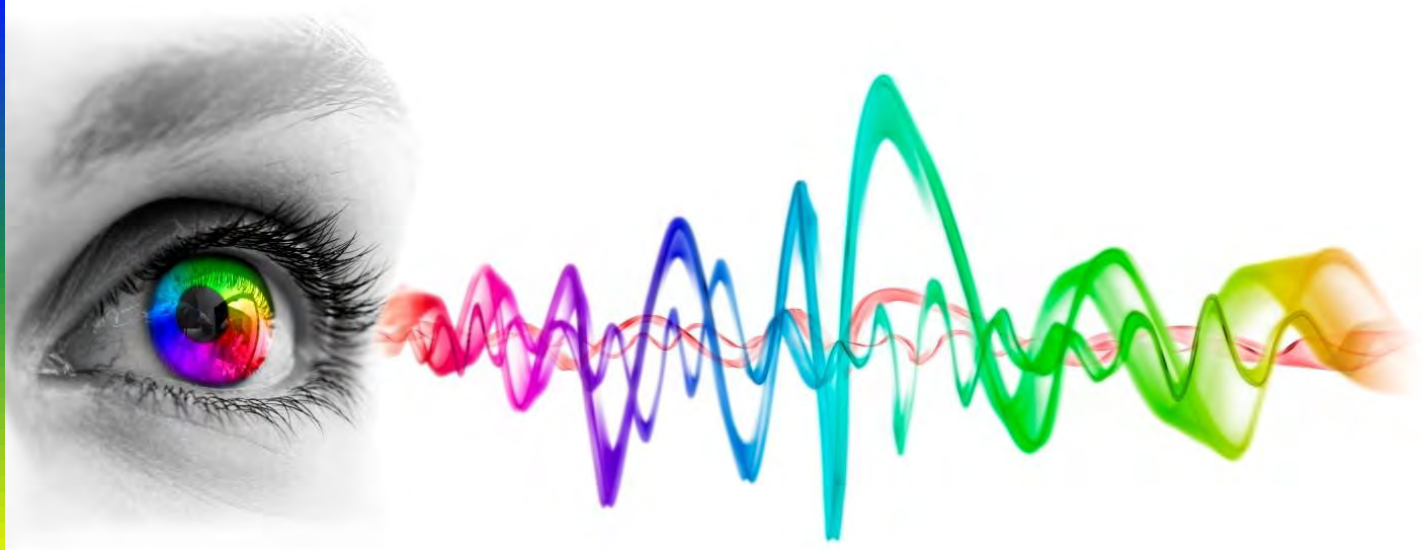
UAV ANTENNA RADIATION PATTERN MEASUREMENTS



30 November 2023

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1 INTRODUCTION

LS of South Africa, part of the International LS Telcom group with Headquarters in Lichtenau Germany, had the privilege to embark on a Cross Country UAV (Unmanned Aerial Vehicle) Antenna Radiation Pattern Measurement Campaign in the United States of America in partnership with its local LS US office, based in Bowie, Maryland.

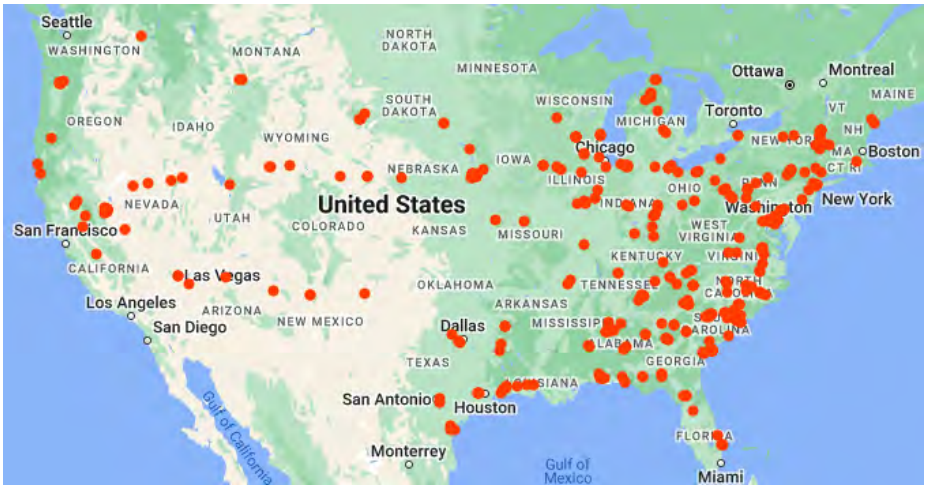
The project was awarded to LS Telcom US, to measure Frequency Re-Packed TV stations. These measurements were done mainly for TV Broadcast Repack antennas. The main purpose for these measurements is to conclude that the stations are functioning as expected and that the actual measured antenna patterns match the theoretical patterns for the planned coverage area.

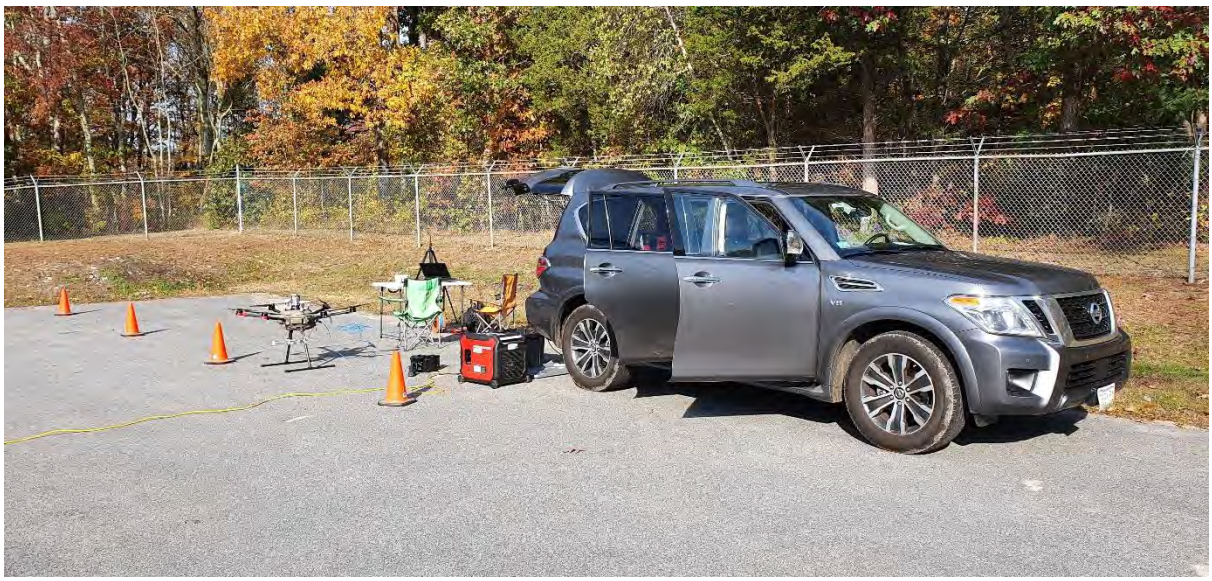
2 Antenna Measurements

2.1 Measurement Campaign

The LS Telcom team travelled throughout the USA with a total of 8 separate trips being made to the USA. To date we have measured over 100 stations in the USA and travelled close to the 100 000km mark across the country by vehicle. In total, we have visited or drove through nearly all 50 states in the US, with the exclusion of Hawaii, Alaska, and North Dakota.

The map below shows the states in the USA where the LS team has conducted Antenna Radiation pattern measurement since 2020.





The measurement campaign yielded many successful measurements, with over 850 successful flights taking place. These missions varied from 20m antenna tower structures to be surveyed and measured to a handful of towers ranging to over 500m AGL in total length AGL. Most flights were conducted within the 400 ft (+-120m) FAA Part 107 rule, to remain within 400 ft. radius from the structure to exceed the 400ft height limit. Certain locations were measured in the Far-Field of these antenna systems under special permission from the FAA. For these Far-Filed missions, LS got special permission through the waiver part 107 process to allow flight to take place further than 400ft. from the structure and exceed the 400ft. radius limitation.

Above is a typical Antenna system installed at 470m AGL.

2.2 Airborne Based Antenna Measurement System

LS of South Africa developed the Airborne based Antenna measurement system, consisting of a specialized Radio Frequency shielded UAV/Drone platform, equipped with the following hardware:

- RTK GPS,
- On-board Computer,
- Spectrum Analyser,
- Receive Antenna,
- Telemetry Links

- Mobile Radio Frequency measurement system
- RTK – Real Time Kinetic system for centimeter position accuracy

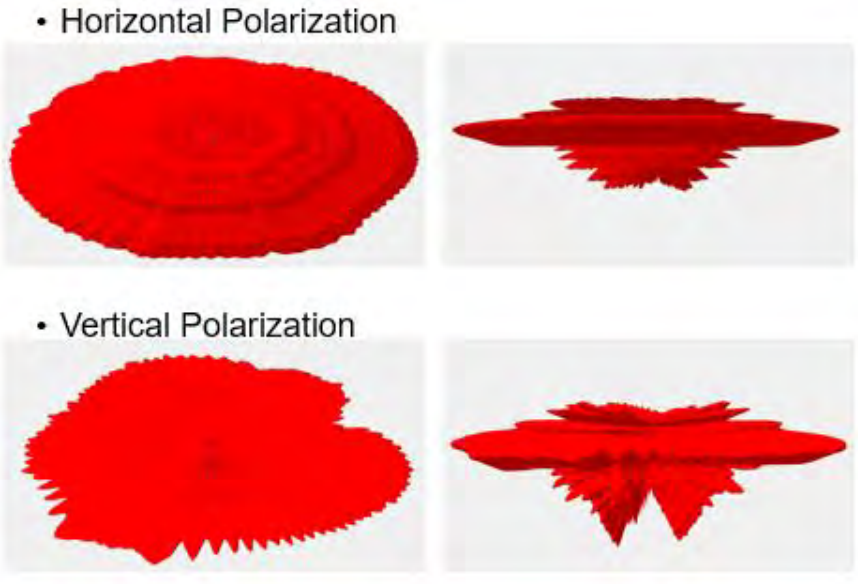
- Onboard Data Processor
- Onboard spectrum measurement system and software
- Onboard wireless telemetry links
- Calibrated antenna

The UAV is equipped with the above-mentioned hardware, the hardware is then integrated with LS's specialized in-house and custom created software to combine the measurements data with the geotagged location of the UAV.
LS joined forces with one of the world leaders for Antenna design and manufacturing, to do measurement in the Near-Field of the antenna system and convert them back to far-field data points to validate the system. Typical measurements would take place in the Far field (unique to each antenna and frequency) of the antenna system.

The results captured at each site included the following:

- Horizontal/Azimuth Antenna Radiation Pattern
- Vertical/Elevation Antenna Radiation Pattern
- ERP (Effective Radiated Power)
- Electrical Beam Tilt on various Azimuths
- Certain Locations included:
    - CoR (Centre of Radiation) of the Antenna System with Lidar and Photogrammetry
    - 3D modelling of the tower with Lidar and Photogrammetry
    - ATSC 3.0 Field point measurements

A typical 2D Vertical and Horizontal – (Azimuth and Elevation) Pattern measured, converted to a 3D representation would deliver the following results:

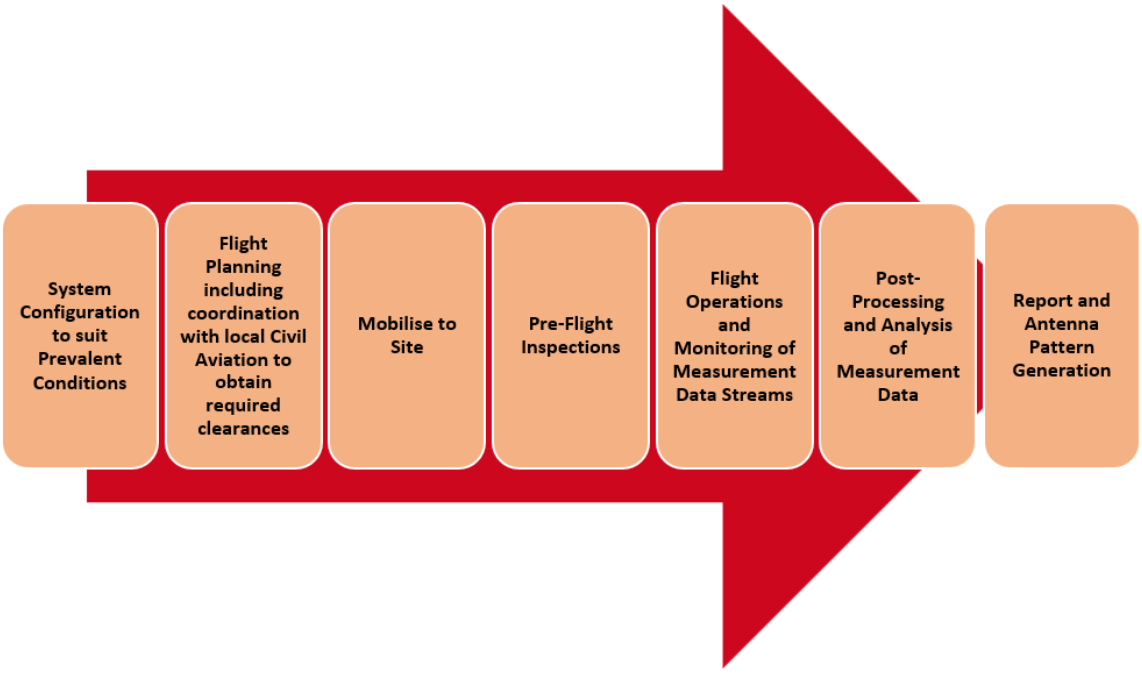


Our specialized UAV with all its hardware is measured inside a full anechoic chamber, to ensure we post process any errors in the measurements. The chamber measurement over the band of interest consists of the following corrections and measurements:

- Roll
- Pitch
- Yaw
- System Gain

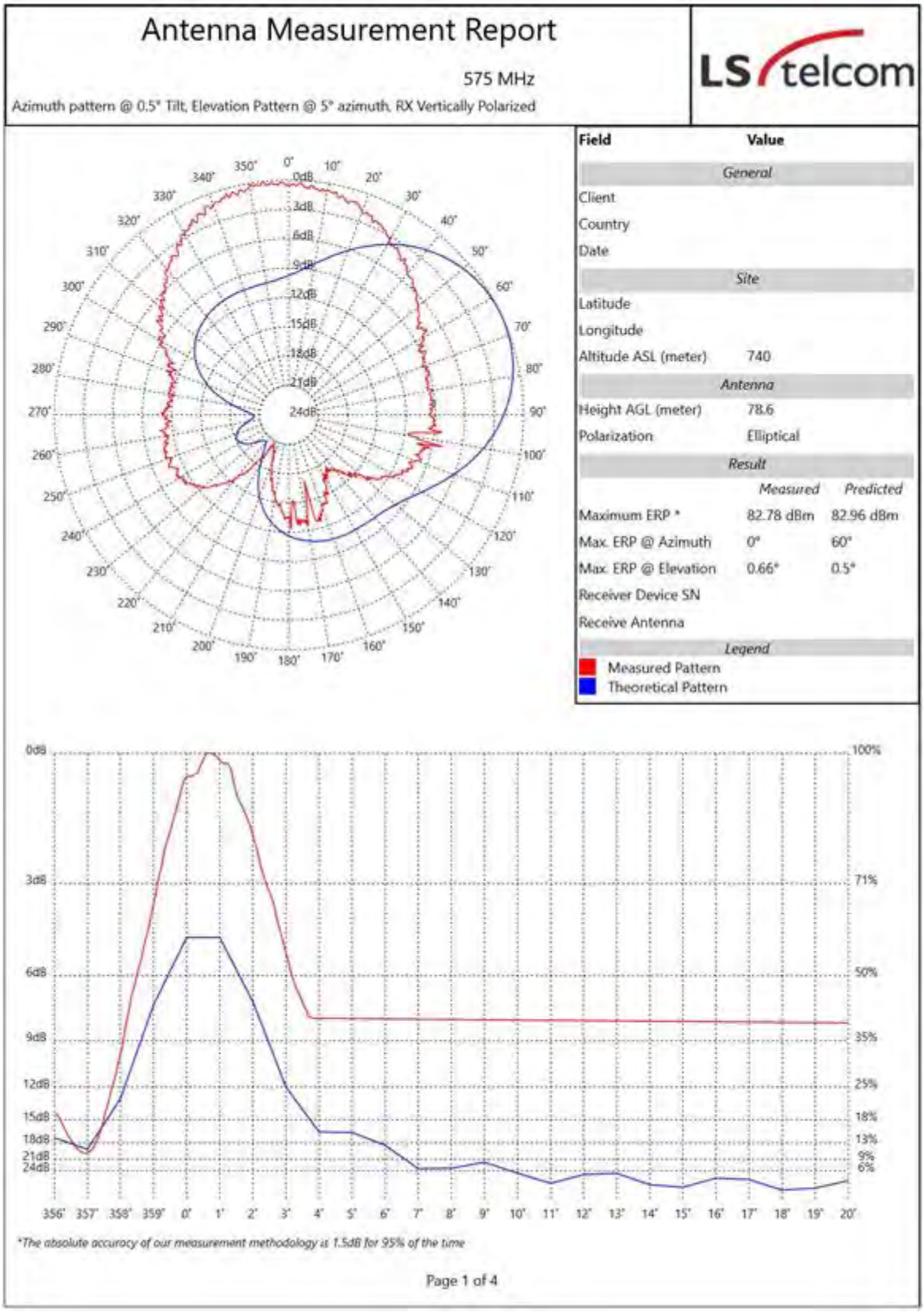
Specialized UAV Platform in our Full Anechoic Chamber.

2.3 Measurement Process:



2.4 Typical Report

2.4.1 Typical Report with common Faults



Antenna Measurement Report

575 MHz

Azimuth pattern @ 0.5° Tilt, Elevation Pattern @ 5° azimuth, RX Vertically Polarized

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Field	Value	
General		
Client		
Country		
Date		
Site		
Latitude		
Longitude		
Altitude ASL (meter)	740	
Antenna		
Height AGL (meter)	78.6	
Polarization	Elliptical	
Result		
	Measured	*Predicted*
Maximum ERP *	82.78 dBm	82.96 dBm
Max. ERP @ Azimuth	0°	60°
Max. ERP @ Elevation	0.66°	0.5°
Receiver Device SN		
Receive Antenna		
Legend		
Measured Pattern		
Theoretical Pattern		

*The absolute accuracy of our measurement methodology is 1.5dB for 95% of the time

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2.4.2 Typical Report without faults:

Antenna Measurement Report

Horizontal @ 1°, Vertical @ 300°

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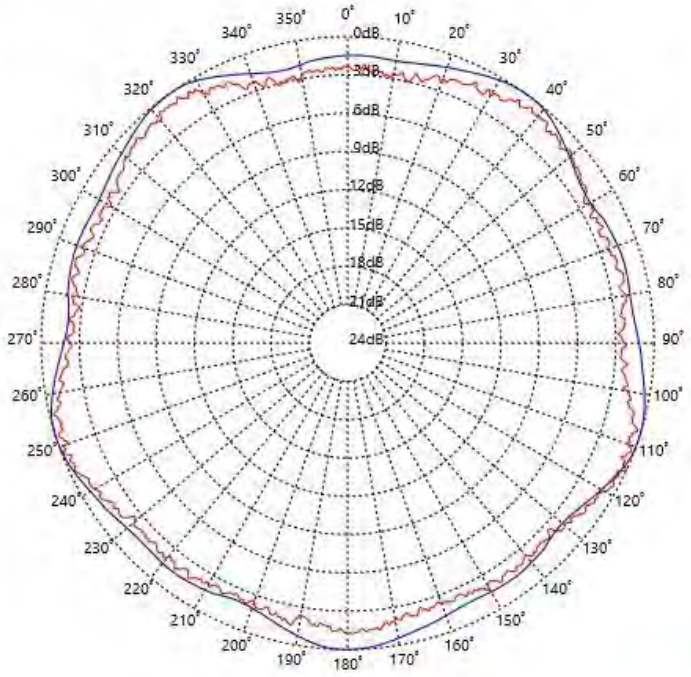
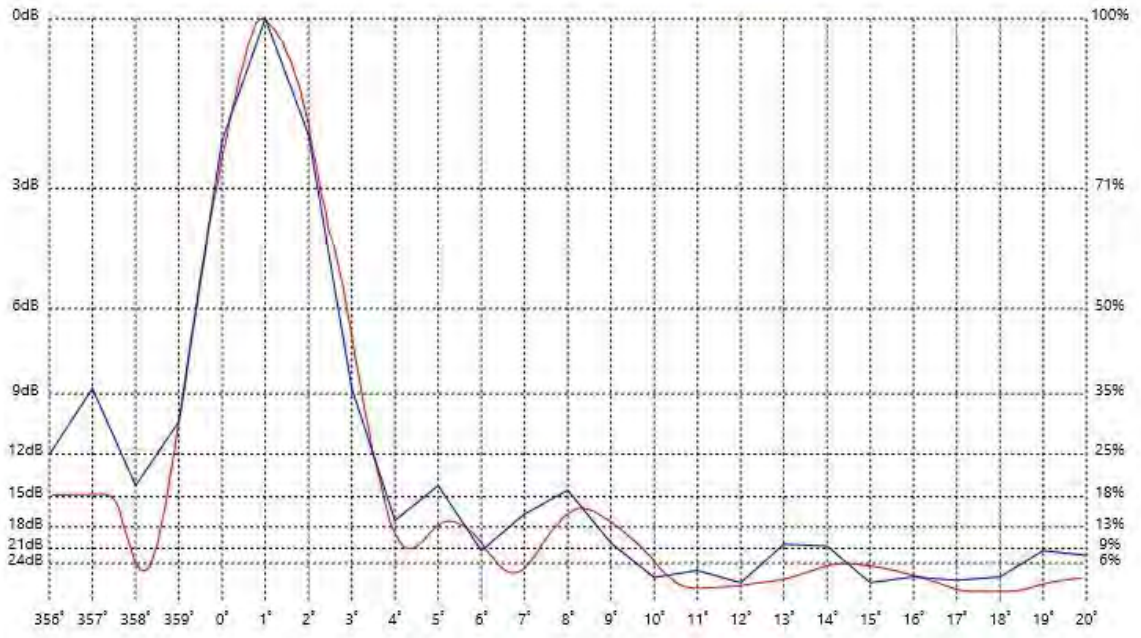


Field	Value	
General		
Client		
Country		
Date		
Site		
Latitude		
Longitude		
Altitude ASL (meter)	320	
Antenna		
Height AGL (meter)	463	
Polarization	Horizontal	
Result		
	Measured	*Predicted*
Maximum ERP *	87.73 dBm	87 dBm
Max. ERP @ Azimuth	Omni	Omni
Max. ERP @ Elevation	0.95°	1°
Receiver Device SN		
Receive Antenna		
Legend		
Measured Pattern		
Theoretical Pattern		



*The absolute accuracy of our measurement methodology is 1.5dB for 95% of the time

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2.5 Typical Faults in general

Typical faults would include:

1. Installation Error
   a. Antenna Direction Installation Error
2. Phasing Installation Error
3. Spline/Mechanical Tilt error
4. Tilt Errors – Centre of radiation error

1. 11 Degree Antenna orientation installation error:

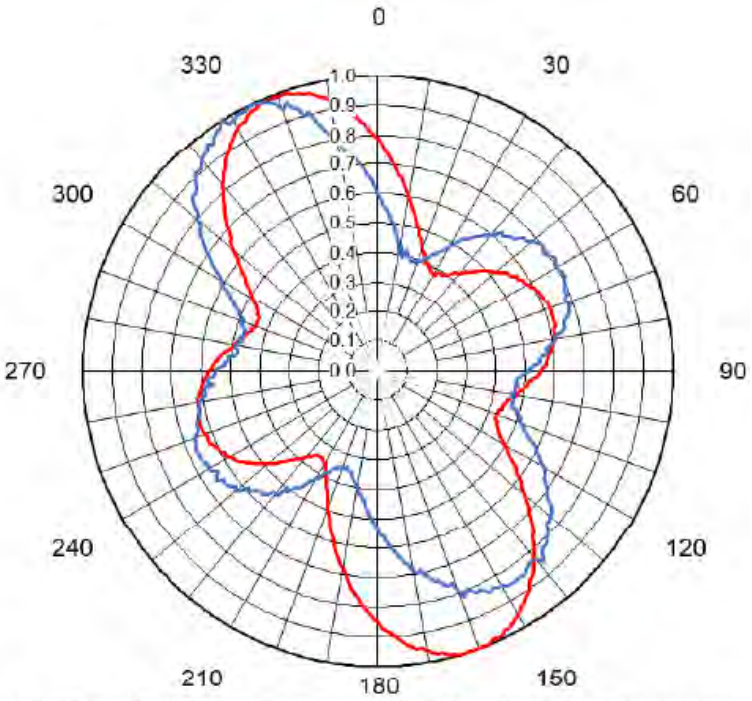
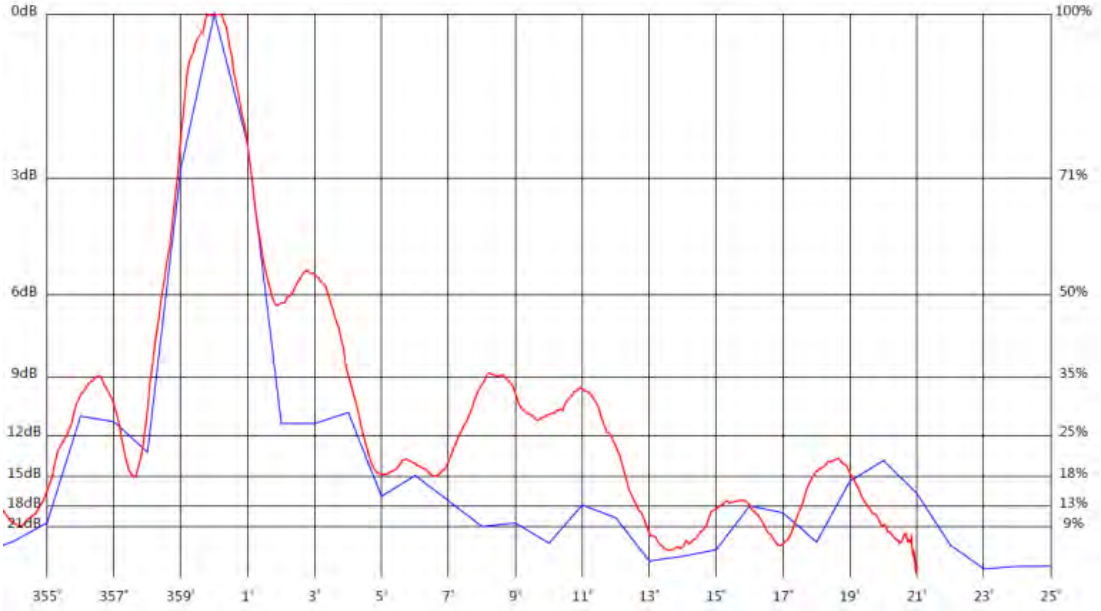
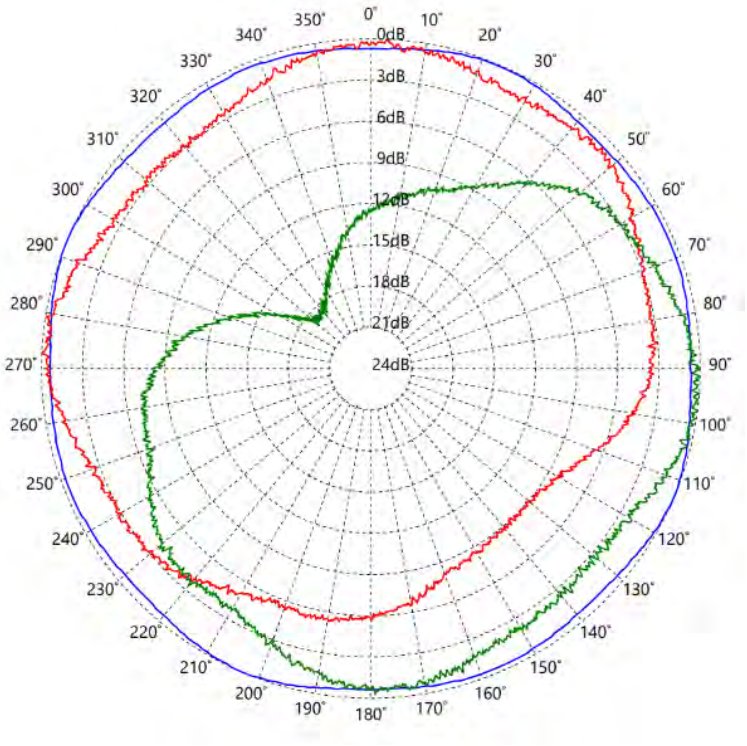


Figure 1: Horizontal polarization azimuth pattern. Red- HFSS. Blue – drone measurement

2. Phasing Installation Error:



3. Spline/Mechanical Tilt Error:

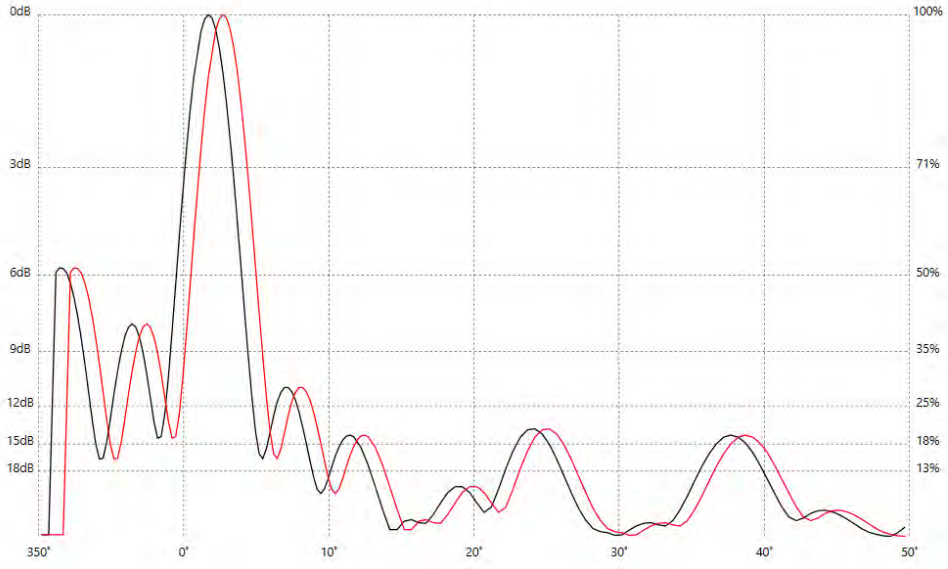


Blue = Theoretical Pattern

Red = Measured Pattern on positive tilt value

Green = Measured Pattern on negative tilt value

4. Tilt Errors:



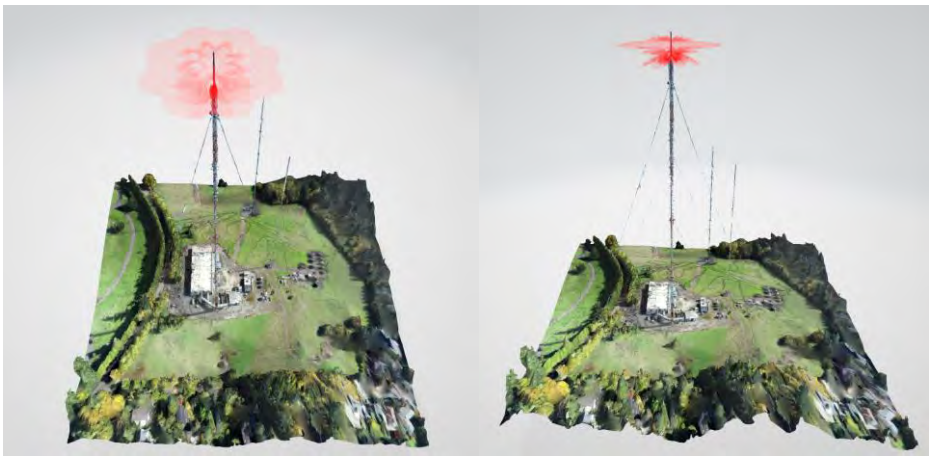
The above figure shows a tilt mismatch

The tilt on the measured pattern (red), is 1° more than the tilt of the theoretical pattern (black). This could be caused by an installation error, or the wrong center of radiation was defined by the specification.

2.6 Advantages of Antenna Radiation Pattern Measurements.

The following advantages are crucial for these types of missions:

- Broadcast Antenna Pattern Measurements:
    - Azimuth and Elevation Pattern Measurement
    - ERP Validation
    - Tilt Validation
    - Far-Field to Near-Field Calculations
    - Antenna/System Performance Verification on all Installations
    - Coverage Prediction correlates with planning
- ATSC 3.0 Point Measurements:
    - Confirmation of Quality of Signal radiated by transmitter
    - Confirmation of Quality of Signal radiated through Antenna.
    - Confirm synchronisation of SFN by measuring Channel Impulse Response.
- Centre of Radiation Measurements:
    - More precise Tilt calculations and configurations
    - Enhanced coverage predictions
- 3D Site Rendering and Reconstruction:
    - Available Space on the Tower
    - Mechanical Antenna Tilt if applicable
    - 45MP High Definition Images of complete site for Maintenance etc.
- Radiation Safety:
    - Health and Safety Policy compliance



LS Telcom provides an advanced Remotely Piloted Aircraft (RPA) / Unmanned Aerial Vehicle (UAV) system enabling a full UNINTRUSIVE mobile site audit that supports:

- *A spectrum scan displaying active channels*
- *Detailed information of individual channels based on the National Radio Frequency Plan Band plans (Service Provider, frequency, bandwidth, technology, etc…)*
- *A display of the radiation pattern of each individual transmitting channel (Vertical pattern, Horizontal pattern, and 3D representation)*
- *Technical specifications of the channel transmission (Effective Radiated Power (ERP) and bandwidth)*
- *Highly accurate positioning of individual antennas mounted on the mobile tower/mast*
- *Antenna characteristics: Centre of Radiation (CoR), Height Above Ground Level (AGL), Antenna Width, Antenna Length, Electrical tilt, Mechanical tilt*
- *A list of the channels being transmitted from each individual antenna*
- *A scaled model of the mast for mechanical and civil analysis*
- *3D viewer of the mast with integrated RF information for client-side analysis*