Real World Results from a Signal Measurement Drone

Presented by Ian Gair

SixArms

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Outline of this Presentation

SIXARMS
MEASURING RF
"500kHz TO 6GHz"

What we are measuring

Quick recap of Drone Based measurements

Case Studies:

1) Main feeders cut to the wrong lengths
2) Mechanical lean – storm damage
3) Panel Orientation incorrect
4) Inverted Panel
5) Adjacent tower or structure effects
6) Measuring in the near field

What are we measuring

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Broadcast TV Antennas mounted on towers or masts.

Typical Broadcast Antenna

High Power – can be several MegaWatts Radiated Power

High EMR levels – personnel and equipment can't get close

High gain

Antenna split into an Upper and Lower Half for redundancy reasons – 2 main feeders needed

Narrow vertical beamwidths

Typically 4 faces of 12 panels with each panel having 4 horizontal dipoles = 48 elements on 4 faces giving 192 dipoles.

Typically 50 feet high and 600 feet above the ground

What could go wrong?

What & why are we measuring

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- We need to measure antennas radiated power to verify they are operating as they were designed to.
- Antennas transmit power in all directions, ie 3D
- Measuring a horizontal slice and vertical slice gives us a very good picture of the power level and direction
- These slices are called the Horizontal Radiation Pattern (HRP) and Vertical radiation Pattern (VRP)

Typical EME levels extend out to 1000 feet

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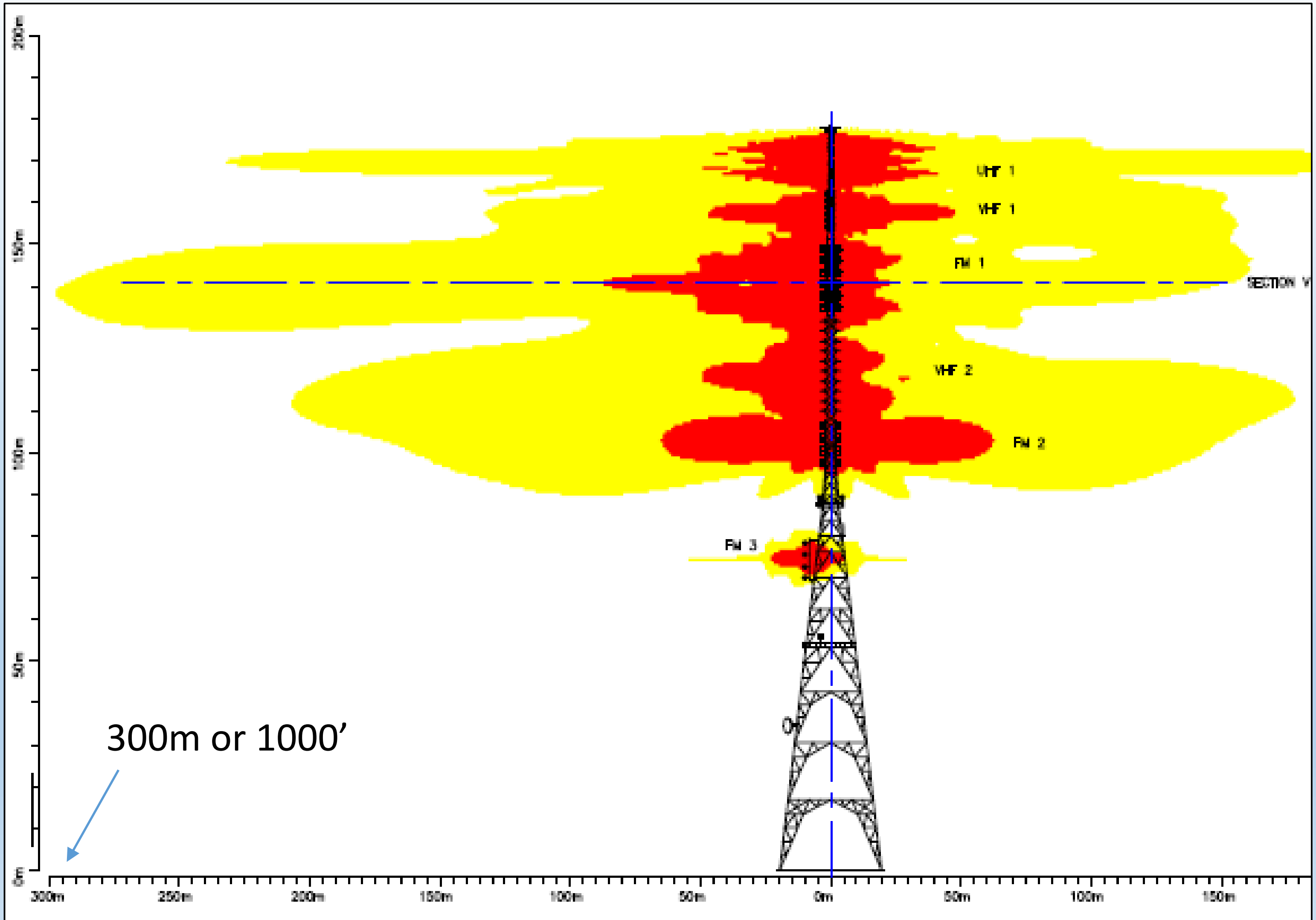

Example of a VRP

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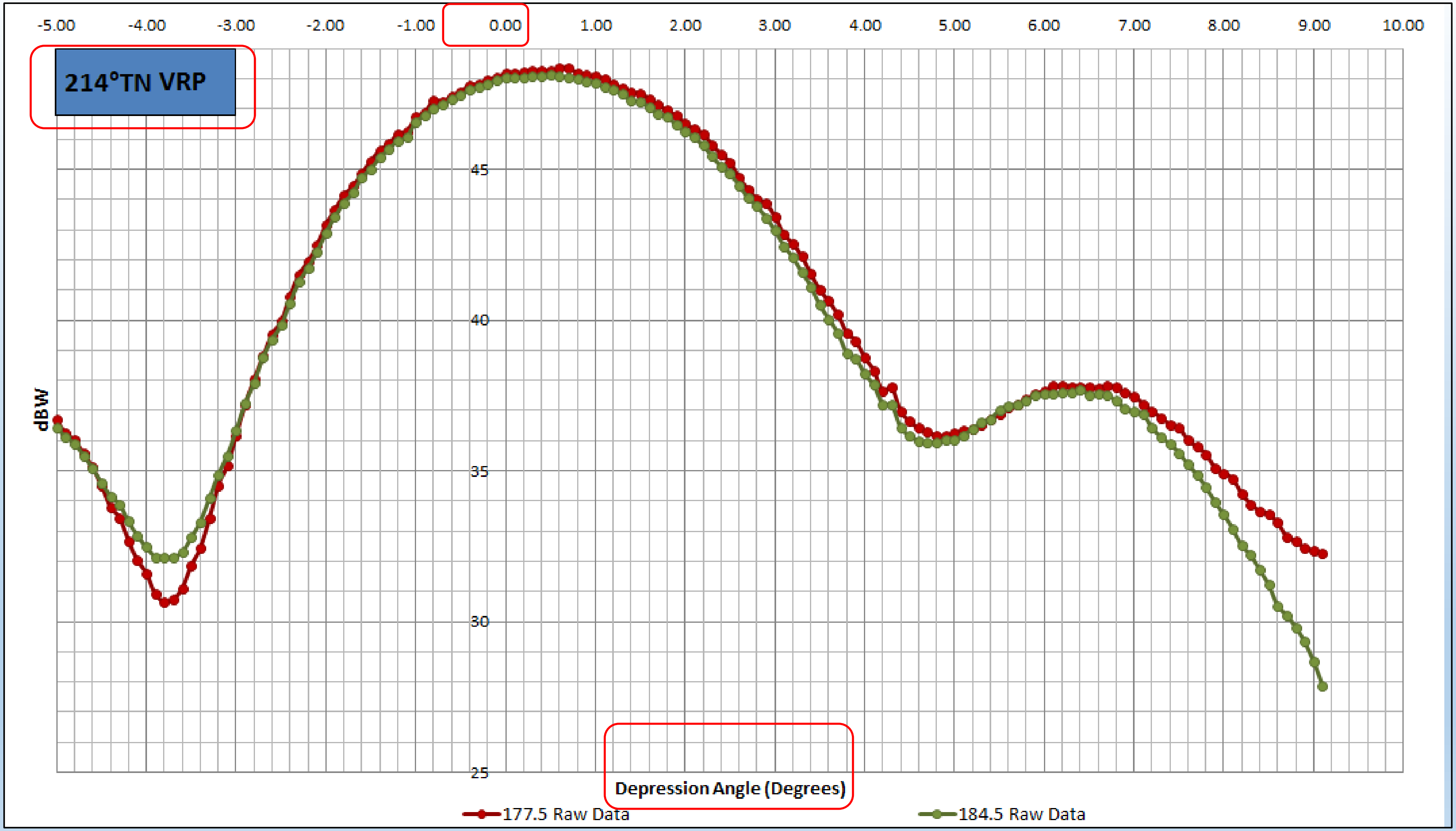
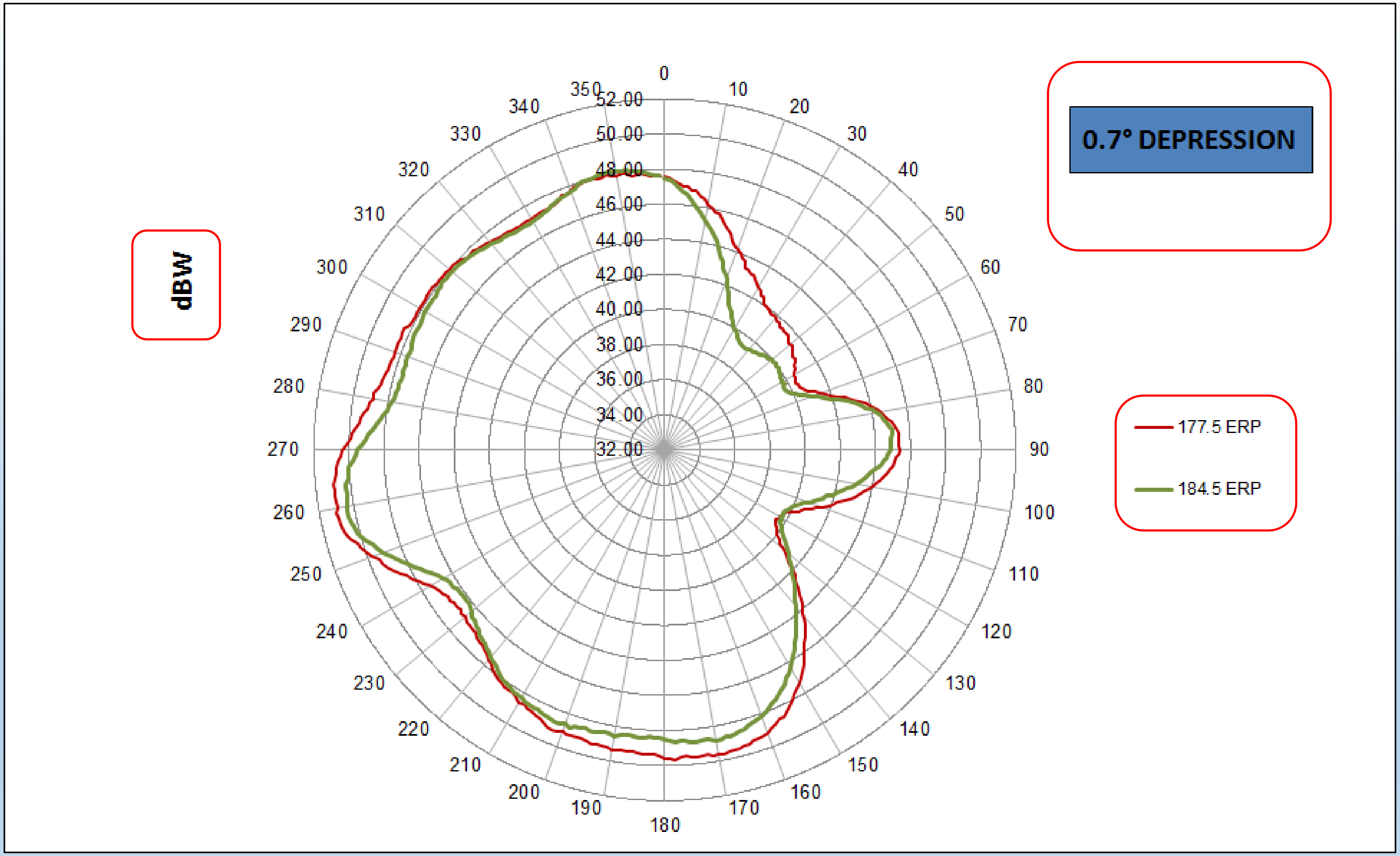


Example of an HRP



Measurement technique

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Hardware consists of:

- UAV with antenna
- Integrated Spectrum Analyser and PC
- High Resolution GPS
- Telemetry to GCS

- Pre-flight Software - flight path – pre-programs the drones auto pilot with the appropriate flight path for the specific antenna
- Software driven capture, display and logging of data

Airborne Measuring Software

Other than data logging the software:

- Discards invalid data – due to excessive yaw, pitch or roll. The drone measuring antenna needs to point to at the Antenna Under Test (AUT)
- Calculates the distance between drone and AUT
- Calculates pathloss and applies correction and calibration factors
- Determines the absolute power and plots it on a results template
- Gives Preliminary results are available to the operator live via the link to the ground station

Methodology (1 of 2)

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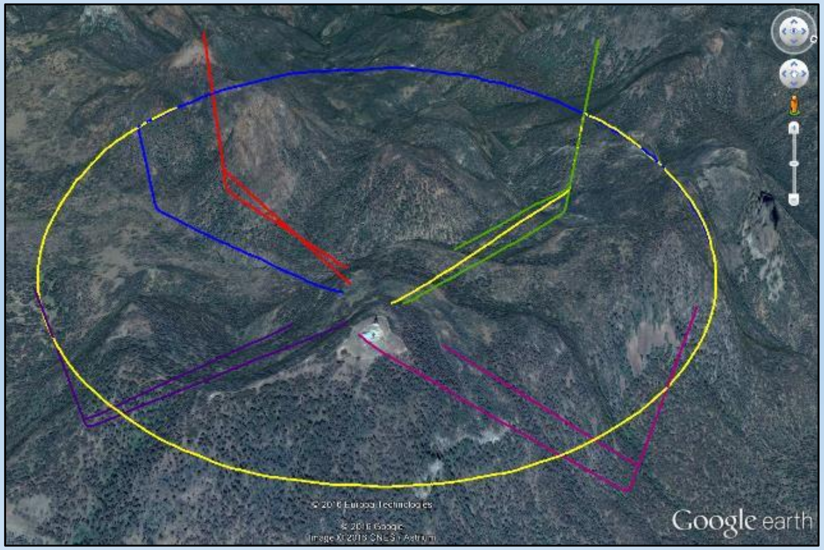
- Determine the position of the Antenna Under Test (AUT) accurately
  - GPS location and height above mean seal level.
- Determine the height of the AUT
  - Use a Theodolite or tower drawings
- Determine the far field distance (>2D^2/lamda)
  - As a rule of thumb with large arrays for FM 450 feet, VHF TV 1200 feet and UHF 1800 feet from the antenna
- Program the VRP runs –
  - one per face of panels (typically 4 faces)
  - over a range of 10 degrees above to below the horizon but as low as practical

Methodology (2 of 2)

- Fly the VRP runs in the far field and
- determine the angle of peak power (typically 1 degree below the horizon)
- Fly an HRP run in the far field at the angle of peak power (typically 1 degree below the horizon)



Typical Accuracy

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Absolute is ±2.0 dB
Relative is better at ±1.3 dB

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, $u_c = \sqrt{\Sigma(u_i^2)}$						1.003
Coverage factor, k						2 (95% CI)
Expanded Uncertainty, $U = k \times u_c$						**±2.0 dB**

Case Study 1 - Main feeders cut to the wrong length

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Most large antenna systems have 2 or 4 feeders from the transmitter to the antenna for redundancy reasons.

Antennas are separated in halves or quarters each with it's own feeder.

The relative length of these feeders is critical.

Incorrect lengths will result in beam tilt up or down.

VRP will show this, with same effect will be seen on all faces.

Case Study 1 - Main feeders cut to the wrong length

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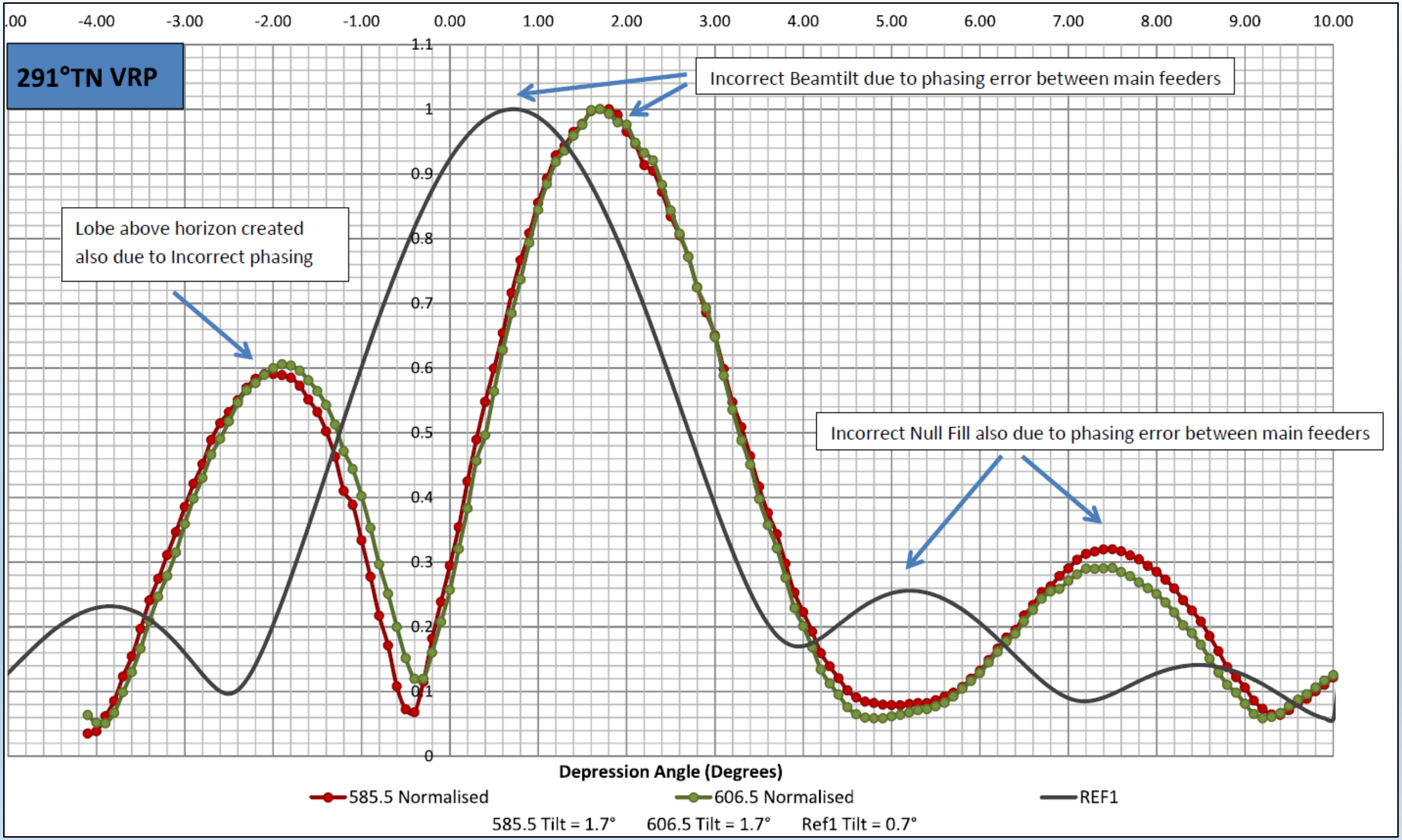

Case Study 2 - Mechanical lean storm damage

Large UHF TV arrays have a small vertical beam width

Less than 2 degrees typically

A small mechanical lean or “banana-ing” can result in excessive uptilt on one side and down tilt on the other.

Rigging teams may not pick up the small deflection

Theodolites may not detect it if the antenna is housed inside a protective radome.

VRP measurement will show the problem.

Case Study 2 - Mechanical lean storm damage

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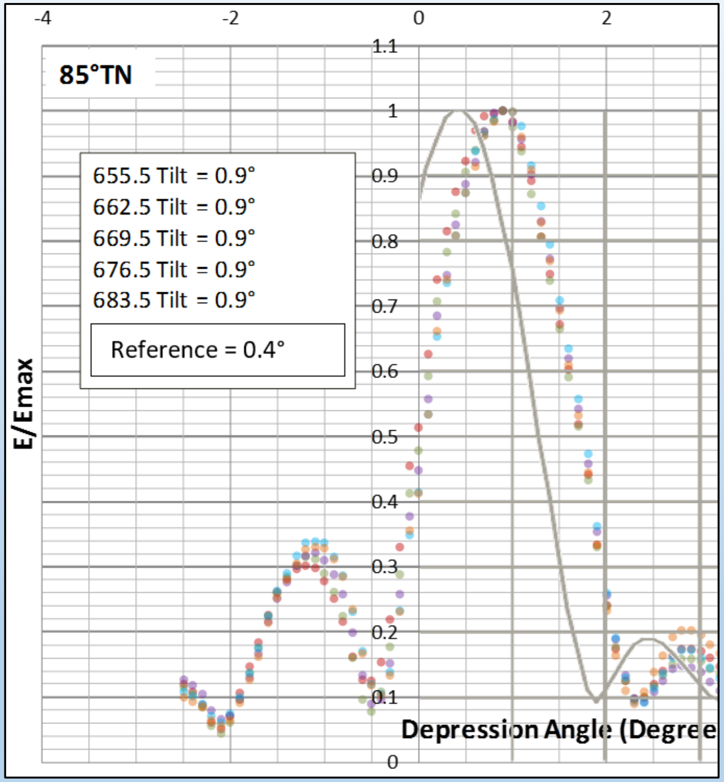

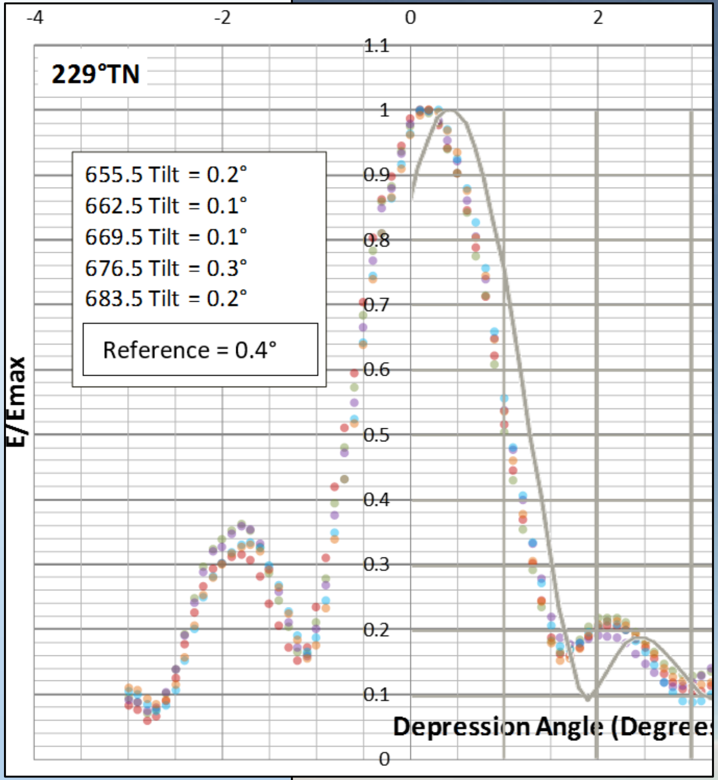

Case Study 3 - Panel Orientation incorrect

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Large UHF antennas can consist of dozens of panels on multiple faces.

Occasionally during installation an error can occur

Panels can be installed on the incorrect bearing

The HRP will show this.

Case Study 3 - Panel Orientation incorrect

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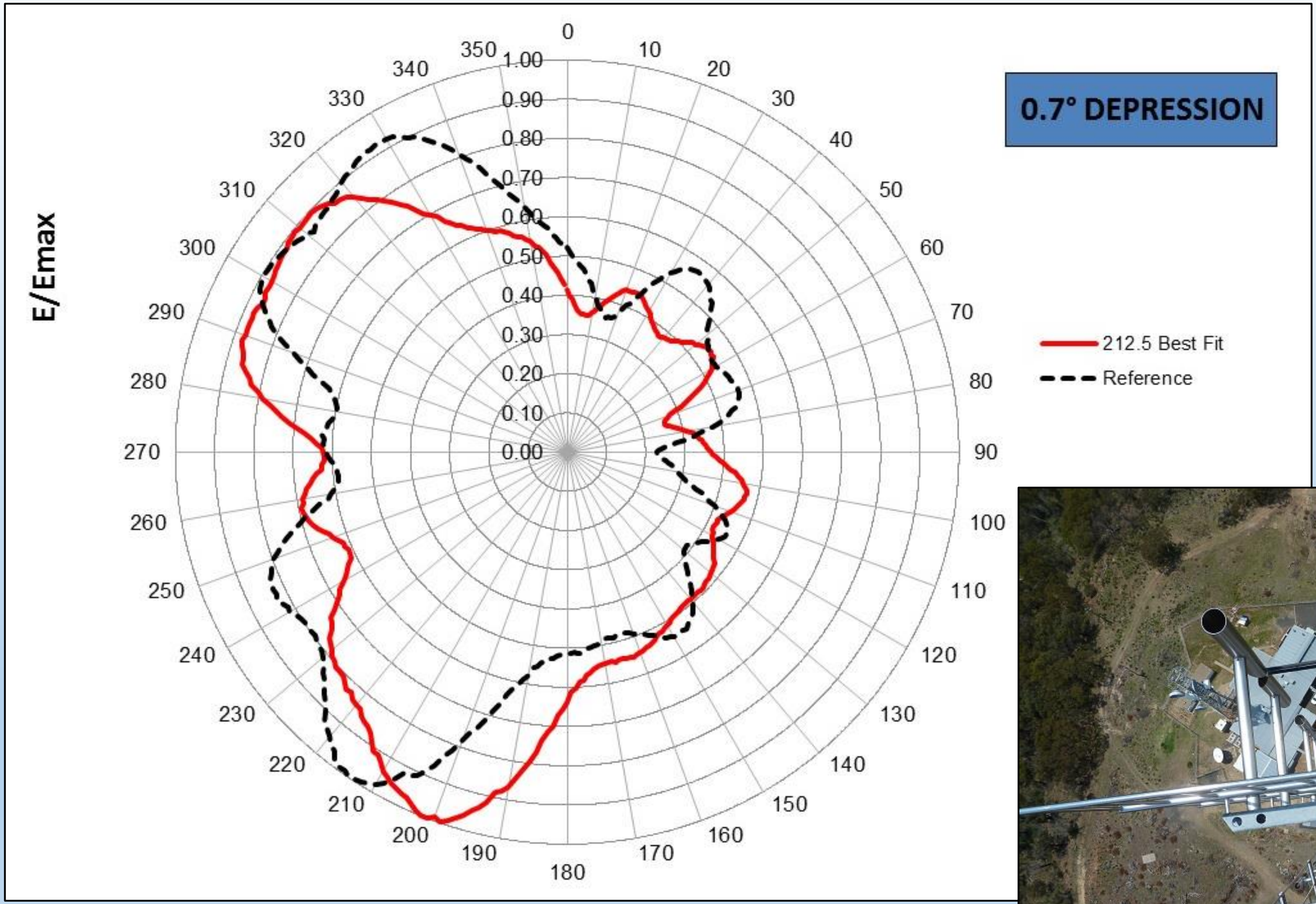

Case Study 4 – Inverted Panel

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Large UHF/VHF antennas can consist of dozens of panels on multiple faces.

Occasionally during installation an error can occur

Panels can be inverted (upside down).

The HRP and the VRP of the affected face will show this

Case Study 4 – Inverted Panel

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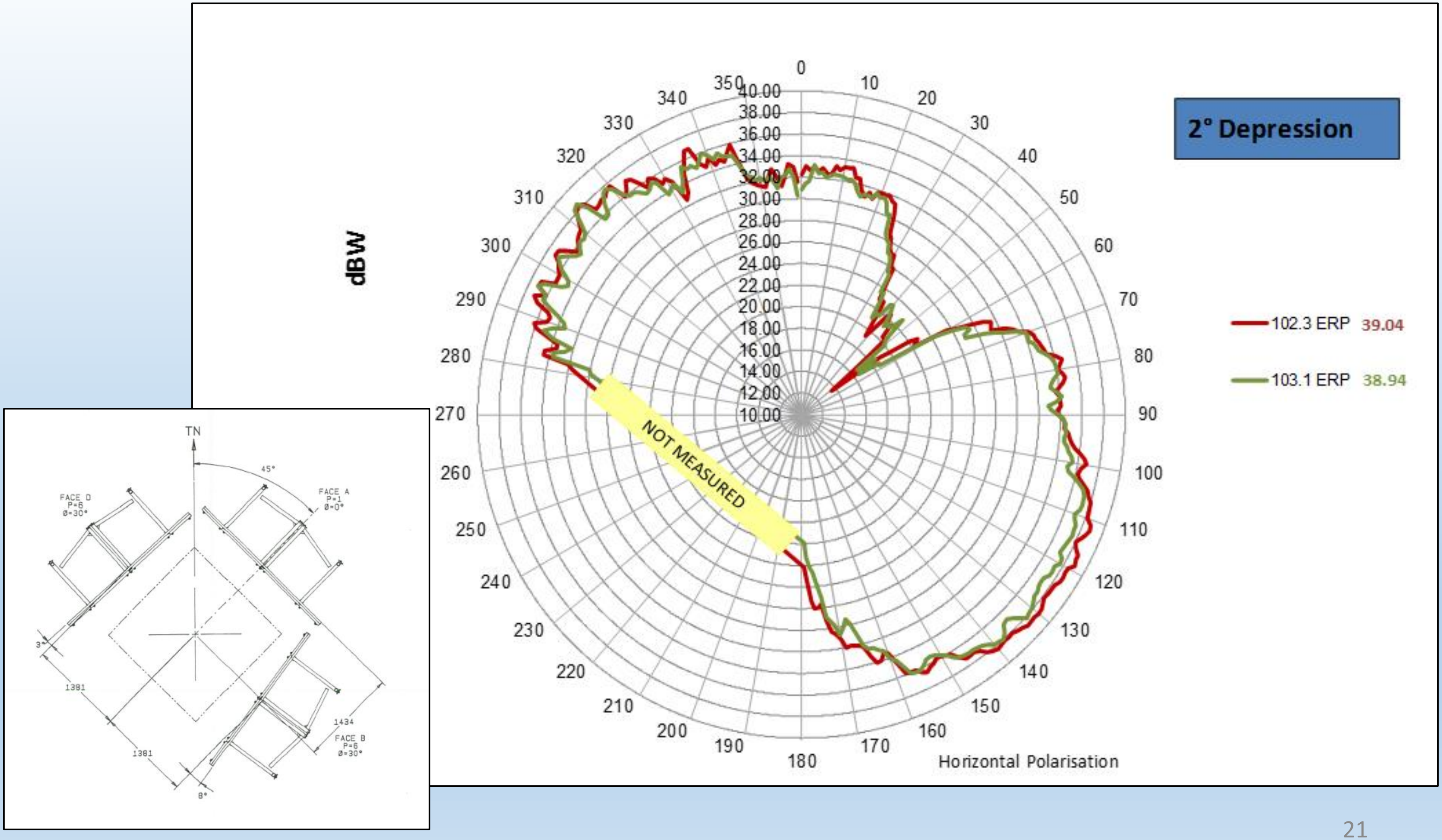

Case Study 5 – Adjacent tower or structure effects

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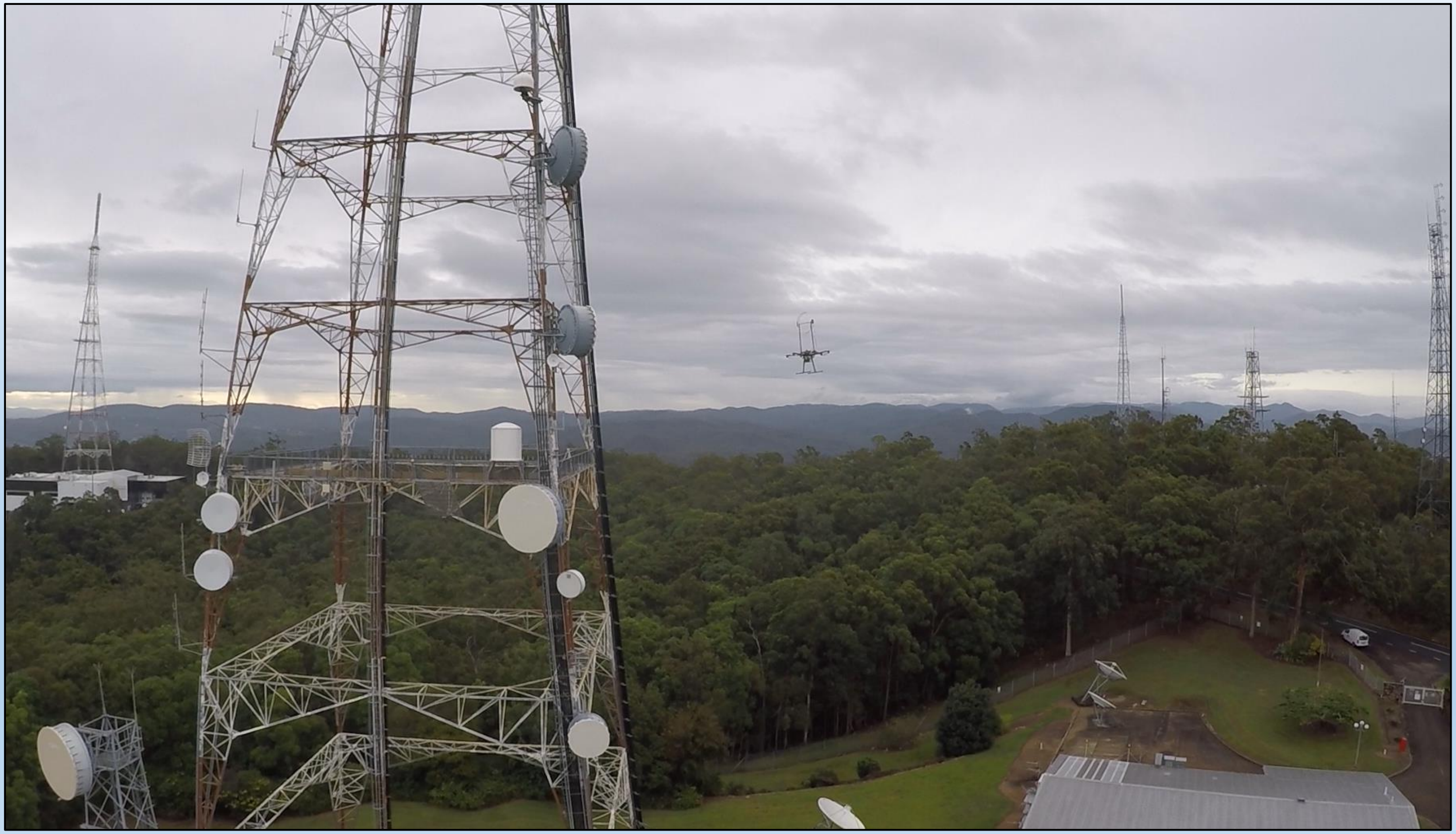
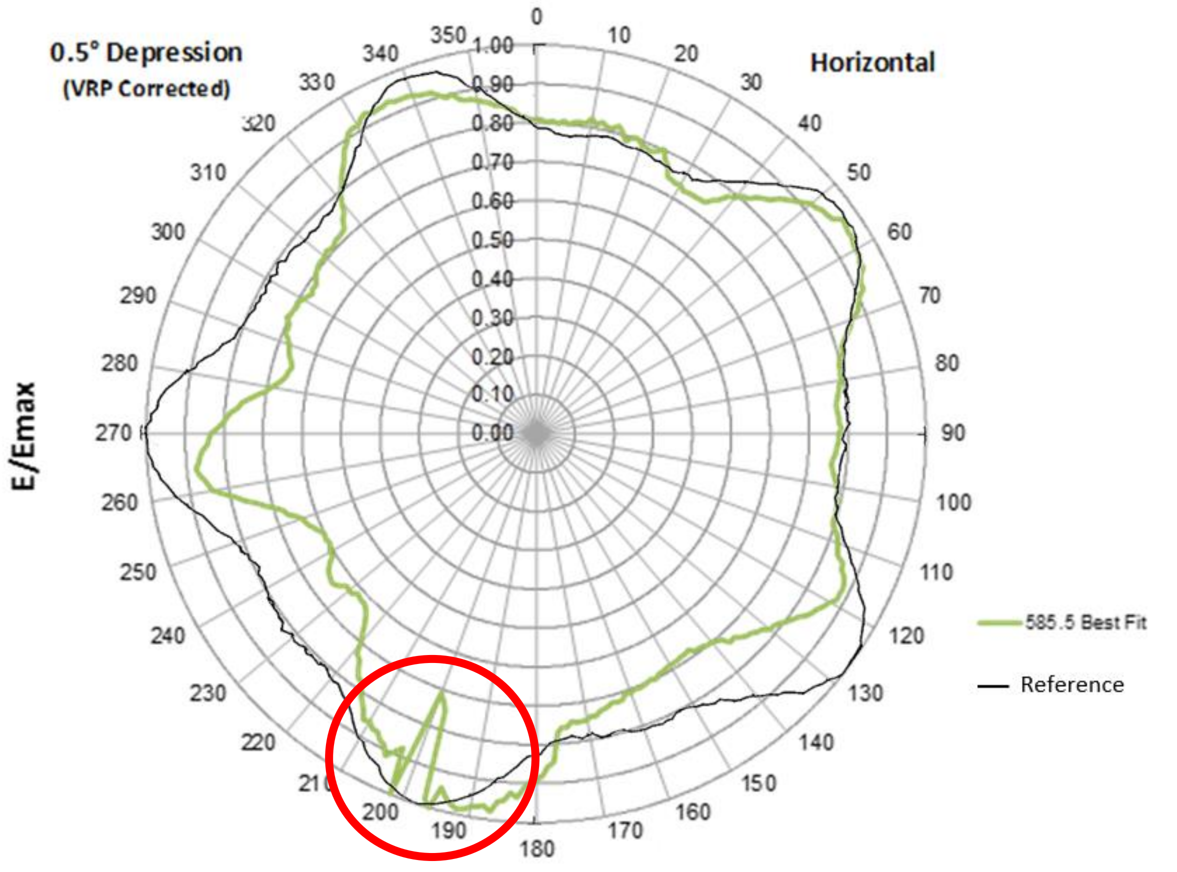
Other nearby structures affect the antenna pattern



Case Study 5 – Adjacent tower or structure effects



Plot 2 Normalised (E/EMAX)

- 5 sided array
- Black trace is the design
- Green trace is measured
- Adjacent tower (650 feet away) at 200 degress puts in a 3dB notch

Case Study 5 – Adjacent tower or structure effects

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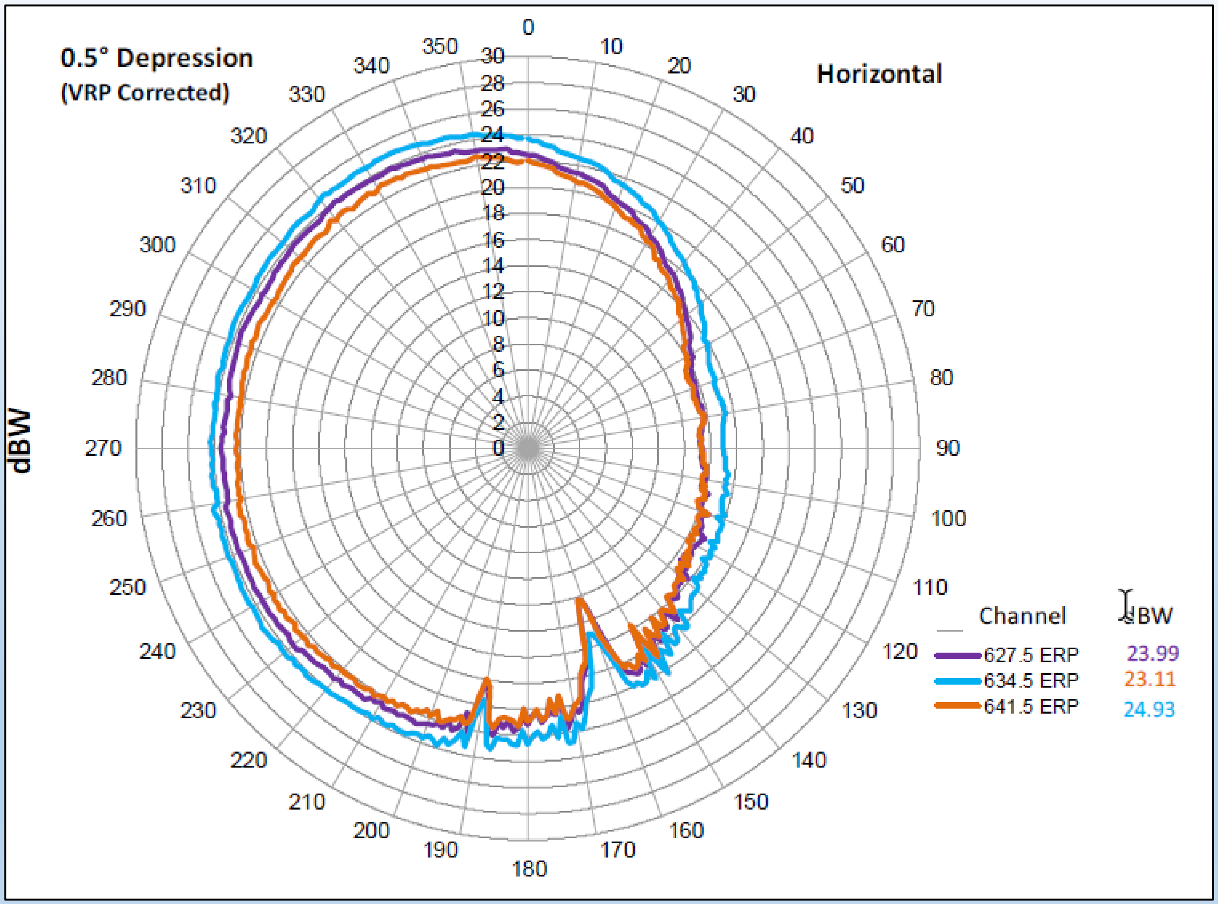

- Red and Blue traces are measured
- Adjacent structures at 160 Degrees (170 feet away) and 190 Degrees (540 feet away)
- 7dB and 4dB notches

Case Study 5 – Adjacent tower or structure effects

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What would the patterns of some these look like?

Case Study 6 – Measuring in the near field

We measure the electric field to derive the power

This is accurate enough when in the far field but sometimes due to restrictions we can't fly in the far field.

Flying inside the near field gives a wider arc of the VRP but less accurate magnitude.

- Antenna – 4 faces of 16 panels.
- Frequency – 662.5MHz
- Far field distance using 2D^2/lamda is 1,400m (4,600 ft)
- Plot below shows results at 300m (1,000 ft), 600m (2,000 ft), 1,150m (3,800 ft) and 1,600m (5,250 ft).

Case Study 6 – Measuring in the near field

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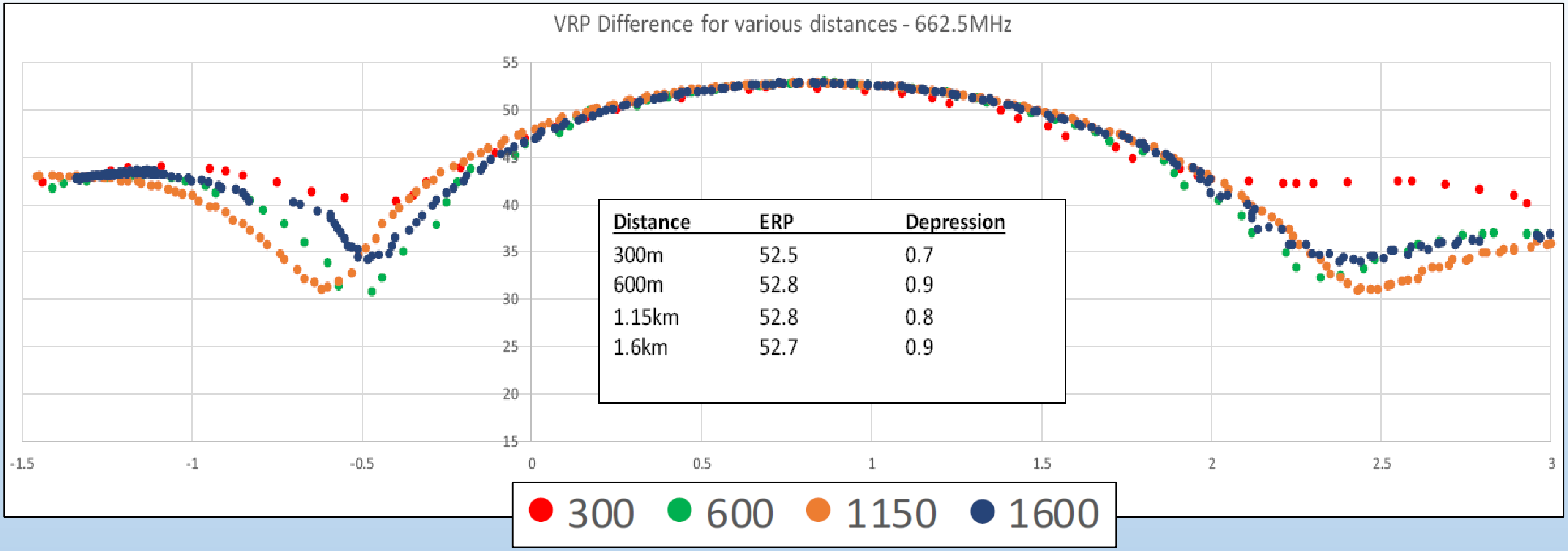

Distance	ERP	Depression
300m	52.5	0.7
600m	52.8	0.9
1.15km	52.8	0.8
1.6km	52.7	0.9

In this case we can say that with a Far Field distance of 1,400m (4,600 ft), measurements at 600m (2,000 ft) from the antenna still provide meaningful results.

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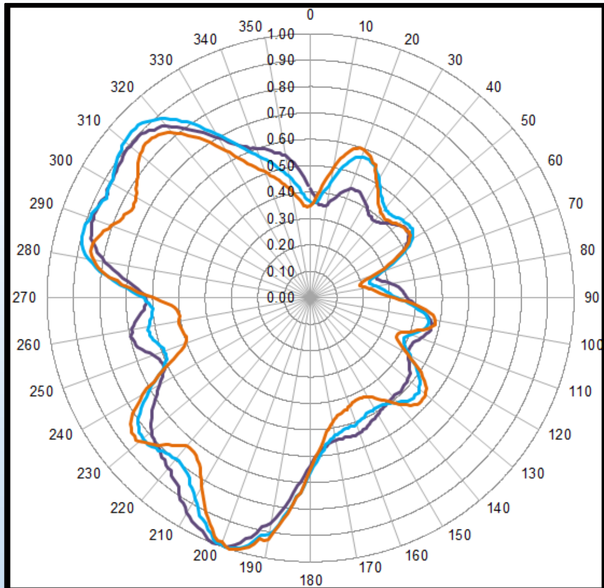
Any Questions?



And for more information go to:

www.sixarms.com

Or contact:

Ian Gair

Director / RF Engineer
Sixarms Pty. Ltd.
m: +61 417 402 767
e: ian@sixarms.com