Drone-based Techniques to Rapidly Characterize Broadcast Antenna Systems and Coverage

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***Abstract*—This paper presents results of using a drone-based measurement system to verify actual in-situ antenna radiation patterns for diagnosis and comparison to the intended design. This specific antenna verification solution uses an unmanned aerial vehicle (UAV) with integrated antenna, receiver and software. Measurements are taken in the far-field of 'live' existing high-powered broadcast systems in order to retrieve the horizontal radiation pattern (HRP), vertical radiation pattern (VRP) and the absolute effective radiated power (ERP) for each service under measurement. Results show greater accuracy, timeliness and cost efficiency compared to traditional measurement techniques (i.e. land-based or manned aircraft based surveys) due to advances in positional accuracy, receiver resolutions and portability. Discrepancies between measured and theoretical patterns outline the potential for installation or manufacturer errors (e.g. incorrect feeder phasing). Use of this solution will enable government regulators, telecommunication network operators, broadcast integrators, infrastructure owners and defense communication/radar operators to verify and troubleshoot their antenna systems. Correcting any errors in operation allows for improved service reception, increased signal coverage and improved data reliability.**

I. Introduction

Measurements of large broadcast antenna systems have always been either a logistically difficult land-based activity or an expensive manned aircraft exercise. There is a need to characterize and understand the performance of these systems in order to maximise the intended broadcast coverage area. Poor coverage performance is usually as a result of installation or manufacturer error which affects the horizontal radiation pattern (HRP – at a fixed height around the antenna), vertical radiation pattern (VRP – as a function of relative height) and the effective radiated power (ERP) transmitted. Installation errors can occur due to the design complexity of many of these antenna systems.

Often errors in feeder phasing, orientation, incorrect power divider splits and physical antenna verticality can produce undesirable antenna pattern effects, all of which degrade the performance of the system. The use of a land-based measurement system does not offer the accuracy and efficiency of airborne-based measurement systems. Appropriate land-based measurement locations are often constrained by local terrain and vehicle access. Airborne measurement systems using manned aircraft (e.g. helicopters) [1] provides an alternative solution. However, the cost of charter flights and necessary antenna mounting certifications lowers the affordability of this solution.

Fig. 1. Typical high-powered broadcast antenna systems *(left)* and Traditional measurement techniques (helicopter, portable mast and vehicle based mast).

The evolution of unmanned aerial vehicle (UAV) technology as well as the miniaturisation of effective portable spectrum analysers and measurement receivers, allows for a more efficient, more accurate and cost-effective solution to be realized.

II. UAV Broadcast Measurement Solution

Verification of these broadcast antenna systems has been achieved by using the Sixarms ARMS (Airborne Radio Measurement System) UAV depicted in Fig. 2 and Antenna Measurement Studio (software).

Fig. 2. ARMS Measurement Platform

The unit flies autonomous pre-programmed flight paths as shown in Fig. 3 around the antenna under test, sending live feedback to the operator showing the measured antenna pattern. Reports are generated automatically to help rapidly identify any areas of concern by showing the measured patterns and output power.

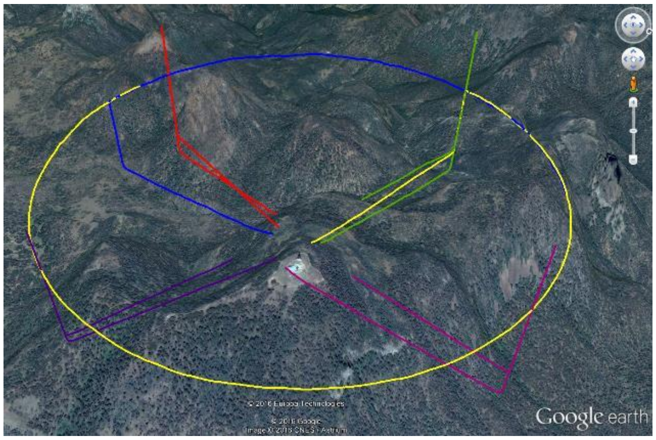

Fig. 3. Example Flight Paths

III. Real Life Measurement Results

Use of the ARMS UAVs to verify the antenna patterns and coverage of high-powered broadcast systems has been proven to significantly lower the time and costs associated with trying to characterize an antenna system. Full antenna characterization is now possible. Below are some real world measured case studies.

A. *Operating as per Designed*

The measured antenna pattern and effective radiated power (ERP) compared to the manufacturers designed pattern are deemed to have insignificant differences. Both the vertical radiation patterns and the horizontal radiation patterns are measured per antenna polarisation. This means circular and mixed polarisations can still be compared to the antenna manufacturers designs.

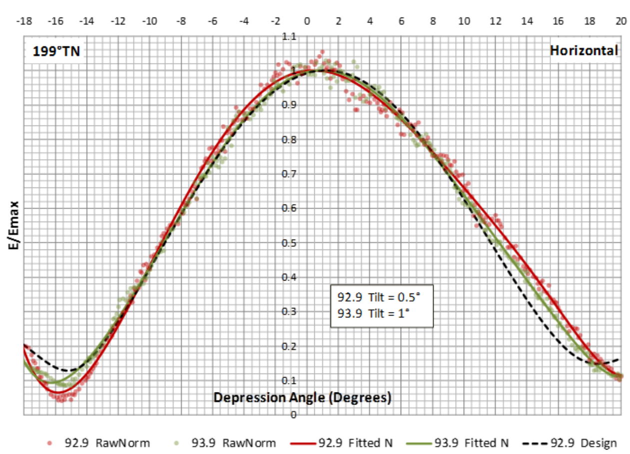

Fig. 4. VRP results showing no issues between the designed (black dashed) and measured patterns (coloured).

B. *Incorrect Feeder Phasing*

Most large antenna systems will have two to four main feeders from the transmitter/combiner to the antenna for redundancy reasons. Antennas are separated into halves or quarters each with its own feeder. The relative length of these feeders is critical and incorrect lengths (phasing) will impact on the up-tilt or down-tilt of the main beam. UAV based measurements of the full antenna and separate halves/quarters is now easily achieved.

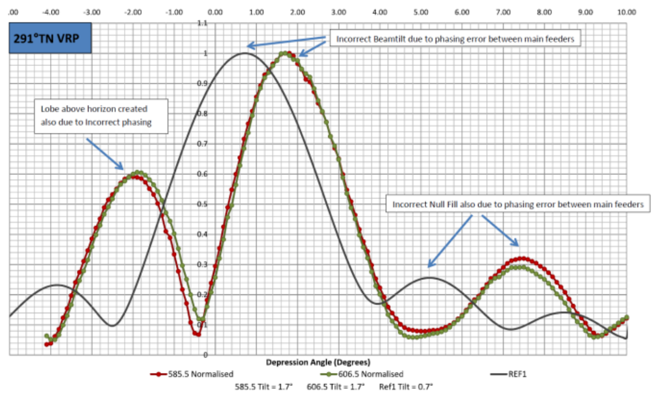

Fig. 5. VRP results showing incorrect main feeder phasing. Measured (coloured), Designed/reference (black).

C. *Mechanical Lean*

Large UHF arrays have very small vertical beamwidths. A small mechanical lean can result in excessive up-tilt on one side and down-tilt on the other which may impact significantly on the intended coverage area. Often, without tools such as a theodolite and even with this, some antennas with radomes are very difficult to measure for verticality, being able to verify the VRP in all directions helps to identify potential mechanical lean issues.

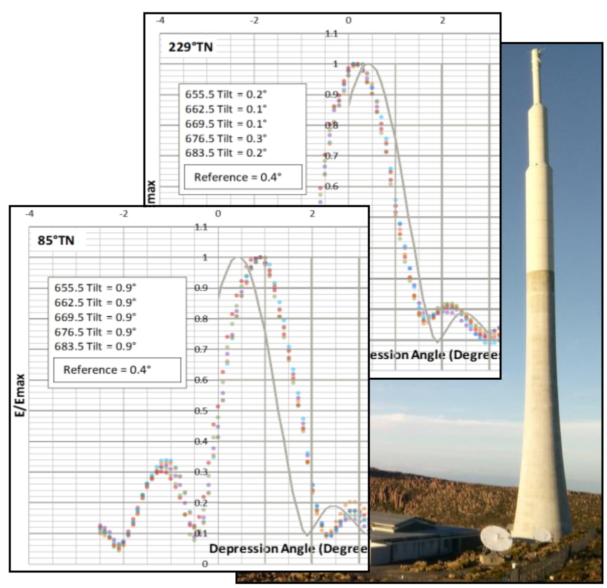

Fig. 6. VRP results showing mechanical lean by measuring the antenna pattern beamtilts.

D. Incorrect Panel Orientation

Some larger UHF antennas can consist of dozens of panels on multiple faces. Incorrect installation or errors in orientation during installation can be easily seen in the measurement results.

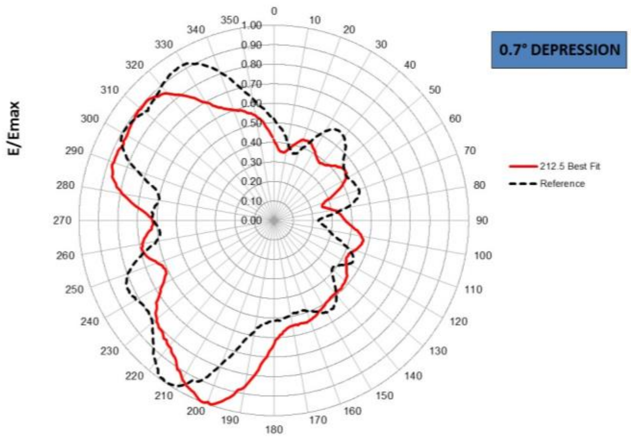

Fig. 7. Measured HRP rotated

Fig.7 shows the measured pattern rotated counter-clockwise by 10 degrees.

E. Inverted Panels

More of a concern with smaller panel arrays. The installation of a single, or multiple panels inverted (upside down) will have detrimental effects to the antenna pattern and coverage area. Fig.8 shows the effect of an inverted panel on the HRP.

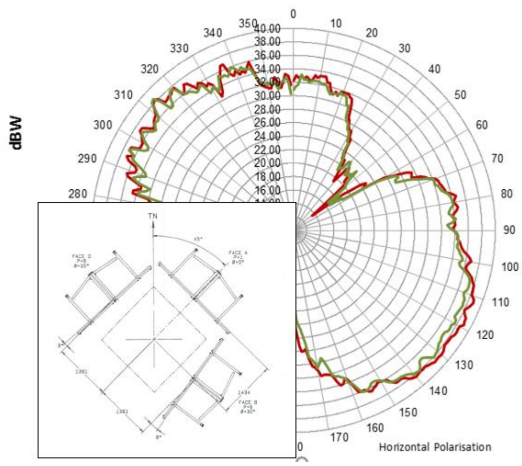

Fig. 8. Null created by inverted panel

F. Adjacent Tower Effects

The effect on adjacent structures and antennas has never been able to be fully analysed due to constraints in land-based measurement techniques. Using Sixarms UAV-based systems, a complete HRP can identify potential issues. Two examples below show the effect on adjacent structures in the UHF TV Band.

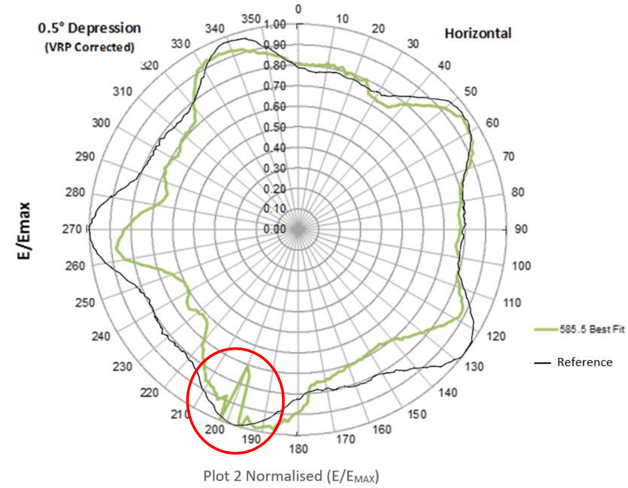

Fig. 9. 3dB Notch due to taller adjacent structure

This first example shown in Fig.9 shows the normalized HRP of a UHF digital TV antenna with a taller adjacent structure that is 650 feet (or 200m away). This produces a 3dB notch in the HRP at this azimuth.

The second example in Fig.10 shows an HRP plot (in ERP) and the effects of two adjacent structures on the antenna pattern. This is a multichannel antenna with an adjacent structure at 170 feet away showing a 7dB notch in received power and another tower at 540 feet away showing a 4dB notch in the measured pattern. Knowing the exact characteristic of the transmitting antenna can help to solve coverage issues.

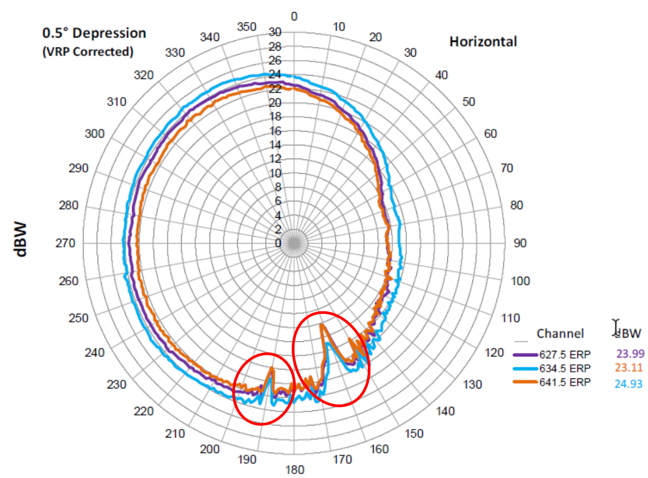

Fig. 10. Multiple adjacent structure effects on the horizontal pattern.

IV. Advantages of a UAV-Based Antenna Testing Regime

The following points highlight the benefits of using a drone-based antenna pattern measurement system:

- **Rapid Deployment**: Mobilization to a single location to perform all measurement flights.
- **Cost Effective:** Almost equivalent pricing to a two-man land-based team in the field for a few days.

- **Timeliness:** Measurements performed in less than a day with results instantly available.
- **Full Antenna Characterisation:** A complete dataset including HRP and VRP patterns is available for a newly installed or existing antenna and used for comparison against designed specifications. Data includes 360-degree circumference for HRP and well below and above the horizon for VRP.
- **Software Driven:** All components integrated and controlled by the Antenna Measurement Studio software to avoid human error.
- **Instant, Repeatable Results**. Fly and measure the exact same flight paths after major changes or weather events to monitor the antenna performance over time. Determine the baseline antenna performance.

V. ARMS CAPABILITIES

The ARMS measurement system has the capabilities summarized in Table I. and this functionality can be easily extended and customized.

TABLE I. CAPABILITES

UAV-based Measurement Capabilities	
HRP Characterization Resolution	<1º
VRP Characterization Resolution	0.1º
Absolute ERP Uncertainties	±1.6dB
Relative HRP, VRP Uncertainties	±0.5dB
Flight Time	45 minutes
Post Processing	Minimal to None
Services (Frequency Range)	9kHz – 12GHz
Receive Antenna	Various
Broadcast Services	AM, FM, VHF TV, UHF TV

VI. CONCLUSION

The UAV-based antenna measurement platform is a cost-effective and flexible service used to accurately determine the complete performance of new and existing broadcast, telecommunication and defense communication systems.

The tool eliminates land-based measurement error and allows for direct comparison of pattern data to that of the client giving piece of mind that the infrastructure is working as designed.

REFERENCES

[1] ITU-R SM.2056-1, "Airborne verification of antenna patterns of broadcasting stations", 2014

[2] Sixarms Website, www.sixarms.com , "Case Studies + FAQs", 2017