Characterization of an In-Situ Ground Terminal via a Geostationary Satellite

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Introduction

- Space Communications and Navigation (SCAN) Testbed launched in 2012 as external payload aboard the International Space Station (ISS)
  - Early testing of Earth-facing antenna showed operational limitations for communication links with Wallops Ground Station
- In 2013, the Space Communications and Navigation (SCaN) project decided it was necessary to build their own specialized ground station
- Ground Station Requirements
  - Facilitate testing novel communication technologies
    - Experimenter provided radios with Cognitive Engines
    - Multi-Node Networking applications
  - Also serve as link between Tracking and Data Relay Satellites (TDRS) and Ground Integration Unit
  - ***Fully Characterized System***
    - ***Extensive component testing***
    - ***Validation of results after installation***
    - ***Monitor potential System degradation over time***

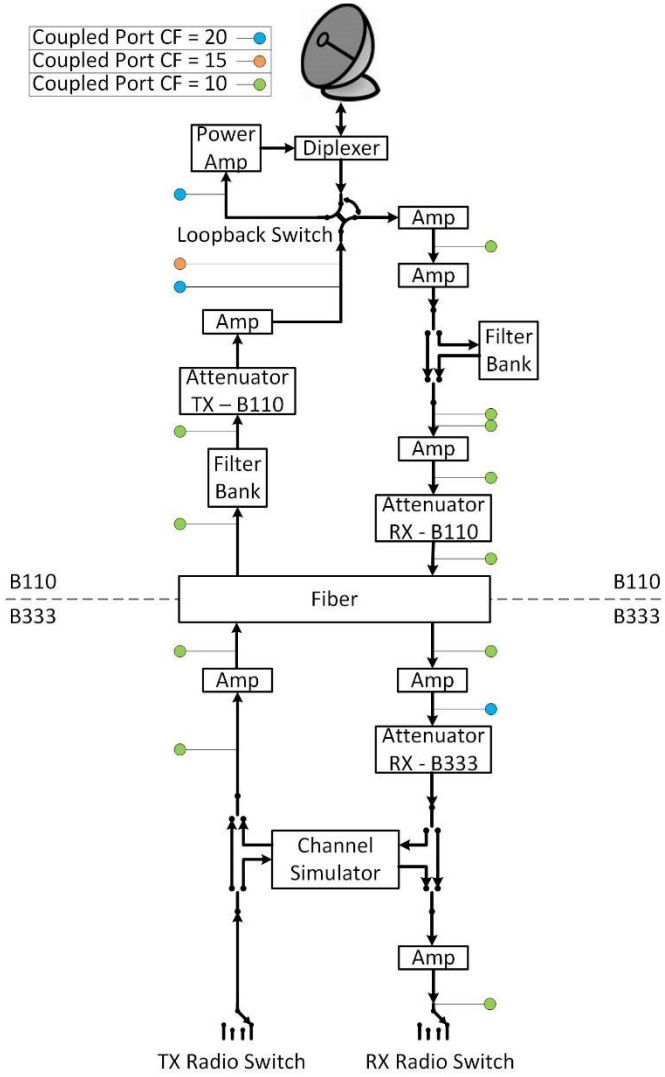
In early winter 2015, the SCaN Testbed Glenn Research Center S-Band Ground Station (GRC-GS) was completed to provide this service.

Overview

- Short description with a focus on design choices for a characterization
  - System hardware design and GUI information
- Pre-installation testing
  - Description and an example subsystem
  - Additional information on antenna testing
- Post-installation Validation
  - Methodologies and data related to subsystem discussed in pre-installation
  - In-depth discussion of use of a geostationary satellite for antenna validation with comparison to range testing
- Lessons Learned

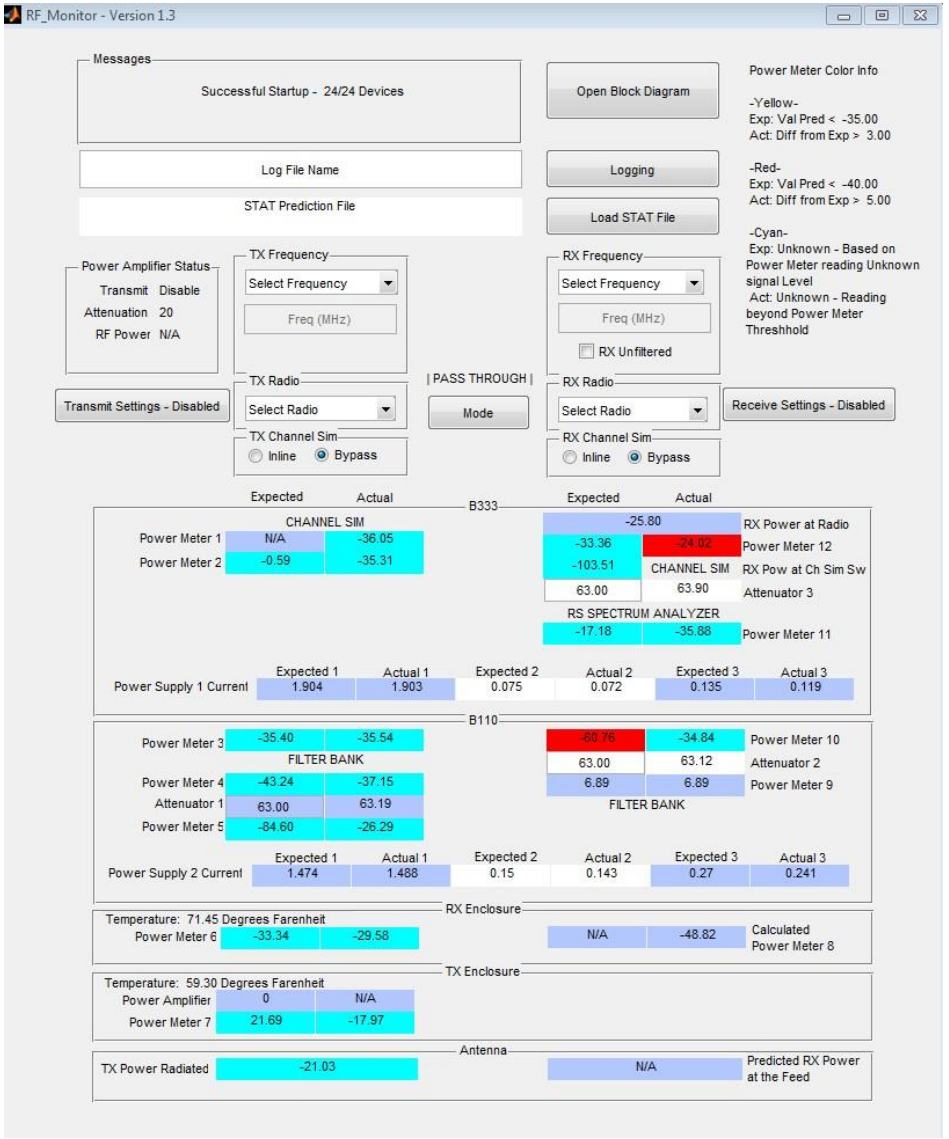
GRC Ground Station

- S-Band (2.0 – 2.4 GHz)
- Equipment located in 2 buildings
  - Building 110 (B110) - Amplifiers, Antenna, Attenuators, Filter Banks, Couplers
  - Building 333 (B333) – Amplifiers switches, Channel Simulator, Couplers
- Communicates with SCAN Testbed and TDRS
- Future validation and monitoring considered in the design
  - 12 Couplers - Power meters
  - 2 Couplers - Spectrum Analyzers
  - Loopback Mode



GRC Ground Station Graphical User Interface

- Messages
- ***Logging***
- Load in predictions for received power levels
- Filter Bank Switches
- Radio Switches
- ***Pass-through/Loopback Switch***
- Channel Simulator Switch
- ***Power Meters***
- Attenuators
- ***Power Supply Current Draw***
- ***Temperature Sensors***
- ***Power Amplifier Feedback***
- Predicted Power at the Feed

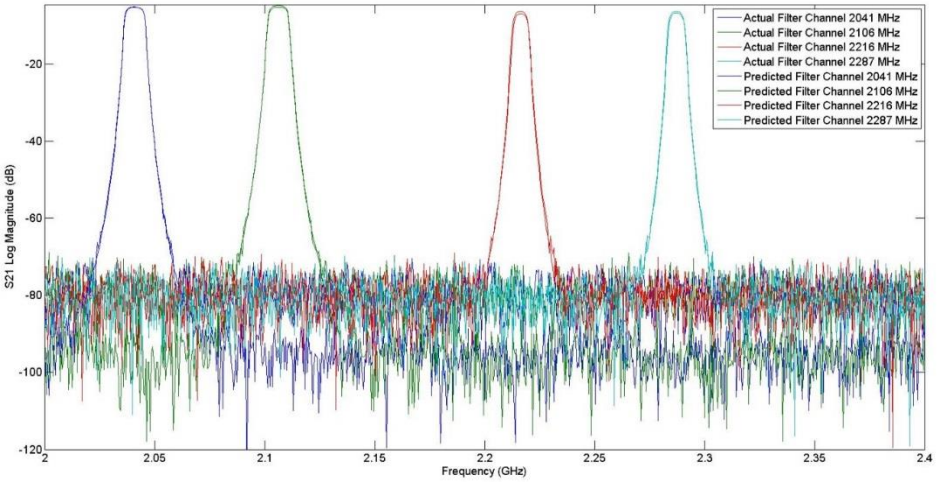


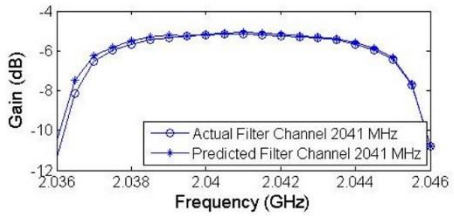
Overall Testing Description

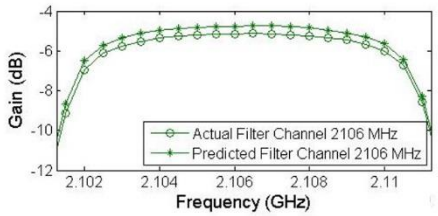
- Passive Components
  - Cables, filters, diplexers, couplers, adapters, and switches
  - S-Parameter Measurements
- Active Components
  - Amplifiers and Fiber Converters
  - S-Parameters, Gain, Noise Figure, Phase Noise, Intermodulation Distortion
- Antenna Testing
  - 2.4m Parabolic Reflector and circularly polarized Feed
  - Antenna pattern and Gain

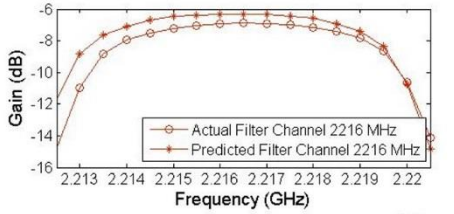
Testing - Components

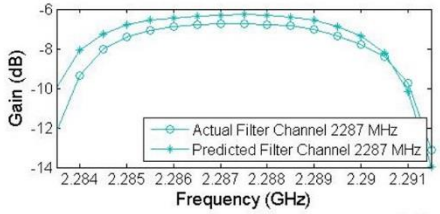
- Testing Example – Filter Bank
  - Includes cables, switches, and filters
  - Each component was measured separately using a VNA
  - Components assembled into a filter bank and then re-measured
  - New measurement compared with cascaded component measurement











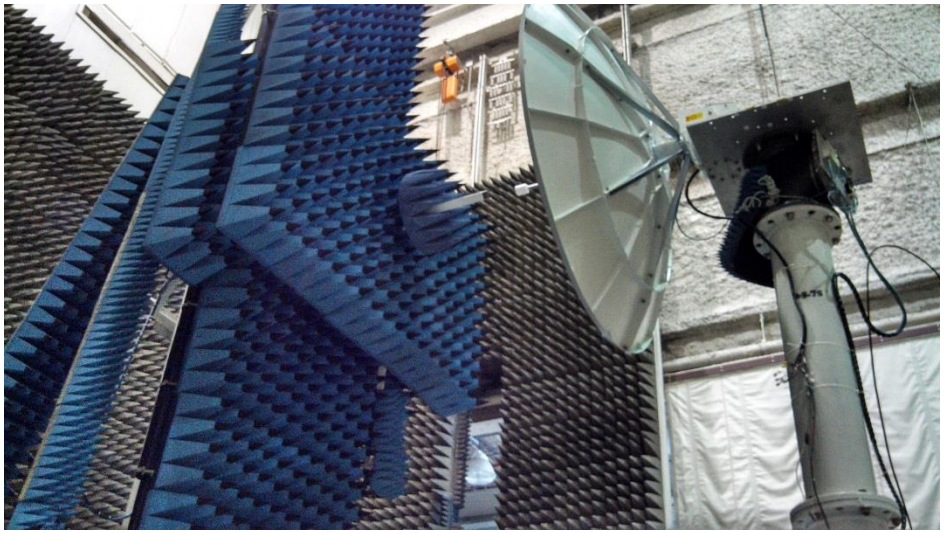
Testing - Antenna

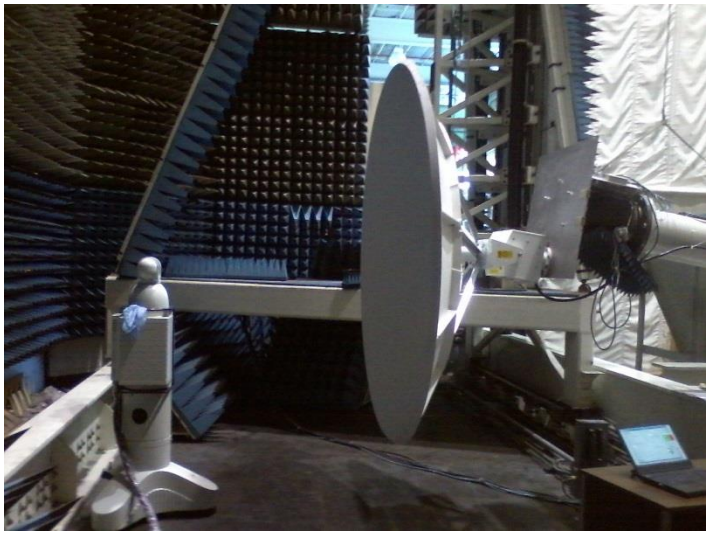
- Antenna arrived in 3 sections
- Assembled inside the Glenn Research Center Near Field Range
- Mounted to testing Pedestal
- Calibrated Horn used to quantify system performance
  - 50cm between antenna rim and probe
- Pattern Measurement Data taken

Characteristic	Value
Frequency	S-Band
Diameter	2.4m
Polarization	LHC
Half-Power Beamwidth (HPBW)	3.9°
Gain	31.5 dB

Vendor Specifications

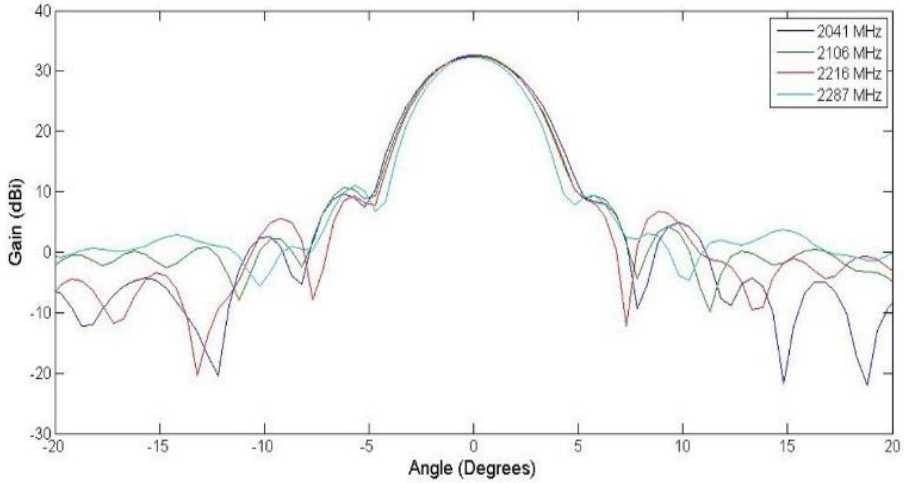
Before and after pattern measurement the surface was scanned with Leica Geosystems LR200 Laser Radar to monitor potential warping

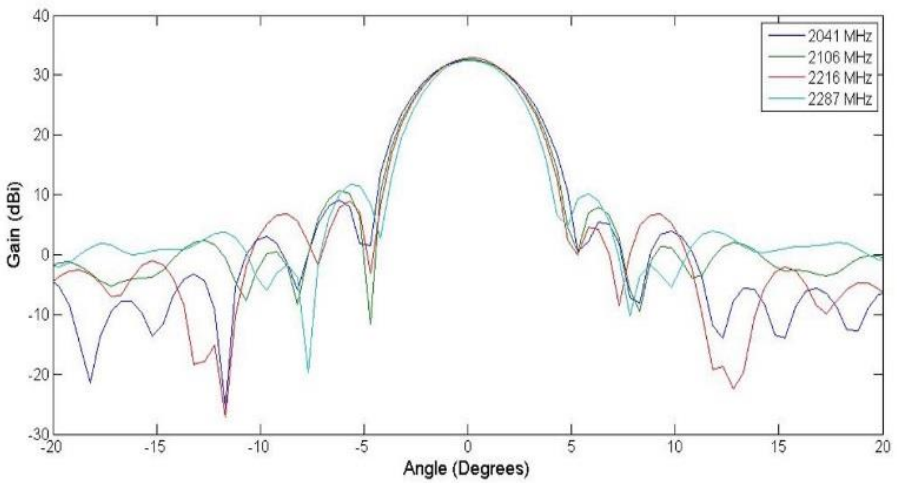




Testing - Antenna

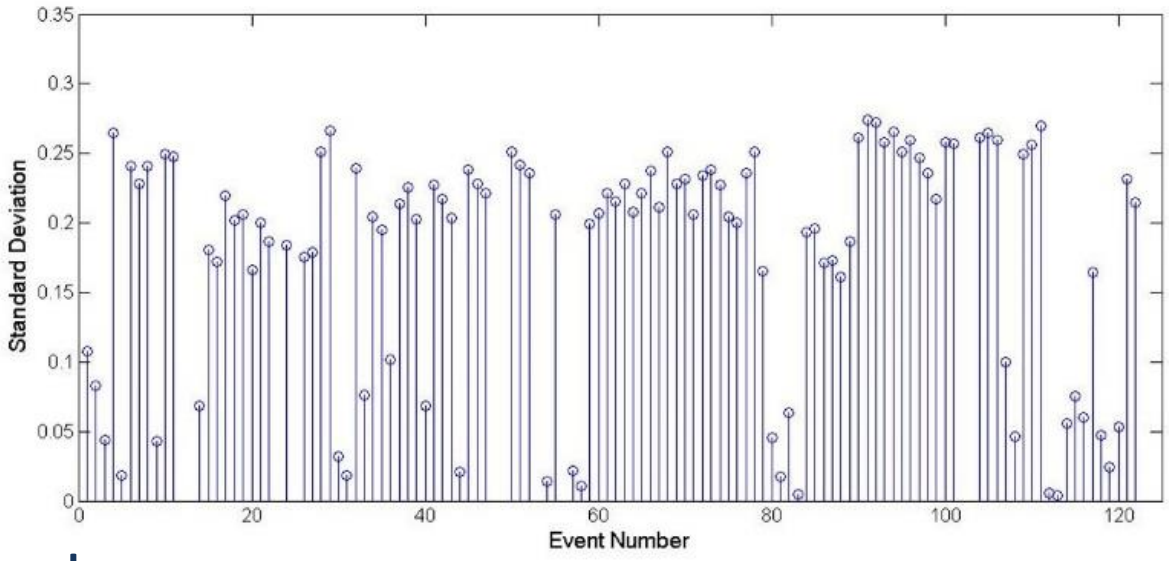
- Pattern Measurements
  - Scanned at each operational Frequency
    - 2041.027 MHz, 2106.406 MHz, 2216.500 MHz, 2287.500 MHz
  - Data processed by the Nearfield Systems NSI2000 software
    - Transforms Near-field Measurements into a Far-field Pattern
    - 60^{o} to Azimuth (Az) and Elevation (El) with 201 points in each dimension





In-Situ Testing Components

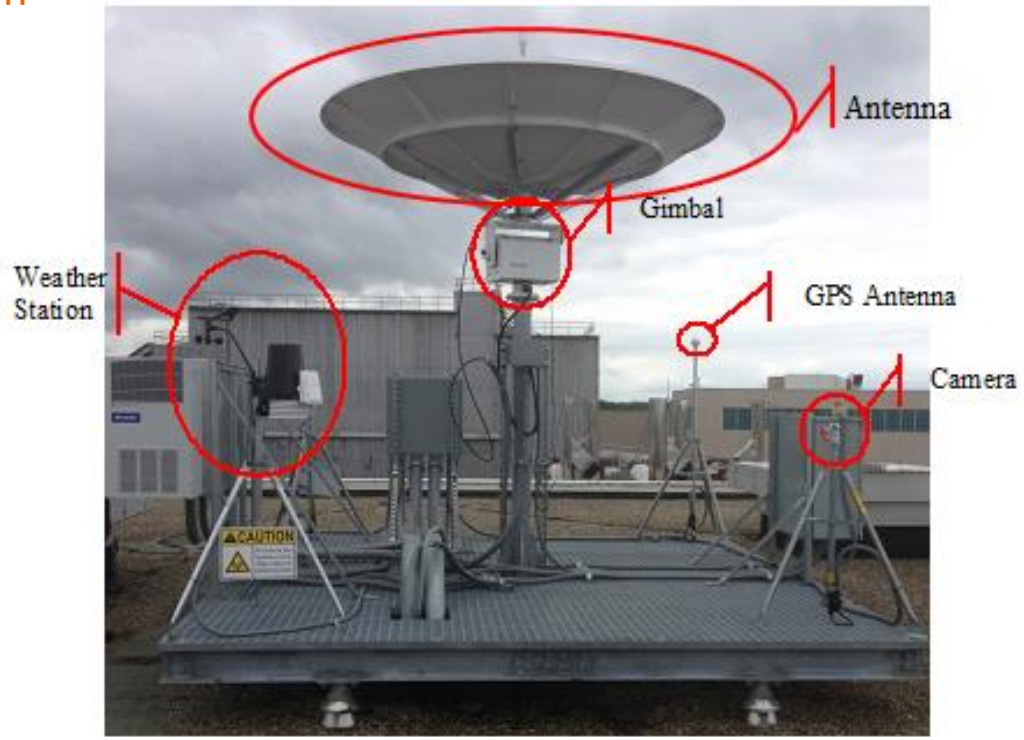
- Pass-Through
  - Radio Frequency (RF) Signals inserted into signal chain to compare against laboratory cascaded measurements



- Loopback
  - TX and RX chains Connected together
  - Insert signal in TX chain at the radio

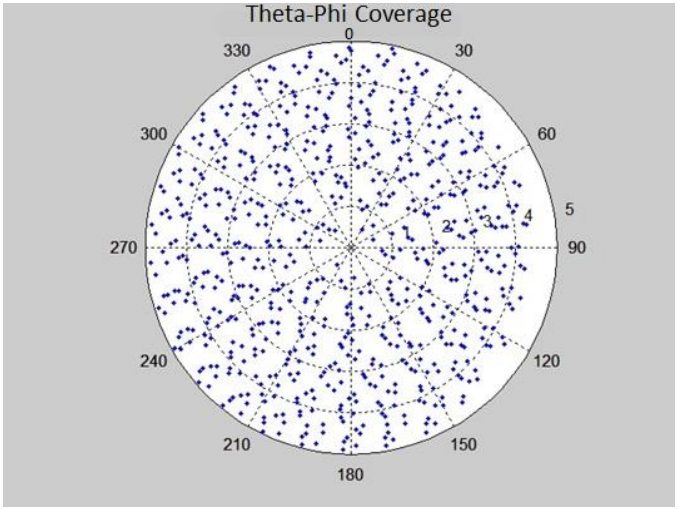
In-Situ Testing - Antenna

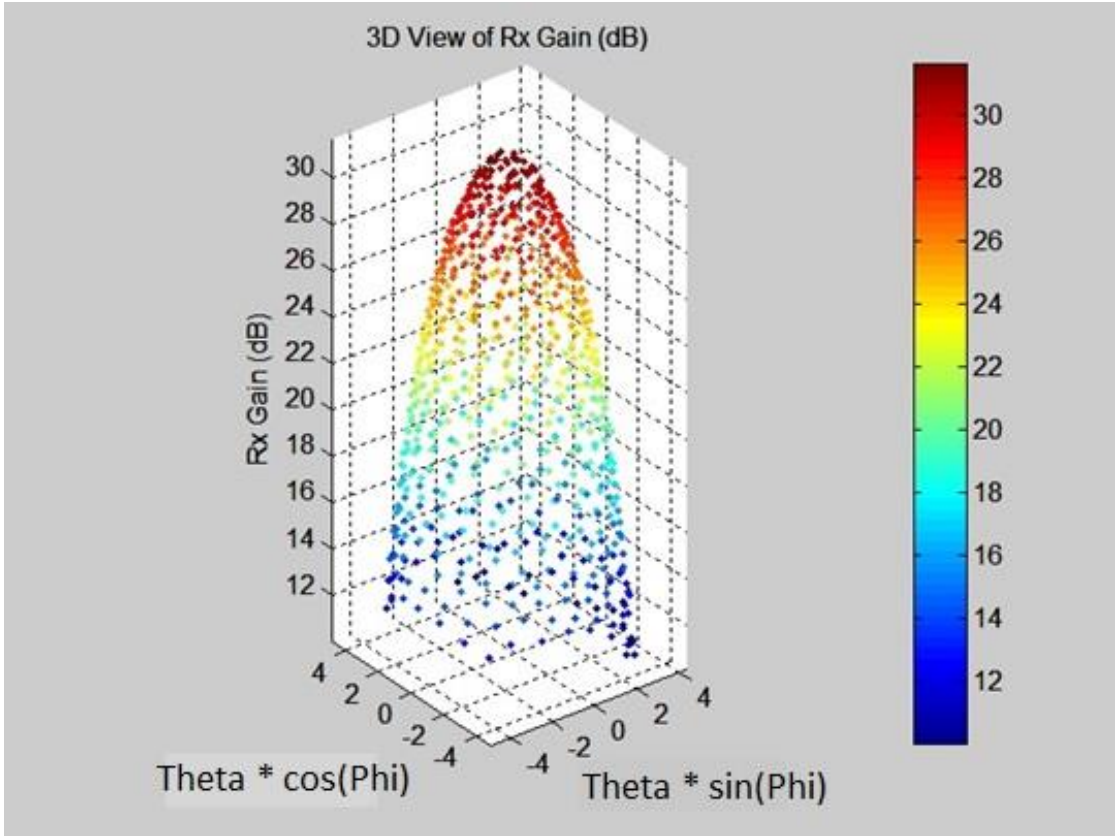
- Testing Setup
  - TDRS contacts to measure Pattern
    - TDRS-Spare (TDRS-6)
    - TDRS-East (TDRS-9)
    - Excellent availability
    - Geostationary Orbit
- Gimbal Pointing
  - Cannot go below 10^{o} above the horizon
  - Rate of motion
    - 20^{o}/s in Az
    - 4^{o}/s in El
  - Hard Stops
    - 210^{o} and -210^{o} in Az
    - 90^{o} and -90^{o} in El
  - Controlled via the LynxCAT toolset



In-Situ Testing - Antenna

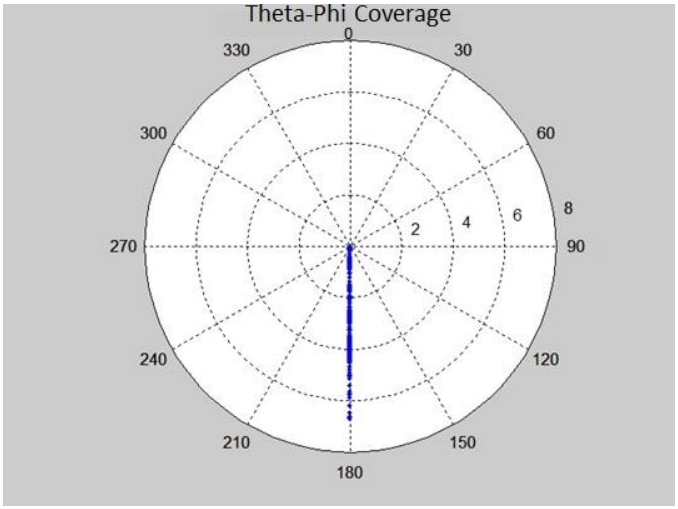
Spiral Track Testing

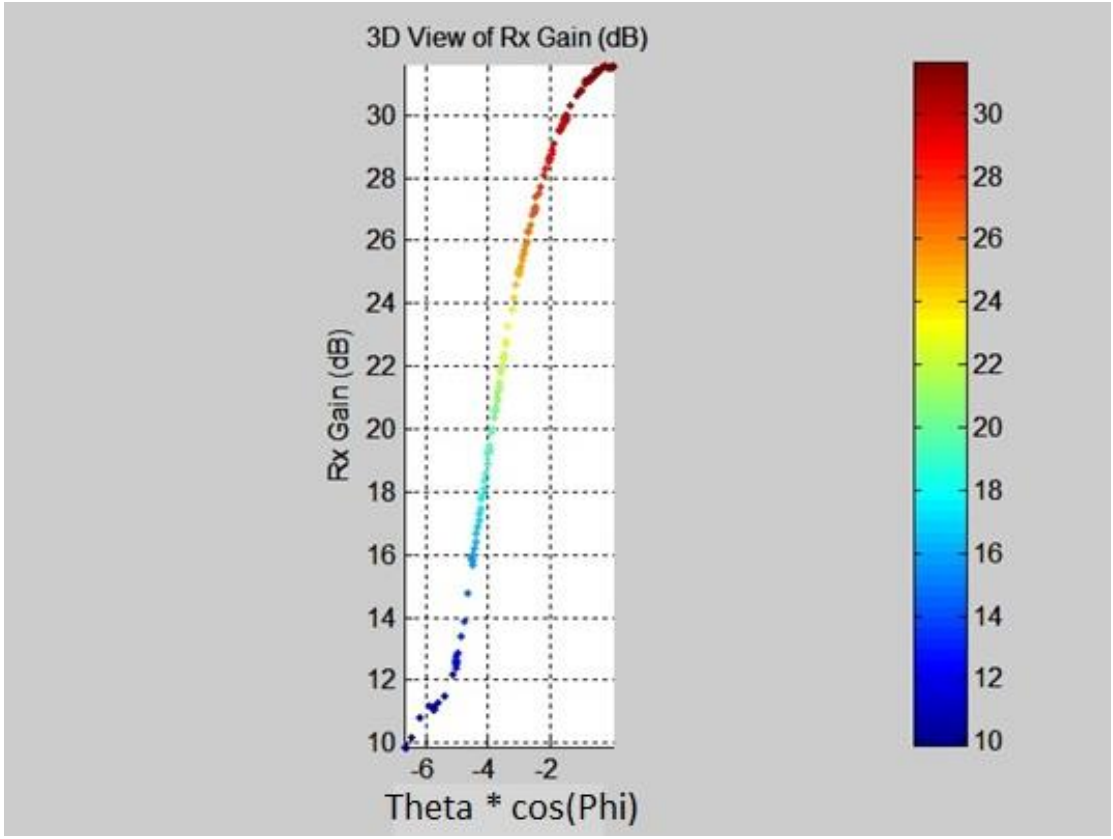




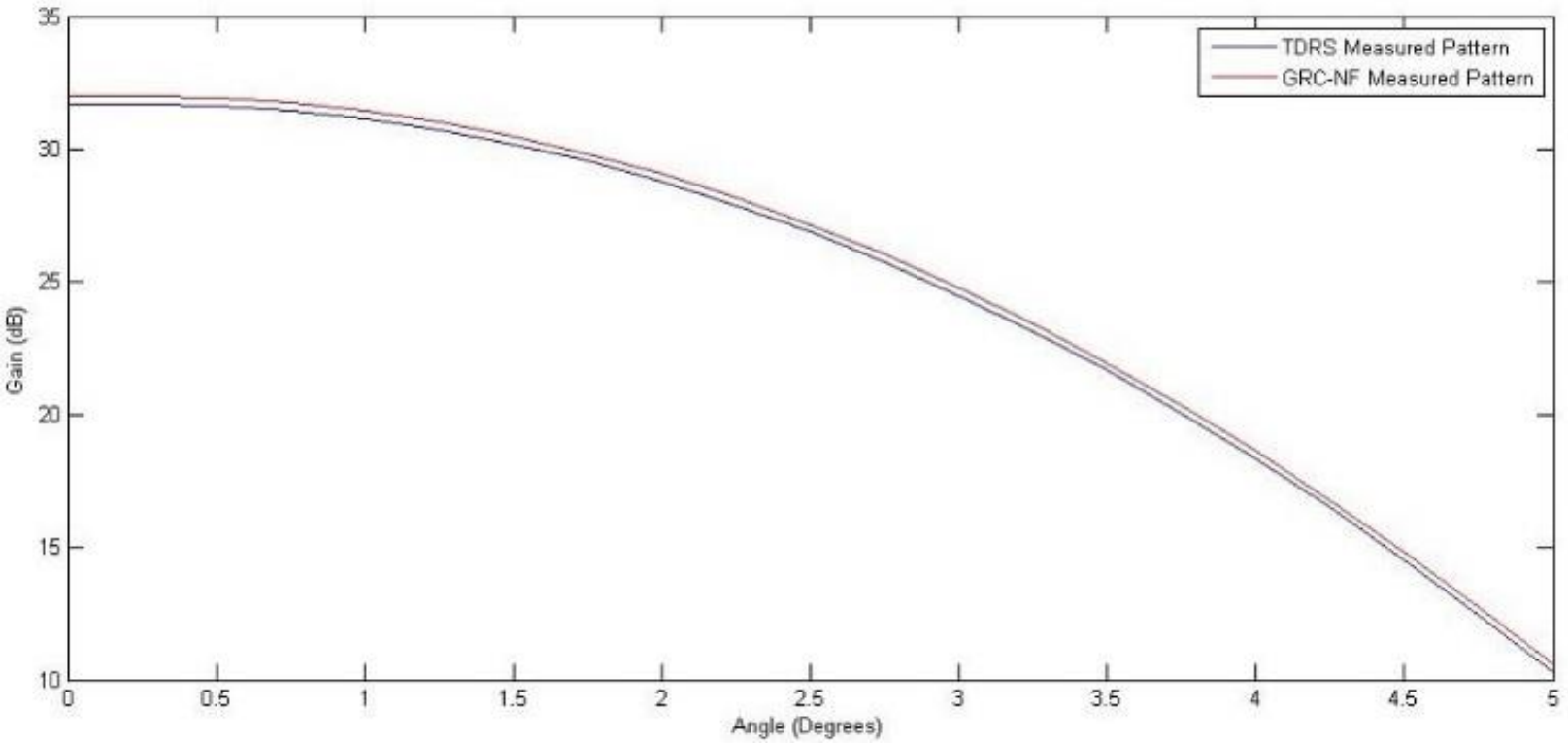
In-Situ Testing - Antenna

Fixed Offset Testing

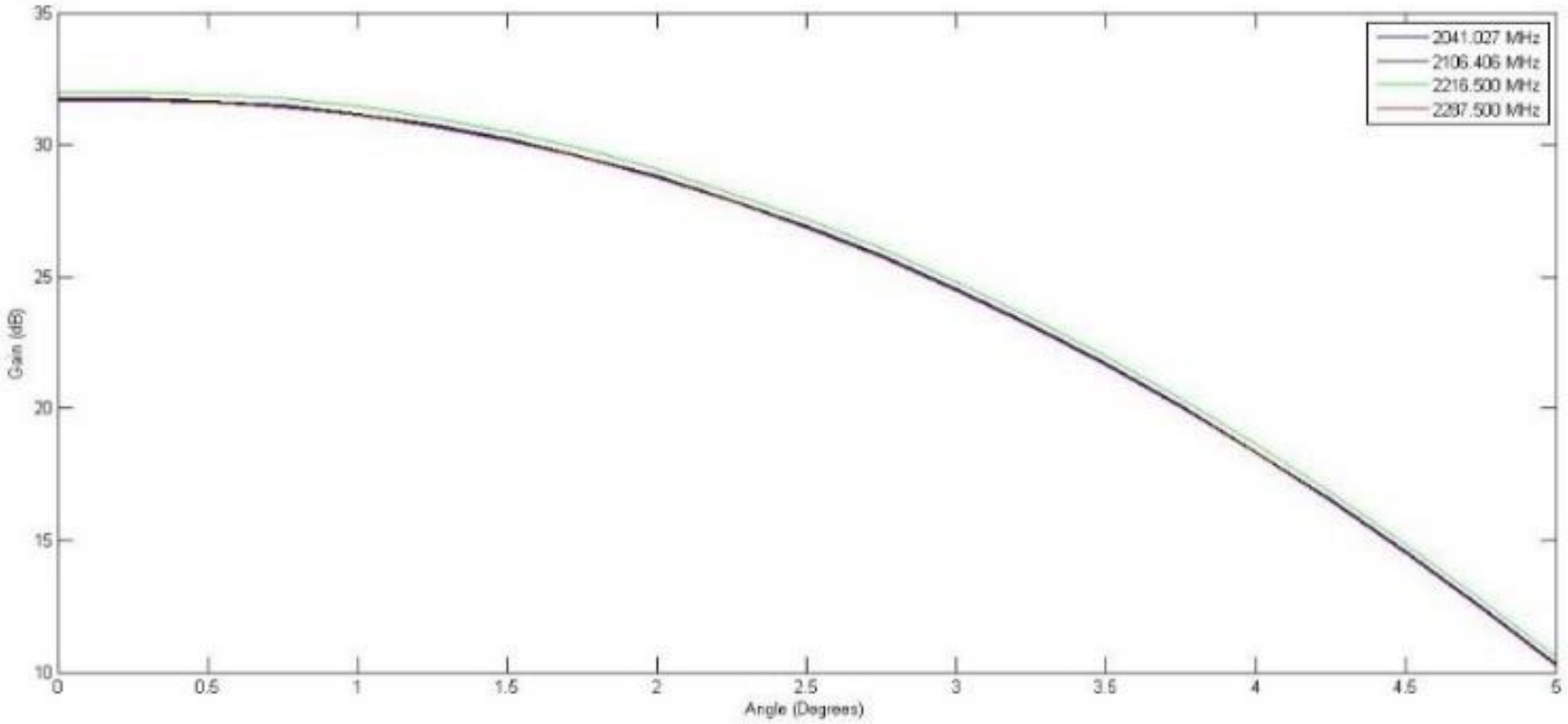




In-Situ vs Nearfield Results



Results at each Frequency



Lessons Learned

- Importance of including monitoring and validation in the initial design
  - Very difficult to include after the fact
  - Lower margin built into the link budget
  - Cost savings
  - Reduces need to disassemble and re-test components
- Various uses after installation
  - Vital for troubleshooting
  - Useful for experimenters for tracking
  - Logging also useful for spectrum coordination
- Usefulness of using a geostationary satellite for validation
  - Verification of the integrity of the antenna after installation
  - Comparison between laboratory and in-situ environments
- Challenges
  - Local interferers – area TV broadcasters
    - Coordinate a “quiet” time for testing
    - Take multiple measurements and average

Acknowledgement and References

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