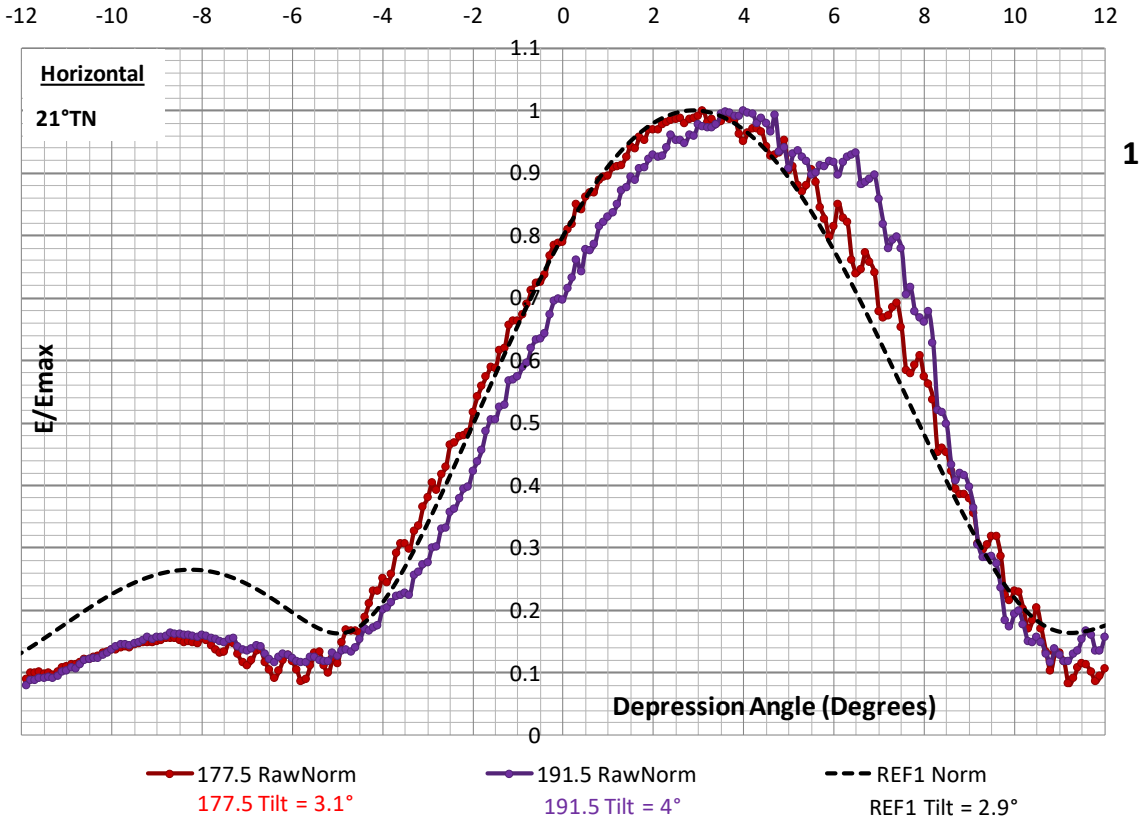


Plot 1: Normalised

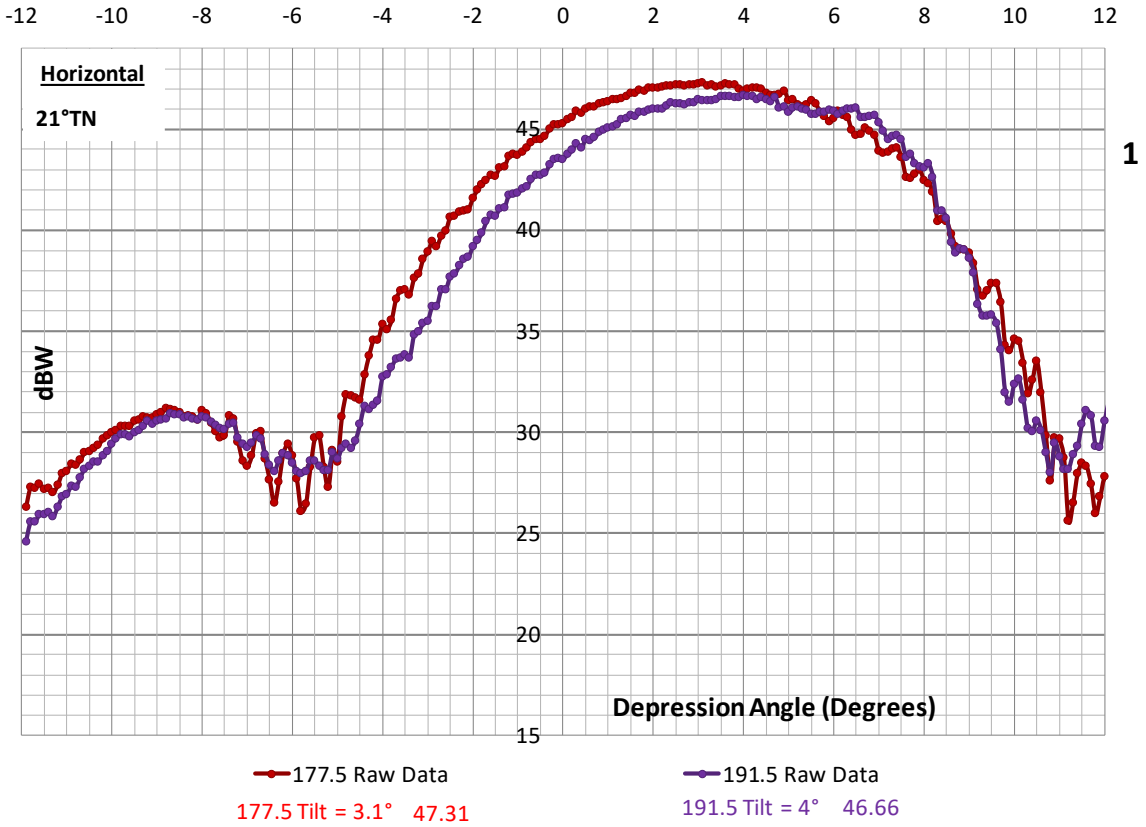


Plot 2 ERP (dBW)

Vertical Radiation Patterns – Face A

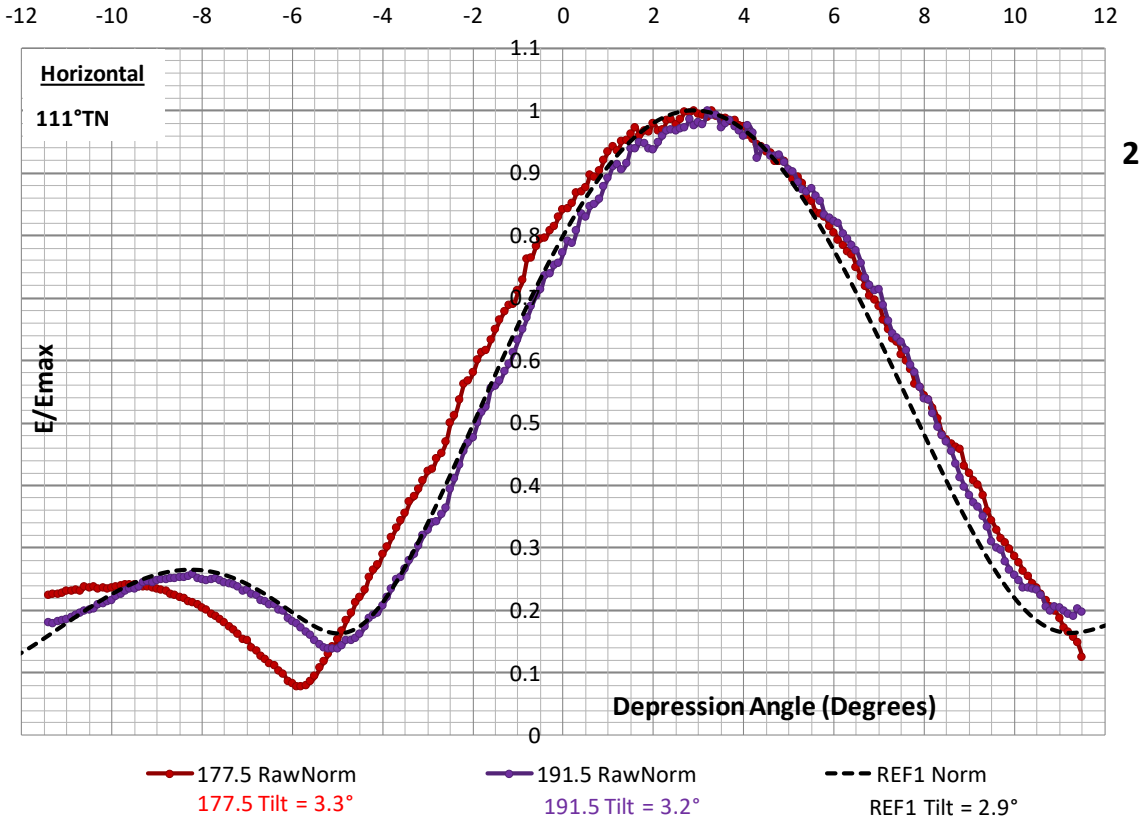


Plot 3: Normalised

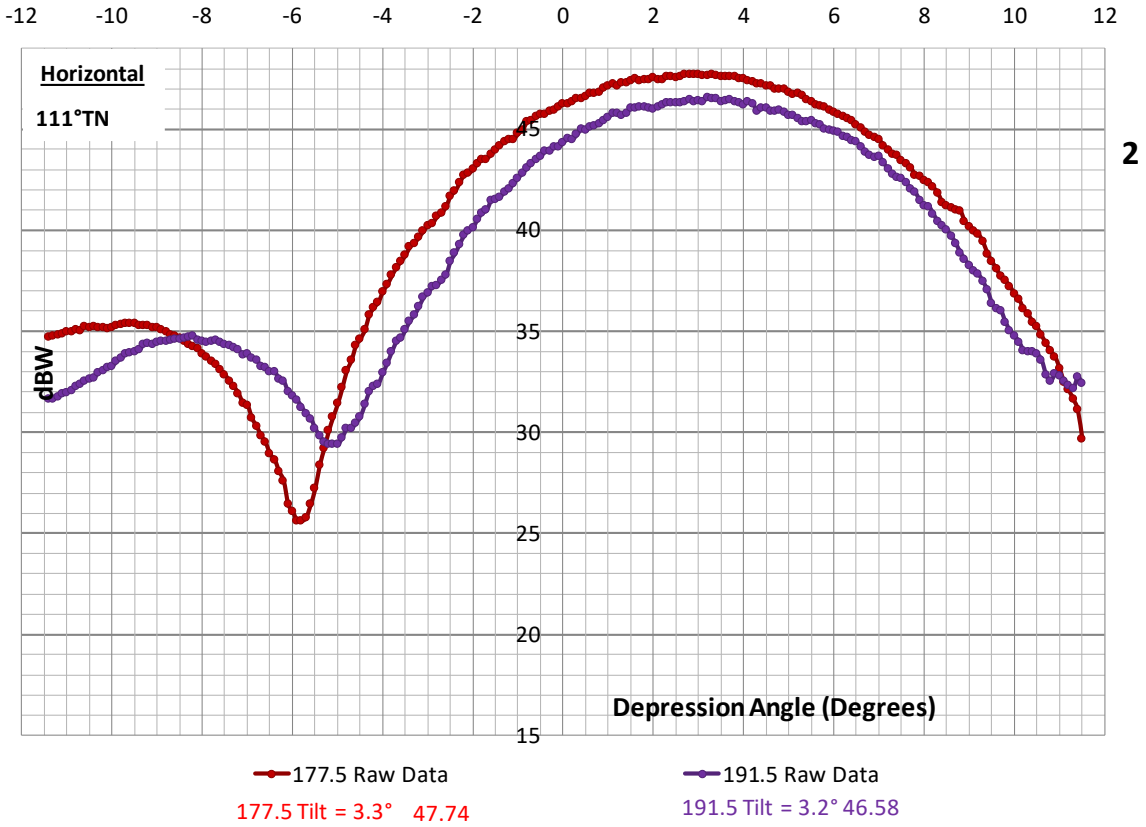


Plot 4 ERP (dBW)

Vertical Radiation Patterns – Face B

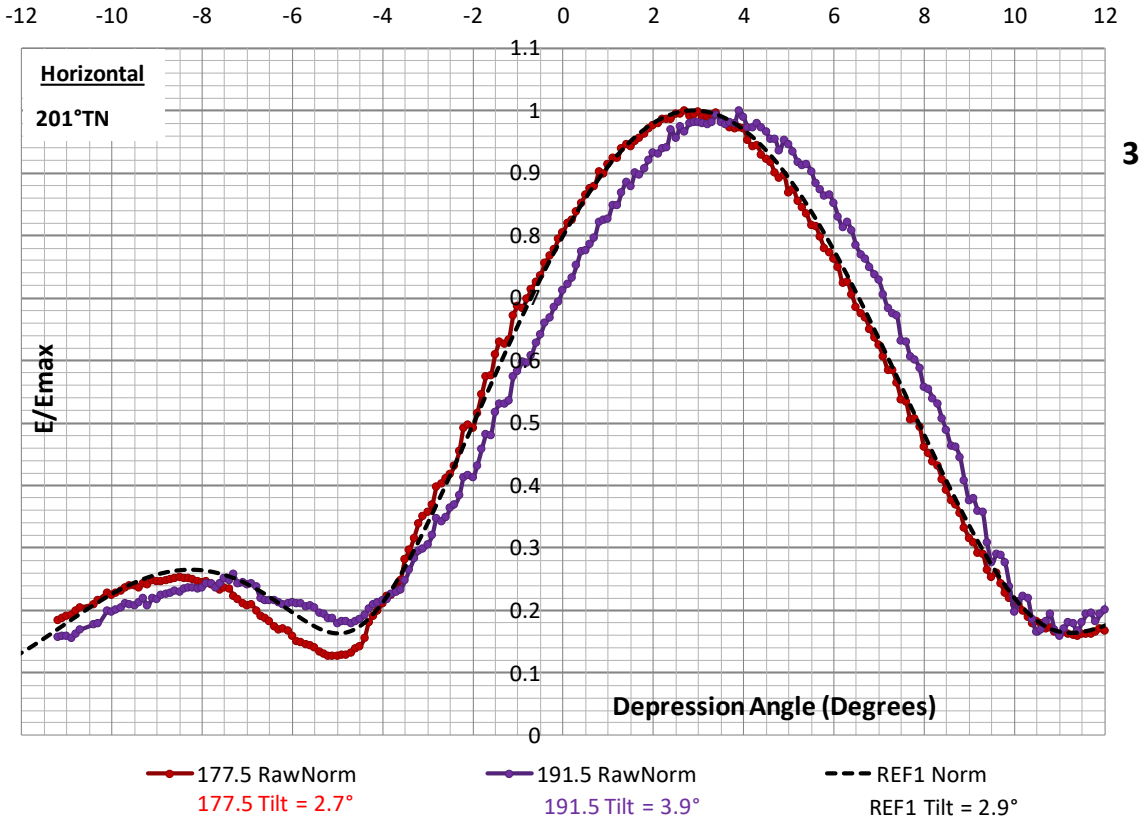


Plot 5: Normalised

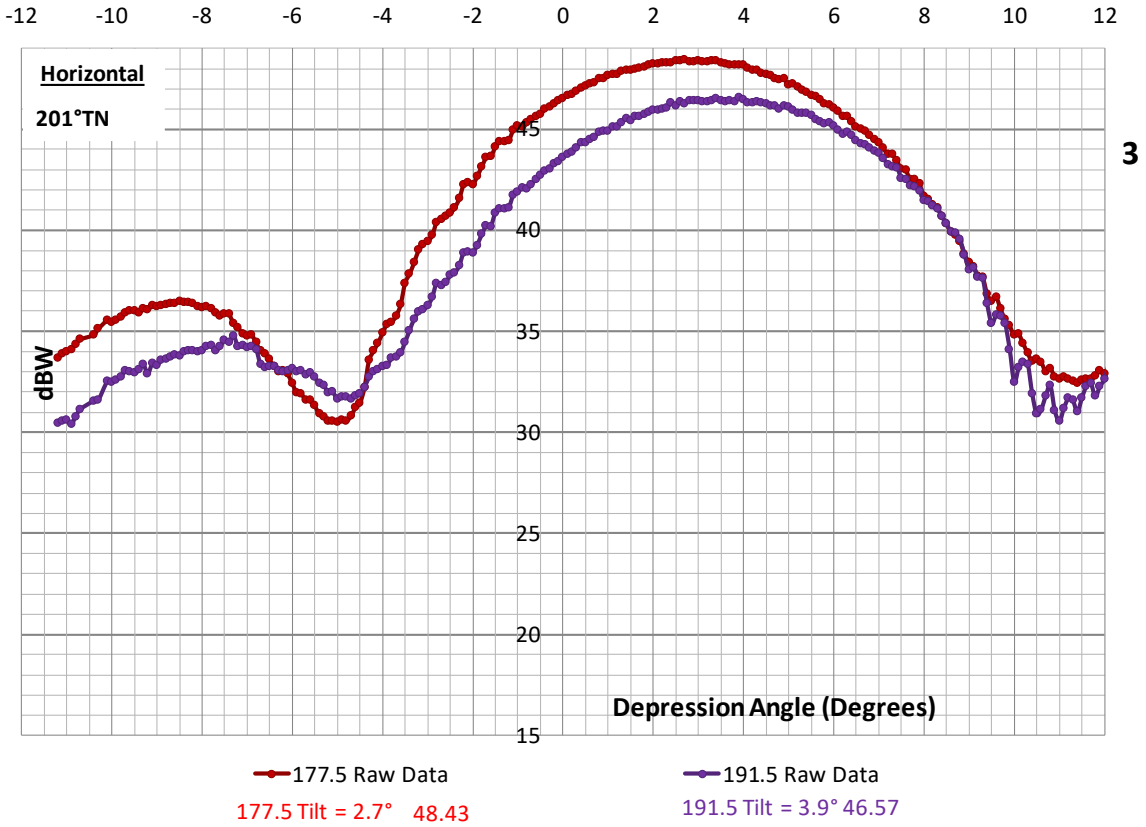


Plot 6 ERP (dBW)

Vertical Radiation Patterns – Face C

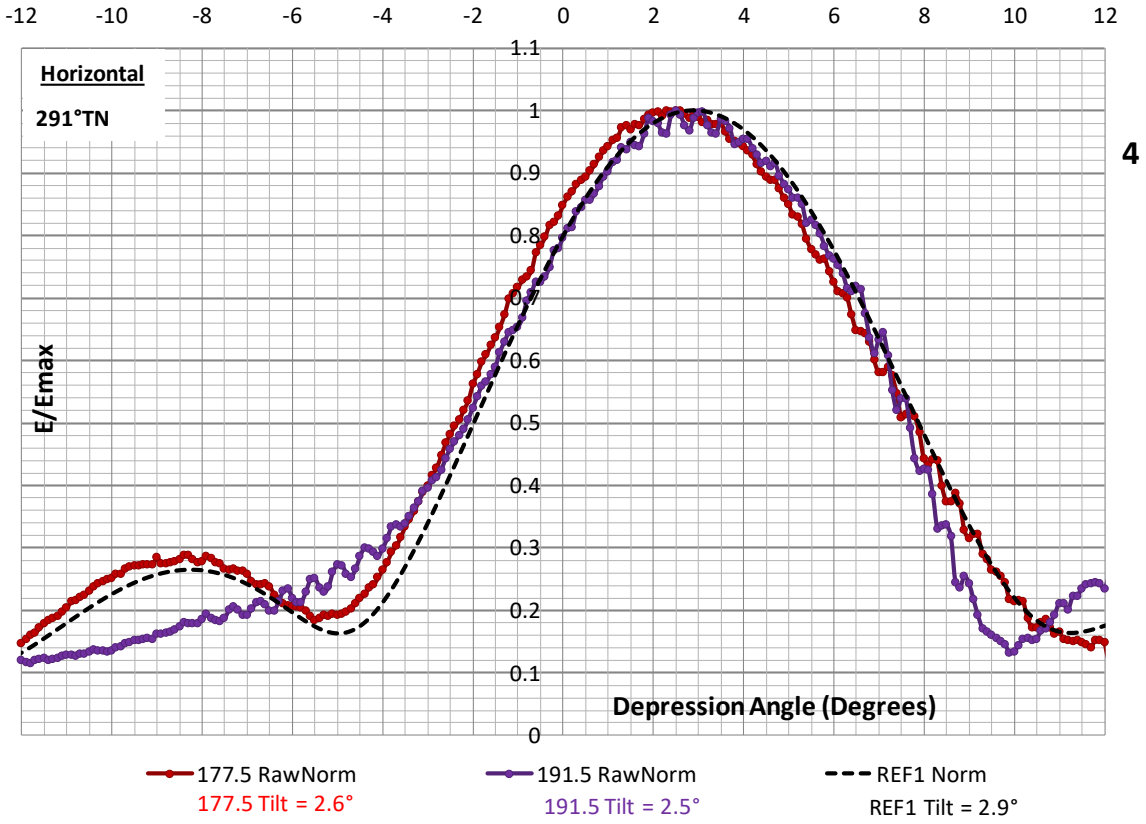


Plot 7: Normalised

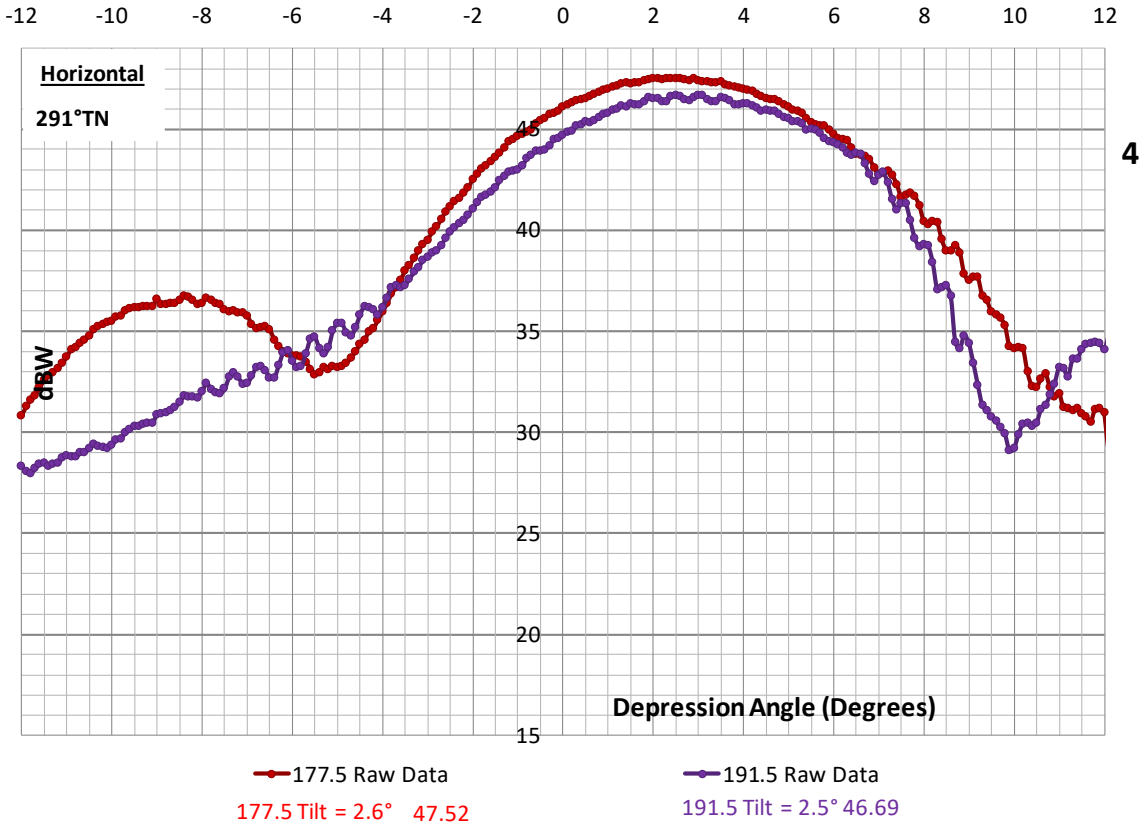


Plot 8 ERP (dBW)

Vertical Radiation Patterns – Face D



Plot 9: Normalised



Plot 10 ERP (dBW)

4/ CONCLUSIONS

The following conclusions can be drawn from the Mt Sample VHF TV 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 reduced width of eastern and western lobes
- Face A measured VRP shows minor variations below 6°depression.
- The measured VRPs for all Faces also agree well with the designed pattern (within 0.5˚), except for Face A and Face C - The beamtilt for 191.5MHz differs by greater than 1˚ from the designed beamtilt
- Maximum ERP values were measured to be 49.5dBW and 48dBW (licensed is 50dBW)

The antenna has been observed to be operating closely to the designed HRP and VRP.

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)			
Sample Site	-xx.xxxxxx° yyy.yyyyyy°	6 7	177.5 191.5	1249	104.1	Face A =21°TN Face B =111°TN Face C =201°TN Face D =291°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)
177.5 MHz	2.76	13.05	0.2	39.7	5.9	46.09
191.5 MHz	3.36	13.71	0.2	39.7	5.9	46.15

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

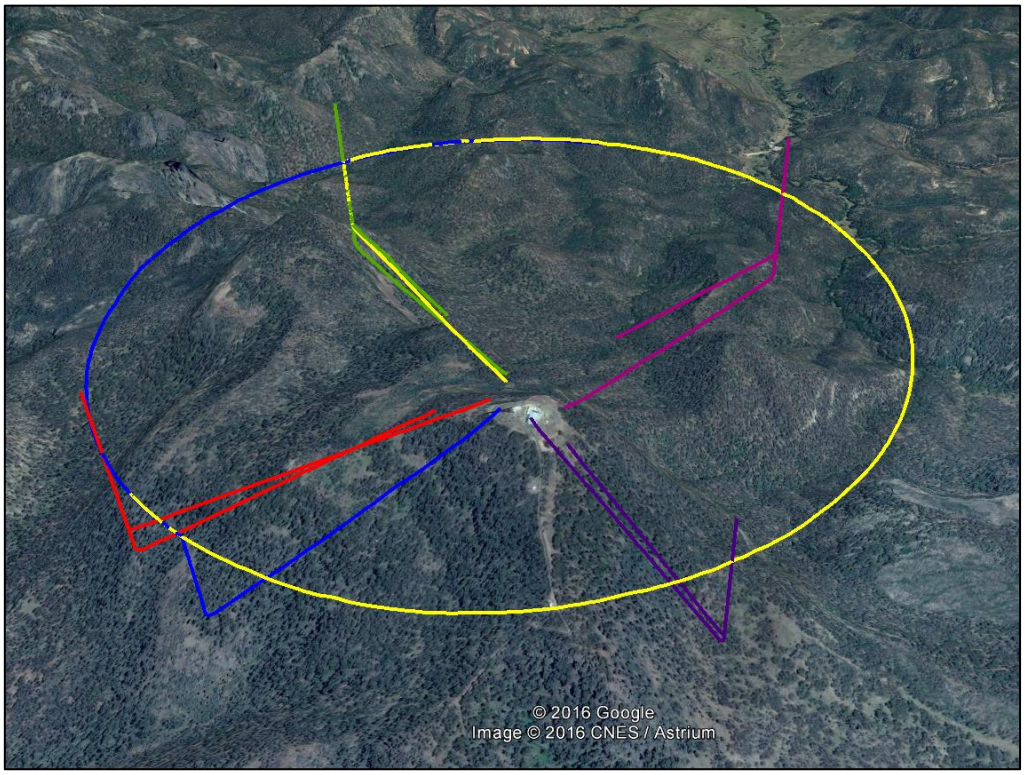
	Serial	Calibration/Verification Date
Unmanned Aerial Vehicle	#Franky	N/A
Receiver System	#32950324	06/01/2016
Antenna System	#VHFLP02	26/12/2016
1m LCU195 Cable	#LCU195-1m	10/6/2016
Attenuation	#1237 &#0839	10/6/2016

TV Measurement System

ACTUAL FLIGHT PROFILES

The following flight profiles were used:

Type	Azimuth	Distance from Site	Depression Angle
VRP	21°	370m	12 to -12
	111°	370m	12 to -12
	201°	370m	12 to -12
	291	370m	12 to -12
HRP	Full	370m	3.5°



Actual Flight Paths (mapped in Google Earth) -HRP and all VRPs

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	dB	Rectangular	1.0	√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**