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412TW-PA-19266

Spectrum Access R&D (SARD) Program: Broadband Conformal C-Band Antenna Project



Ensuring
Warfighting
Superiority



Advanced Antenna Design Team
AVMI: Airborne Instrumentation Systems
Point Mugu, CA

Background: AWS-3 Auction

- Advanced Wireless Services-3
 - Leverage and augment available spectrum in C-Band
 - 4400 MHz – 4940 MHz
 - 5091 MHz – 5015 MHz
 - Relocate, compress, and augment telemetric capabilities
 - *Investigate operational trade-offs from S-Band to C-Band*
 - Invest and upgrade in infrastructure, hardware, and software
 - Mature fielded systems and integrate with new range requirements

Background: Transitioning TM Bands

- Wavelength vs. Frequency
 - S-band Wavelength: 5.26" @ $f_{\text{center}} = 2245$ MHz
 - C-Band Wavelength: 2.47" @ $f_{\text{center}} = 4775$ MHz

Decreased wavelength forces higher element count around missile roll axis
- Transmit Conformal Wraparound Antennas
 - "...C-band antenna contains twice as many elements as the S-band antenna, the interference patterns tend to get more complicated and can be harder to control. As a result, it might be more difficult for a C-band wrap-around antenna to meet a "90% of the gain values must be greater than -7 dBi" specification." ₁
- Receive Dish Antennas
 - Retrofitting and upgrading existing telemetry acquisition & tracking dishes for C-Band operation
 - For a fixed dish diameter, gain increases as wavelength decreases
 - Proportion of dish diameter to wavelength produces narrower beam-width

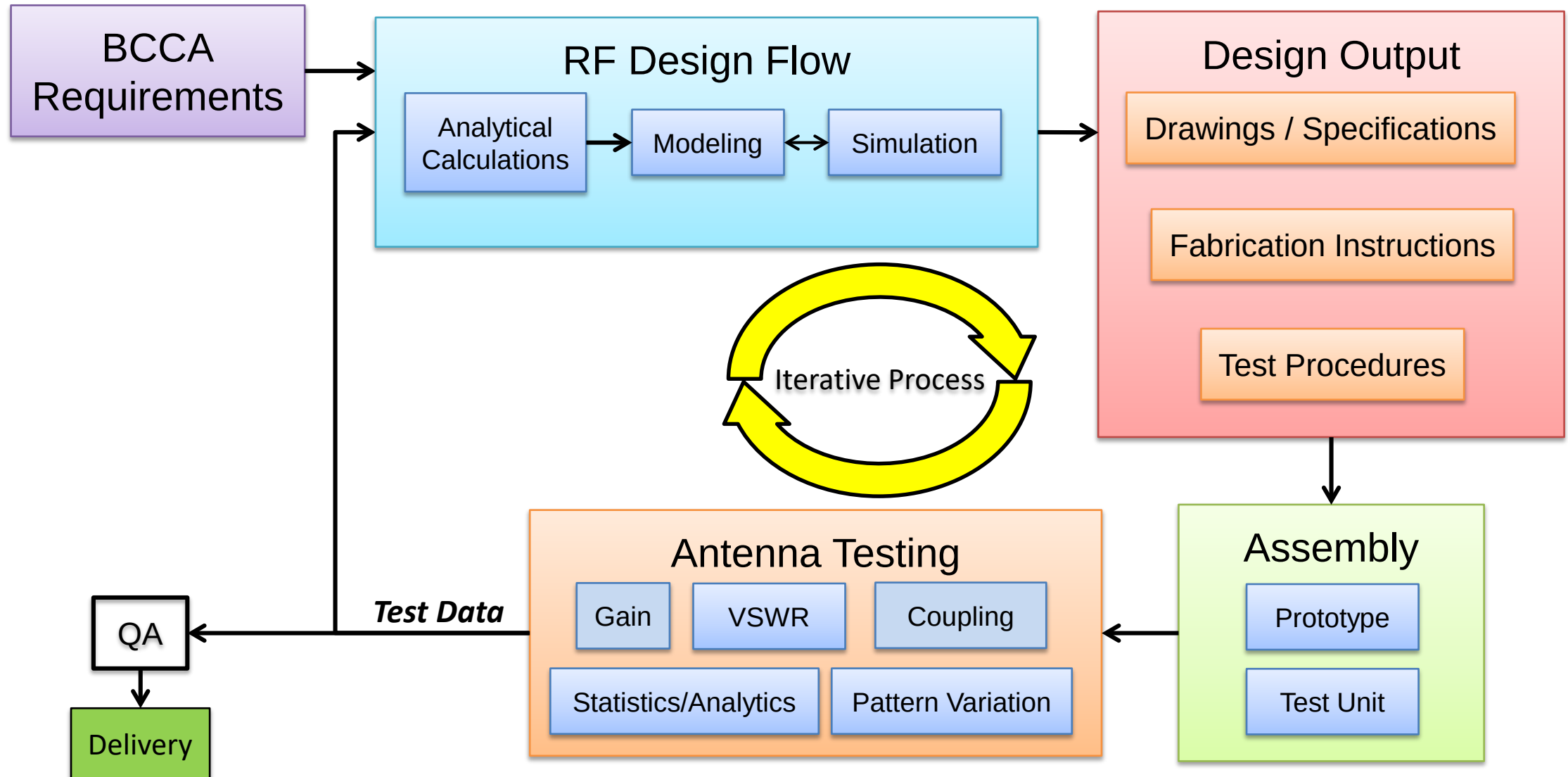
$$G_0 = \left(\frac{\pi D}{\lambda} \right)^2 \eta_i$$
- Link Analysis

- Conformal antenna EIRP: decreased
 - Receive dish G/T: increased
 - Spreading loss: increased
 - Component loss: increased
 - Additional loss: increased
 - Beamwidth: decreased

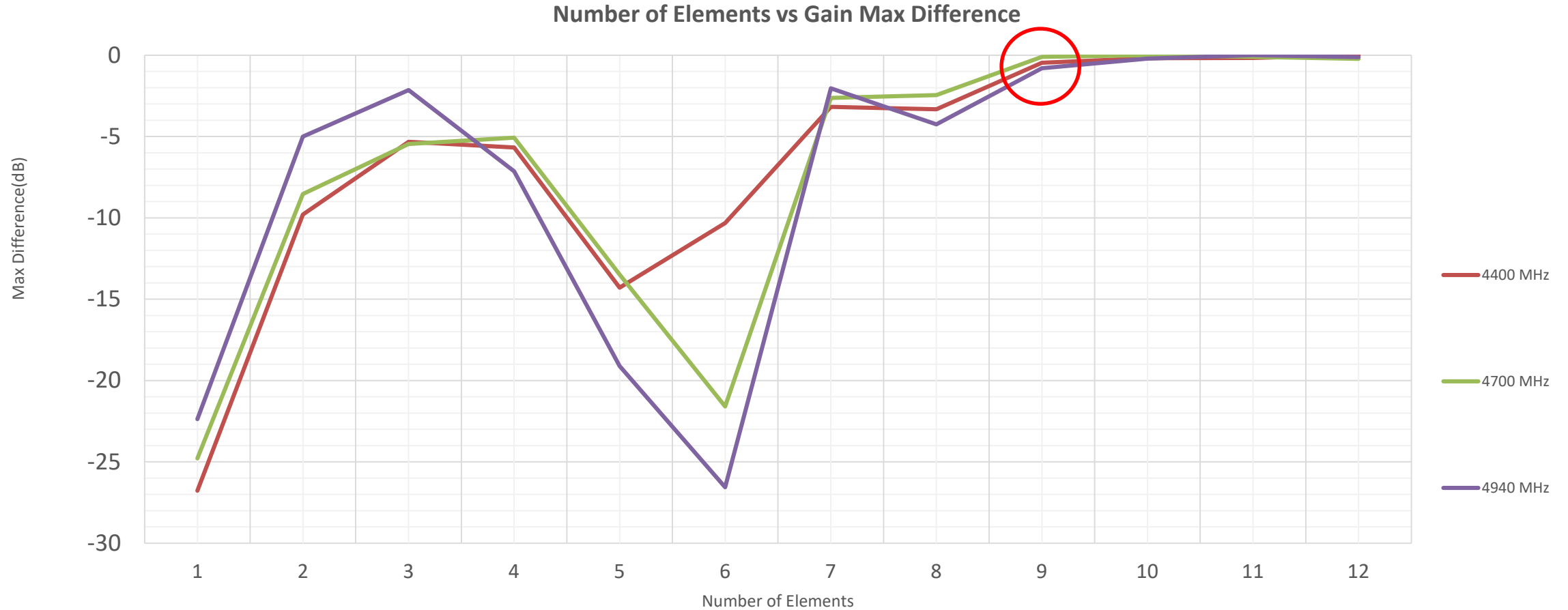
$$\left[\frac{C}{N_0} \right]_{\text{dB}} = \underbrace{\left[P_T G_T(\theta, \phi) \right]_{\text{dB}}}_{\text{EIRP}} + \underbrace{\left[\left(\frac{\lambda}{2\pi R} \right)^2 \right]_{\text{dB}}}_{\text{spreading loss}} + \left[\frac{G_R(\theta', \phi')}{T_{\text{eq}}} \right]_{\text{dB}} - [k]_{\text{dB}} - [L]_{\text{dB}}$$

Net Loss: Increased
- Bottom Line Up Front
 - "The main point is a c-band missile telemetry system must operate with less link margin than an s-band missile telemetry system. How much of a problem this is depends on the application." ₂

T&E: Antenna Design Lifecycle

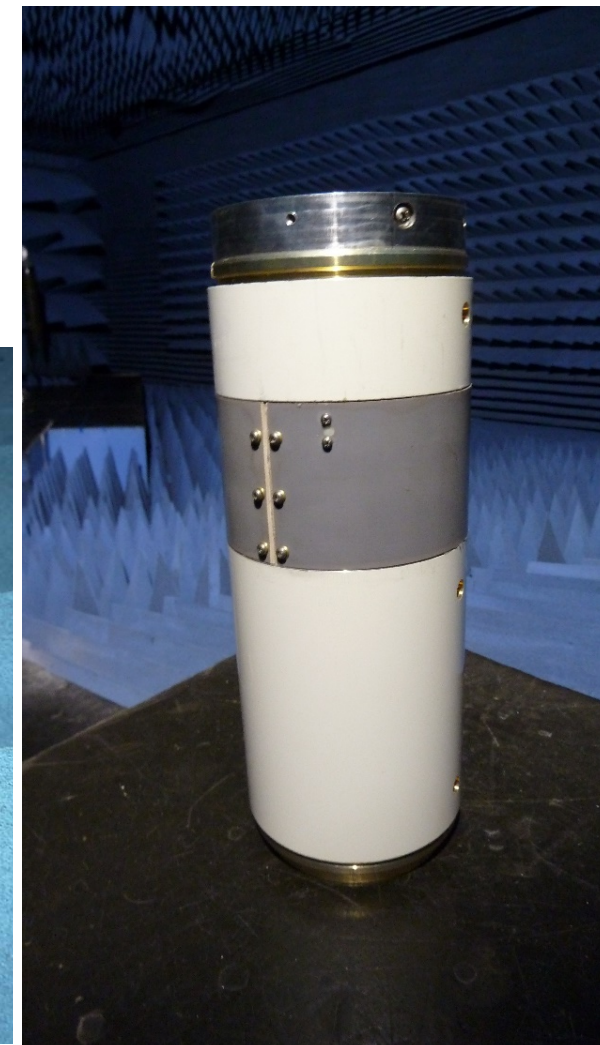
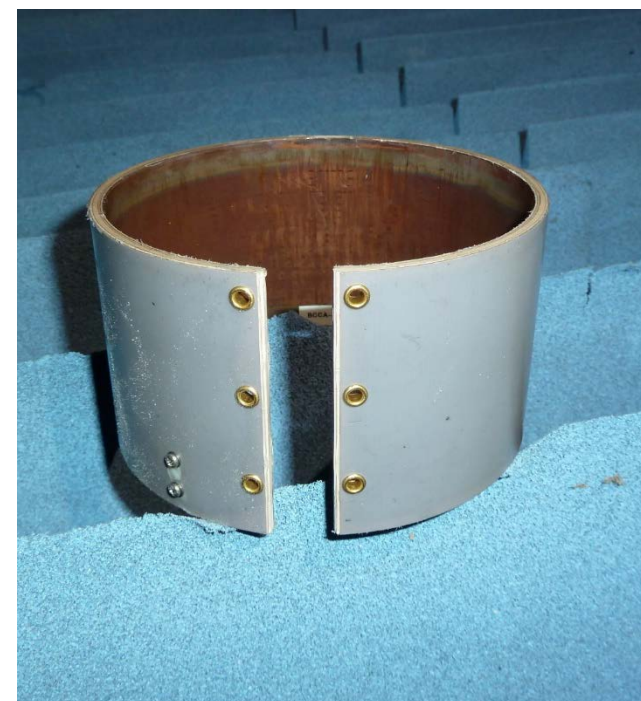
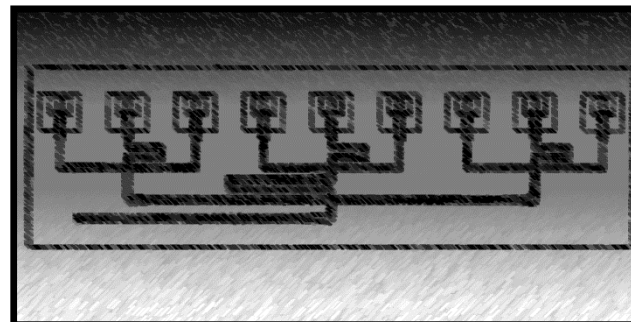


Analysis of Alternatives

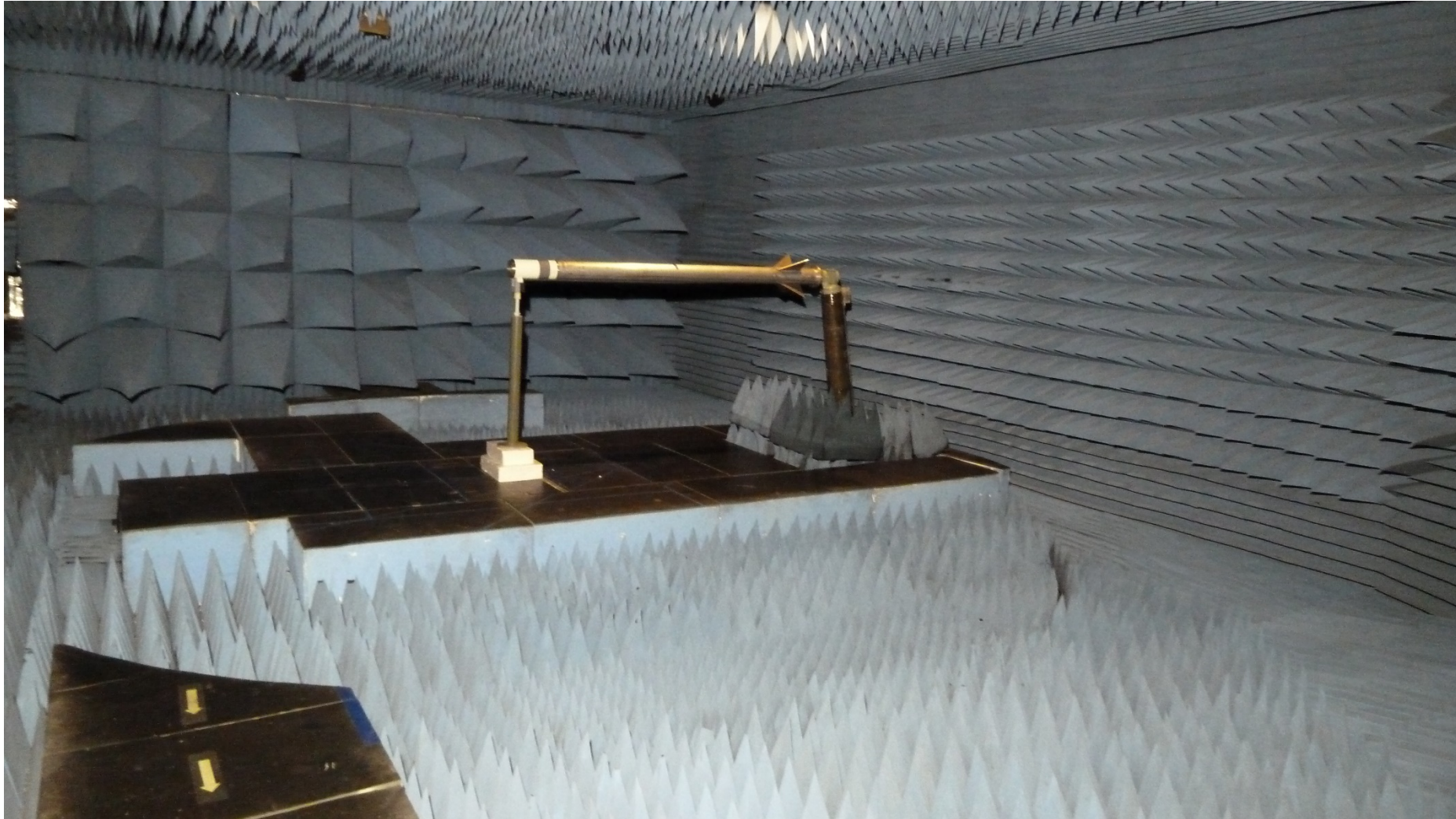


9-Element Conformal Antenna

- Design Approach
 - Antenna Configuration
 - C-Band ready
 - Broadband complex impedance match
 - Form-Fit footprint
 - Highest efficiency
 - Multilayered
 - Reduced gain variation
 - Power distribution objectives
 - Reduce inter-element coupling
 - Reduce feed-to-element coupling
 - Reduce insertion loss
 - Retain phase stability
 - Maintain amplitude stability



Chamber Mockup

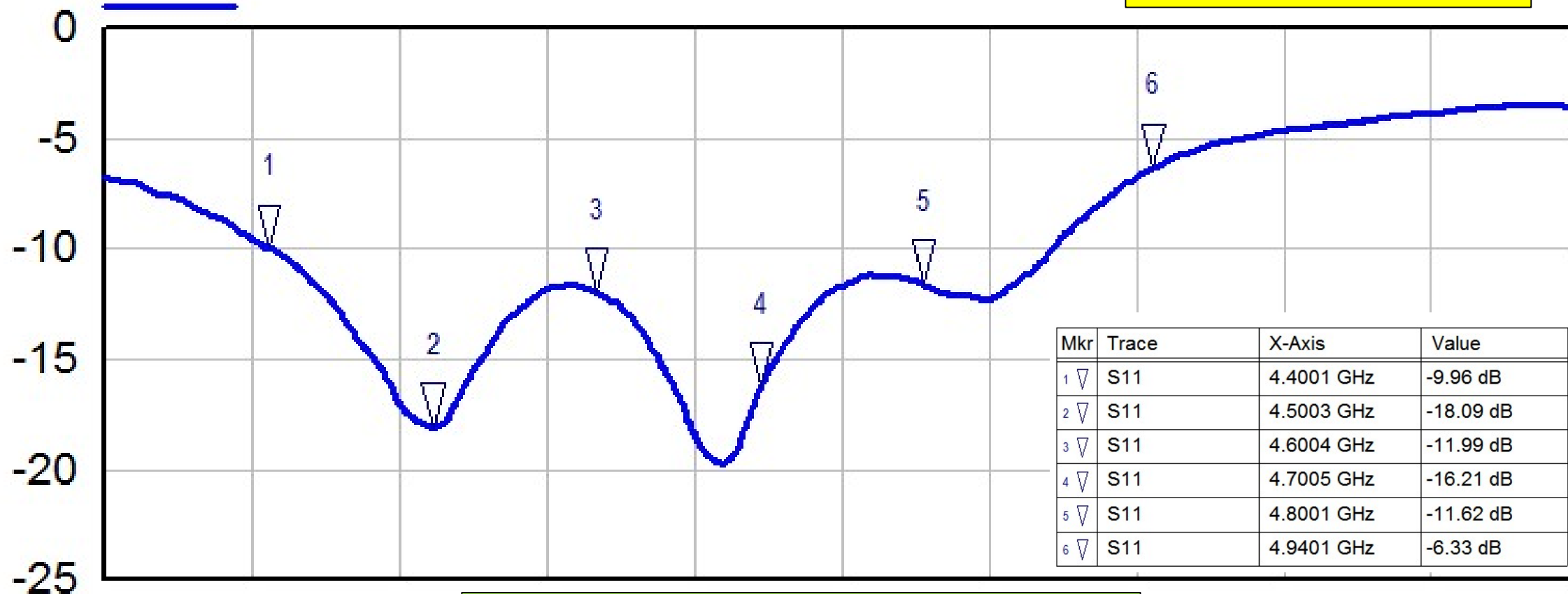


Measured Data: Return Loss

dB

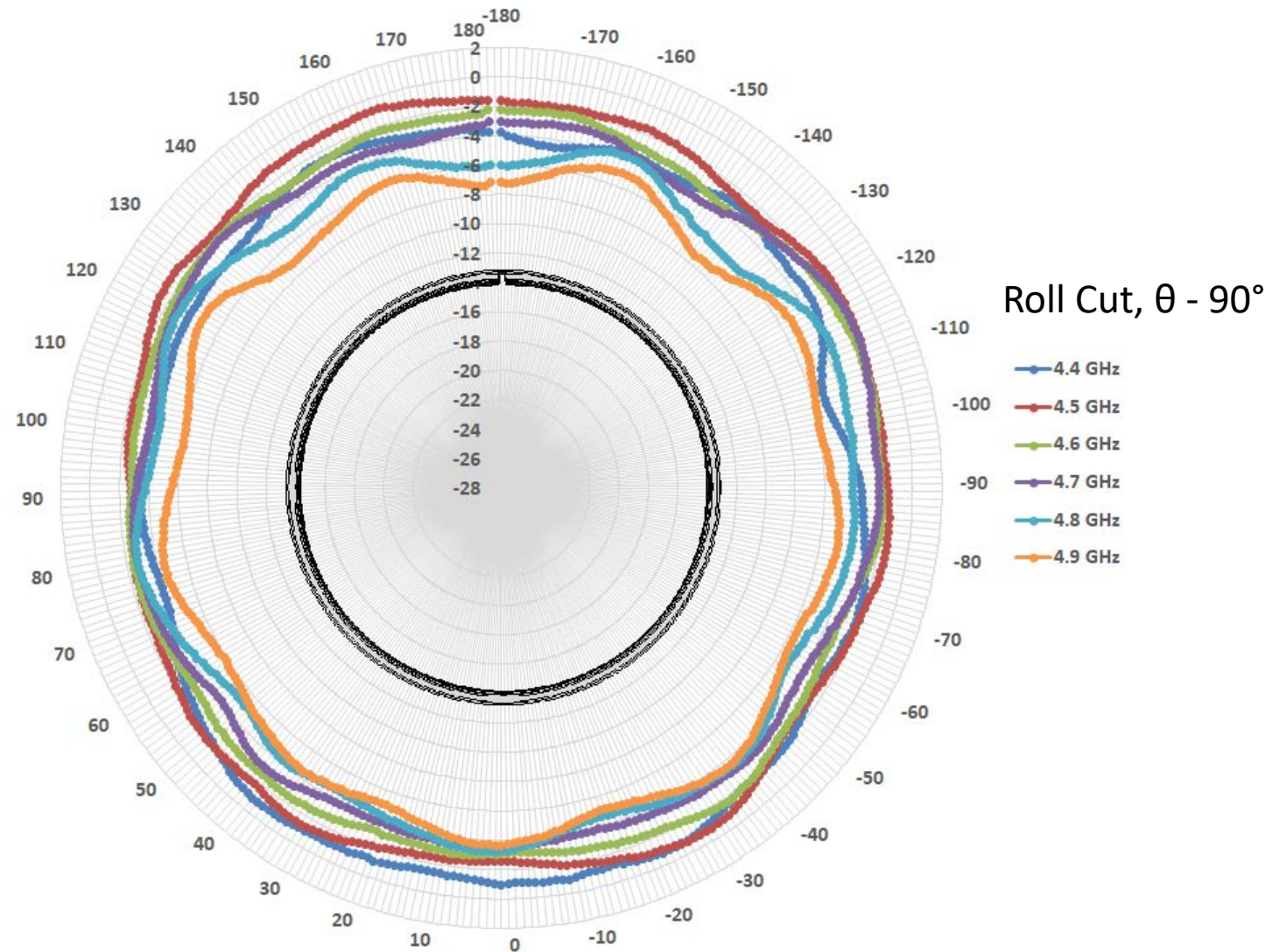
S11

9 Elements- Symmetrical

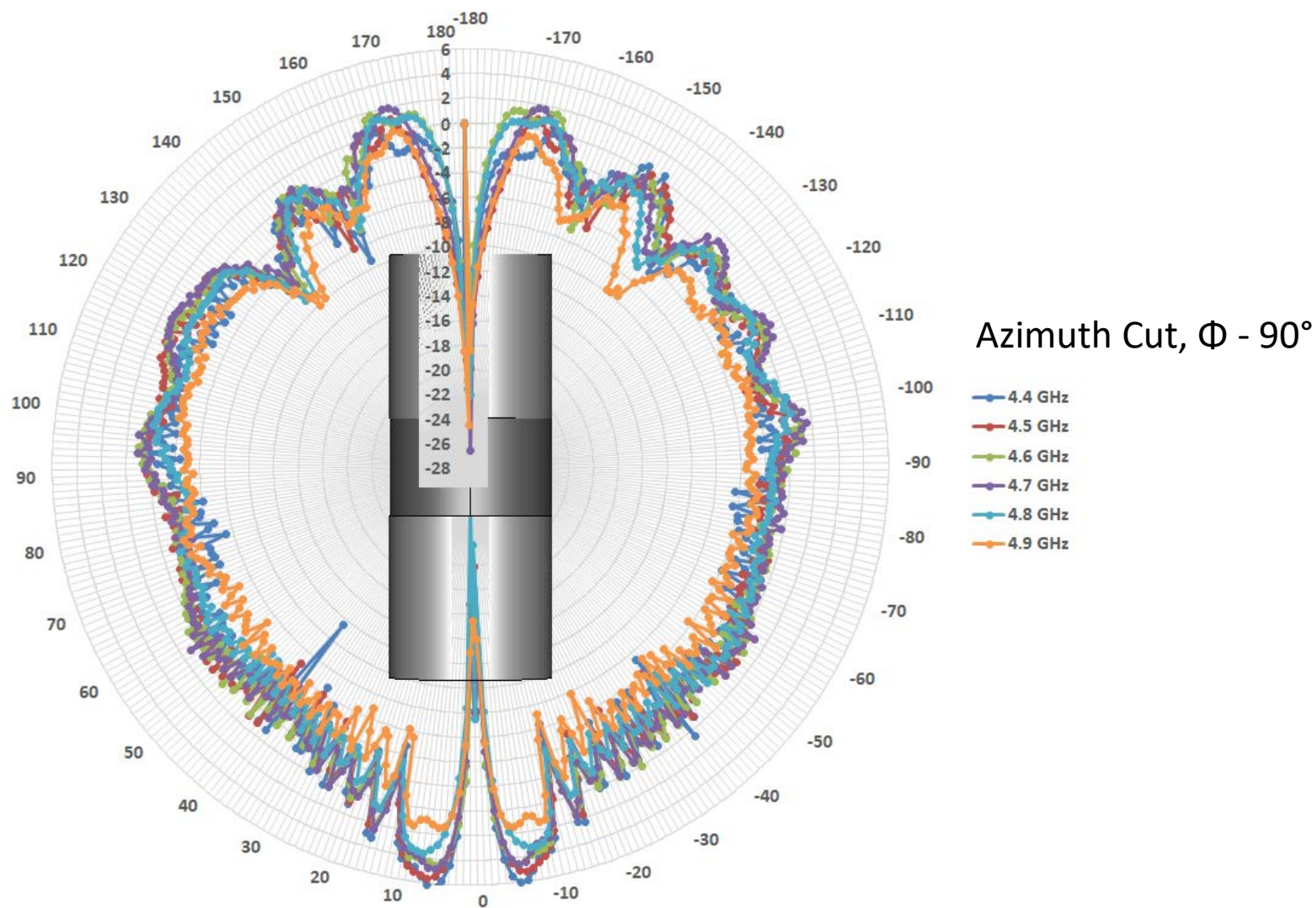


Approximately 440 MHz <2:1 VSWR BW

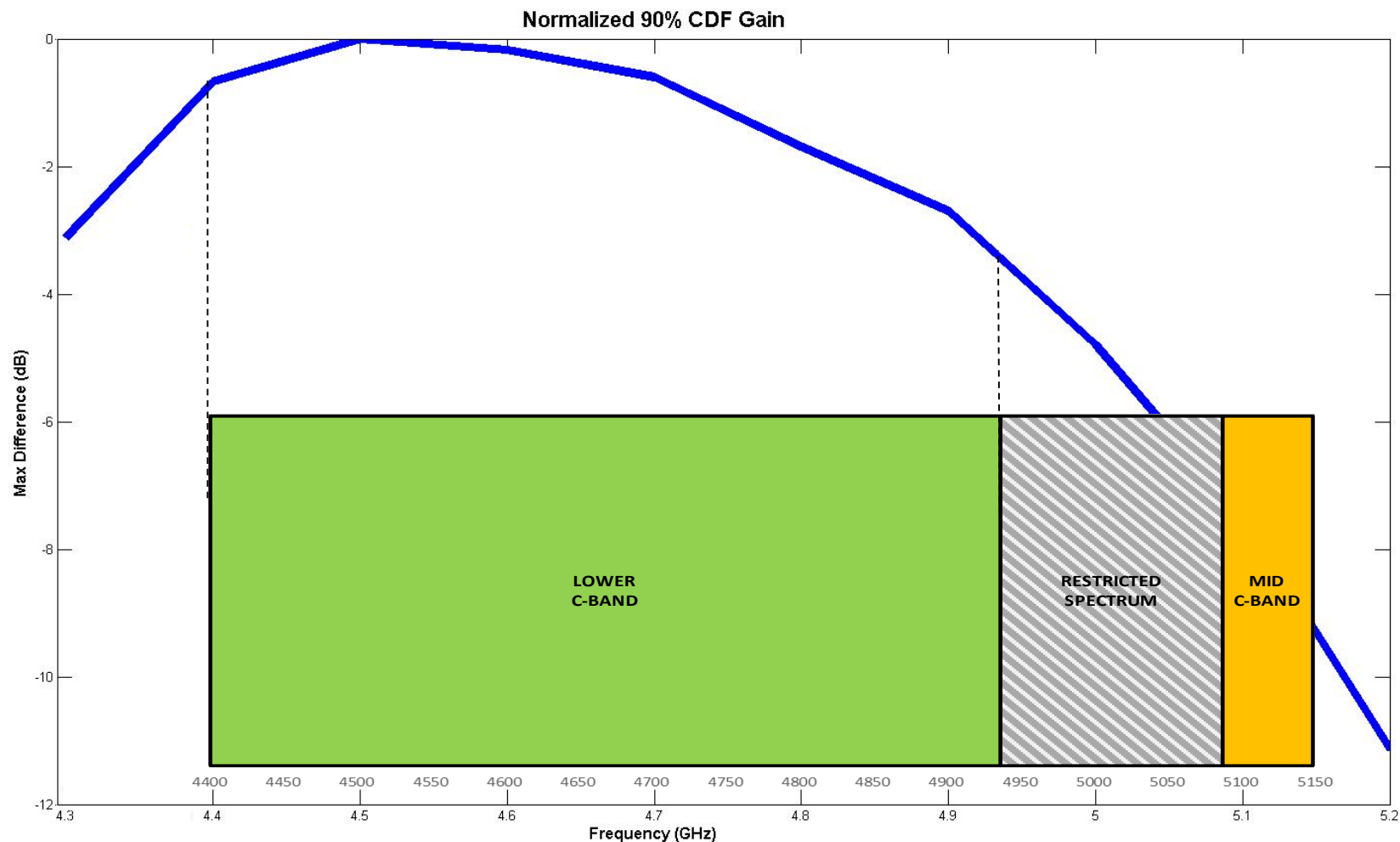
Measured Data: Realized Gain



Measured Data: Realized Gain

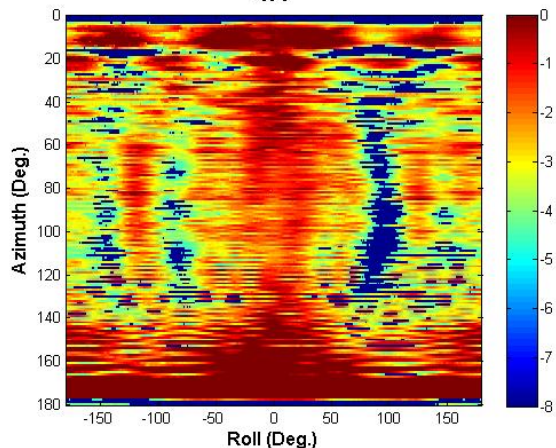


Measured: 90% of Gain Data

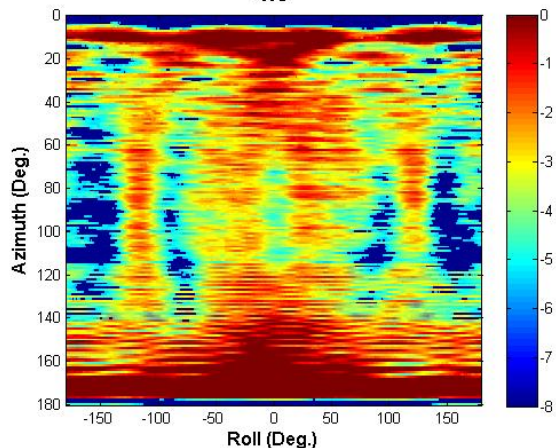


Measured: Normalized Gain Plots

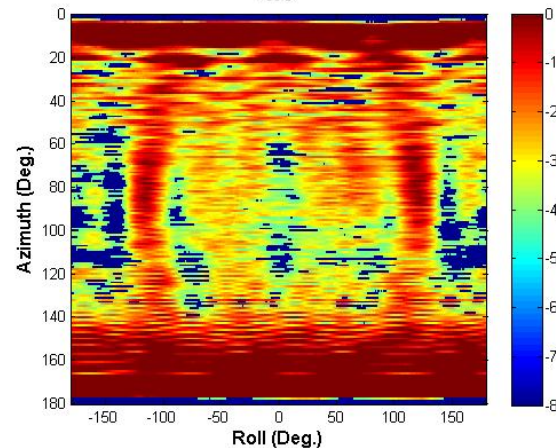
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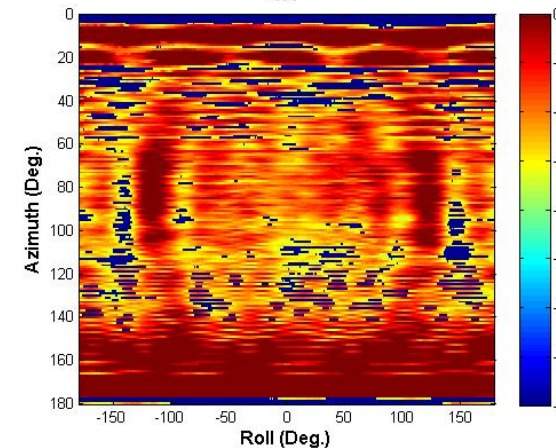
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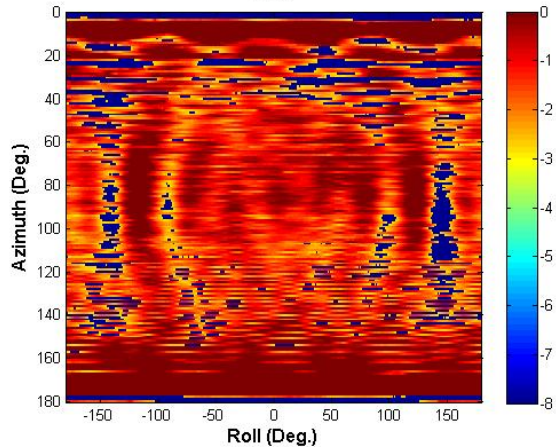
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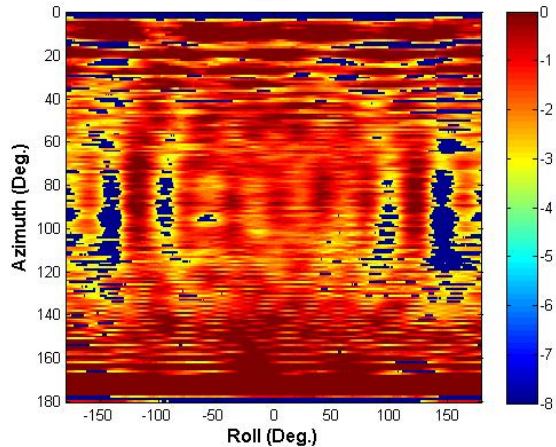
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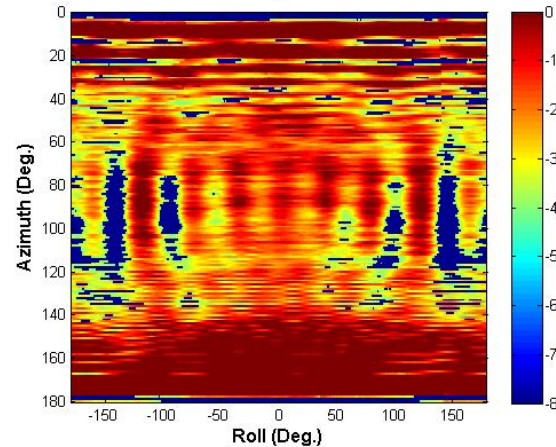
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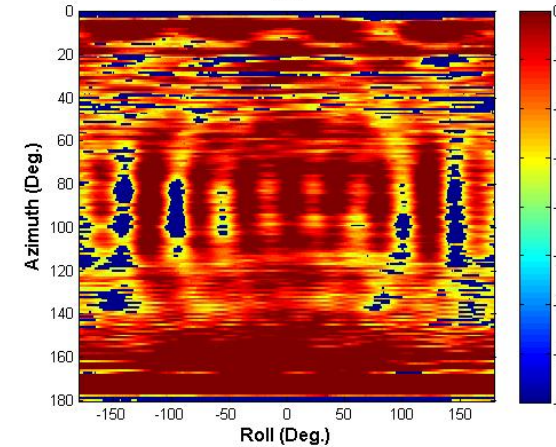
4.9



5



5.1



Link Analysis: TM Band Comparison

Location	Link Range S-Band	Link Range C-Band	S vs. C Delta	Test Range Size
<i>China Lake</i>	54.4	52.6	1.8	35
<i>Eglin</i>	97.8	72.1	25.7	187
<i>Mugu</i>	146.5	148.4	1.9	116
<i>SNI</i>	58.3	148.4	90.1	116

*C-Band gain value obtained from DP01

Summary

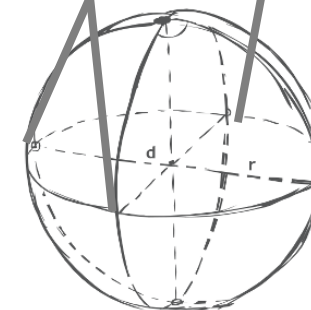
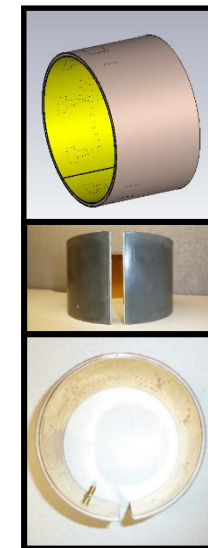
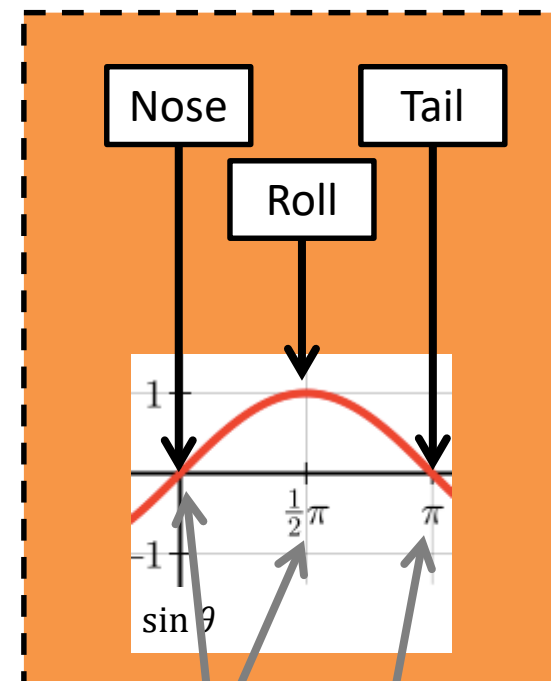
- Designed and Developed Broadband C-Band Conformal Antenna
 - Characterized RF performance
 - Maximized ERP Performance
 - Matured aerodynamic and mechanical footprint
 - Analyzed TM link performance with Test Range Data
 - Presented S-Band vs. C-Band Tradeoffs

QUESTIONS?

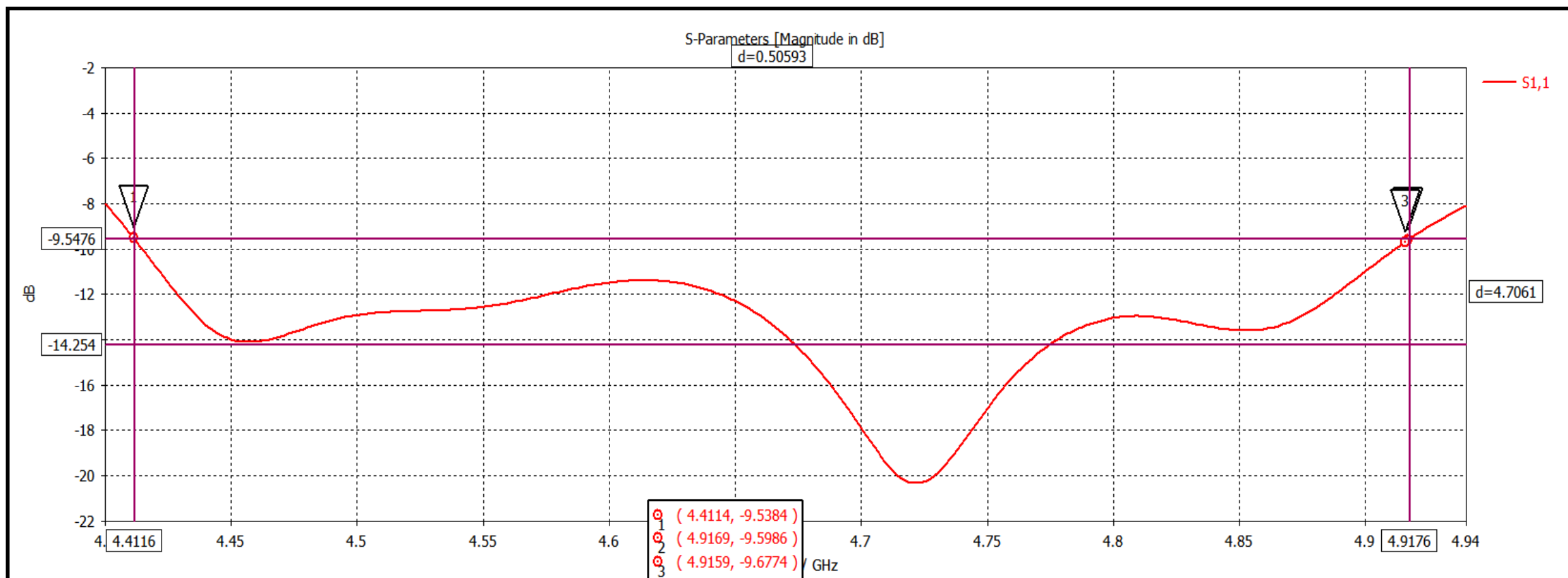
BACKUPS

Intensity Plots: Spherical Data

- X Axis = Roll (ϕ)
- Y Axis = Azimuth (θ)
- Weight Distribution: $\sin(\theta)$
 - Poles become negligible
 - Roll weight highest, $\theta = 90^\circ$
- Gain
 - Highest Gain: Red/Yellow
 - Lowest Gain: Purple/Blue

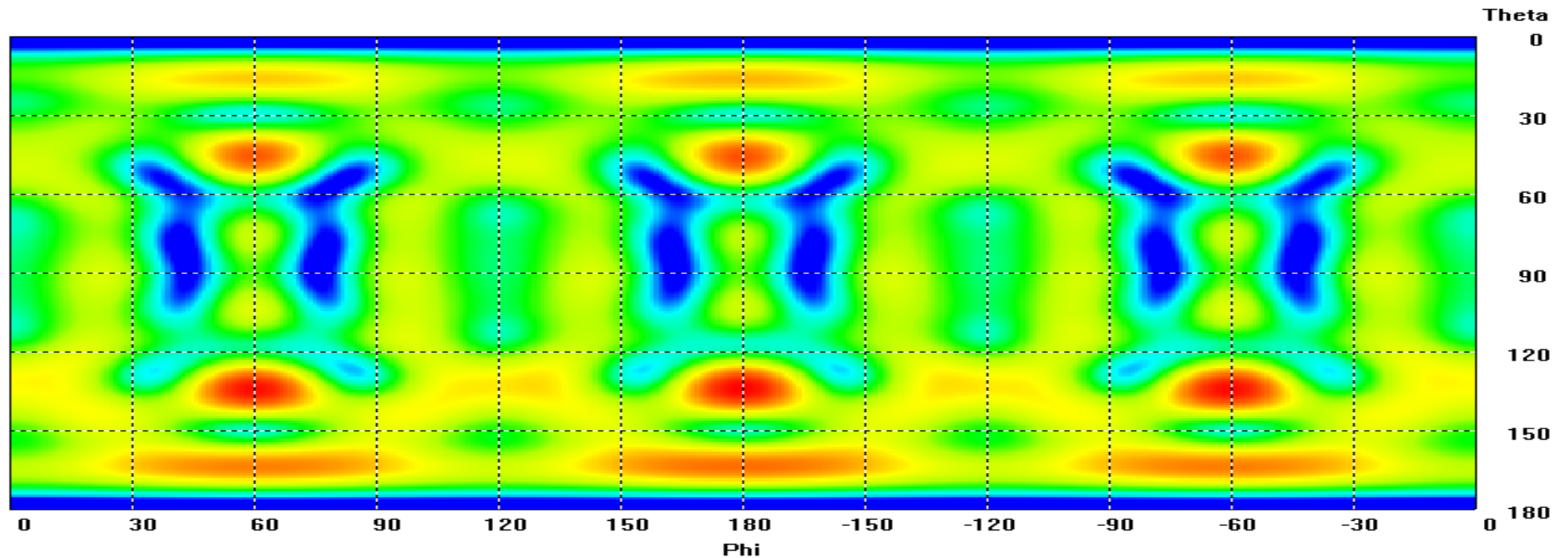


Simulation Data: Return Loss

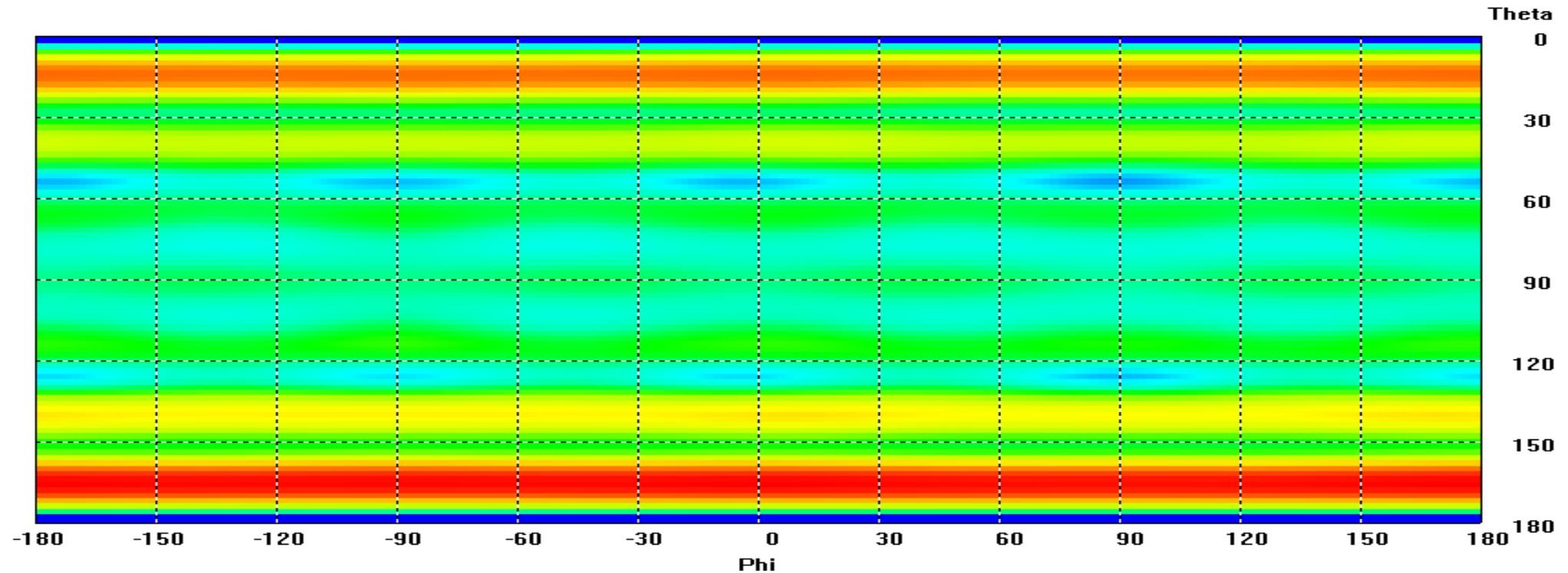


Approximately 500 MHz <2:1 VSWR BW

Simulation: 3 Element Configuration



Simulation: 11 Element Configuration



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