ni.com/awr

Antenna Synthesis for IoT and Wireless Applications

International IoT Seminar

Building Next Generation IoT & Wireless Devices and Solutions

August 24, 2017

NATIONAL INSTRUMENTS

Outline

- Introduction to Antenna Synthesis
- AntSyn System Description
- Examples

Antenna Design Challenges

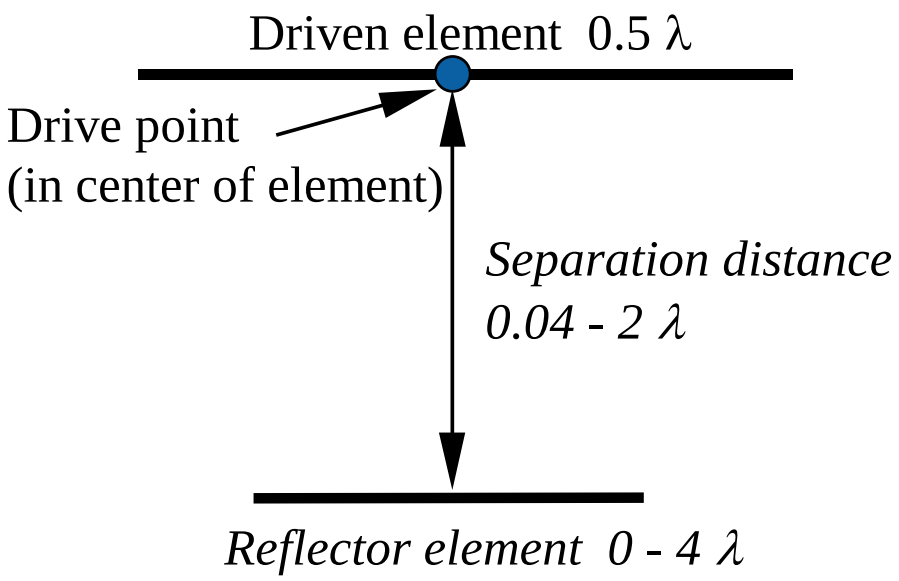
- Challenging size, cost & performance goals
- Shortage of experienced designers
- Time and budget are under pressure
- Productivity difficult when wrestling with physics

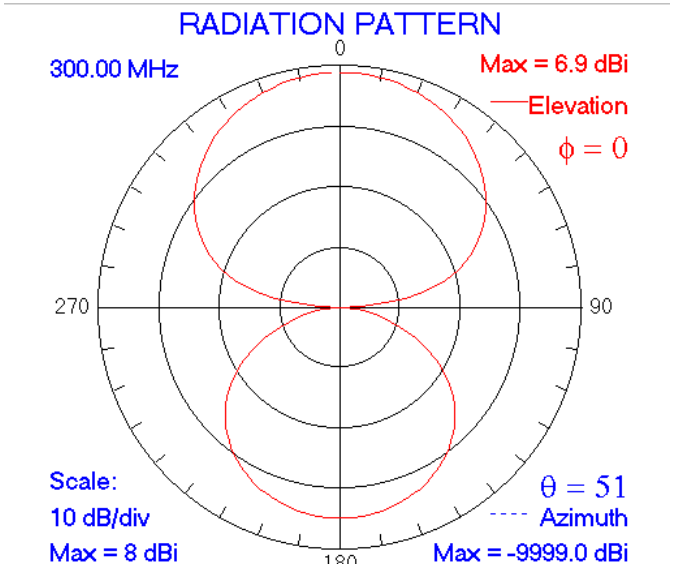
Difficult to Design?

- Enormous range of possible solutions for even the simplest antennas
- Limitless number of antenna shapes to choose from
- Optimum design is often non-intuitive and difficult to find
- EM simulation is very expensive for “blind” optimization

How Difficult is Antenna Design?

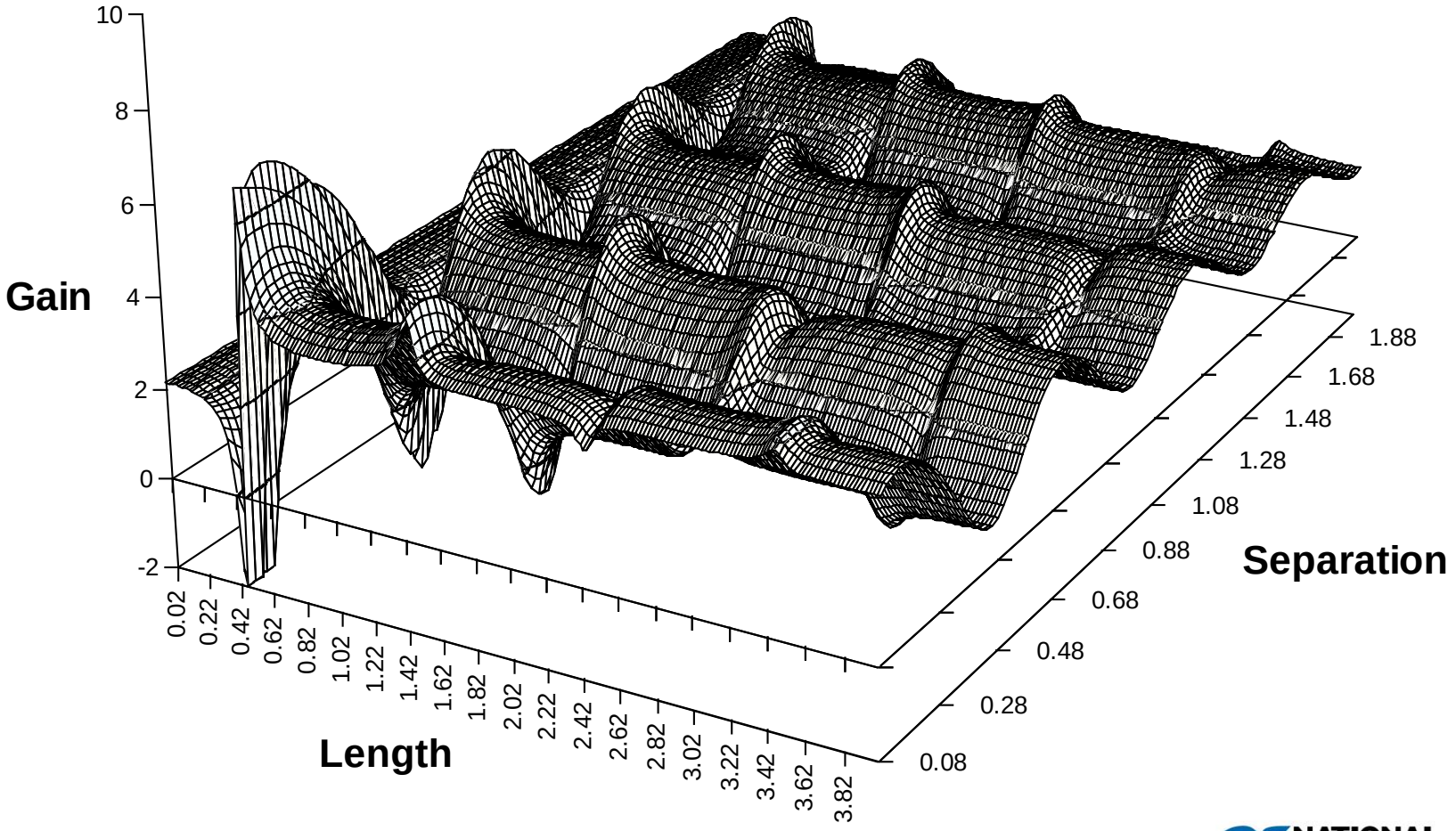
A Simple Wire Antenna Example





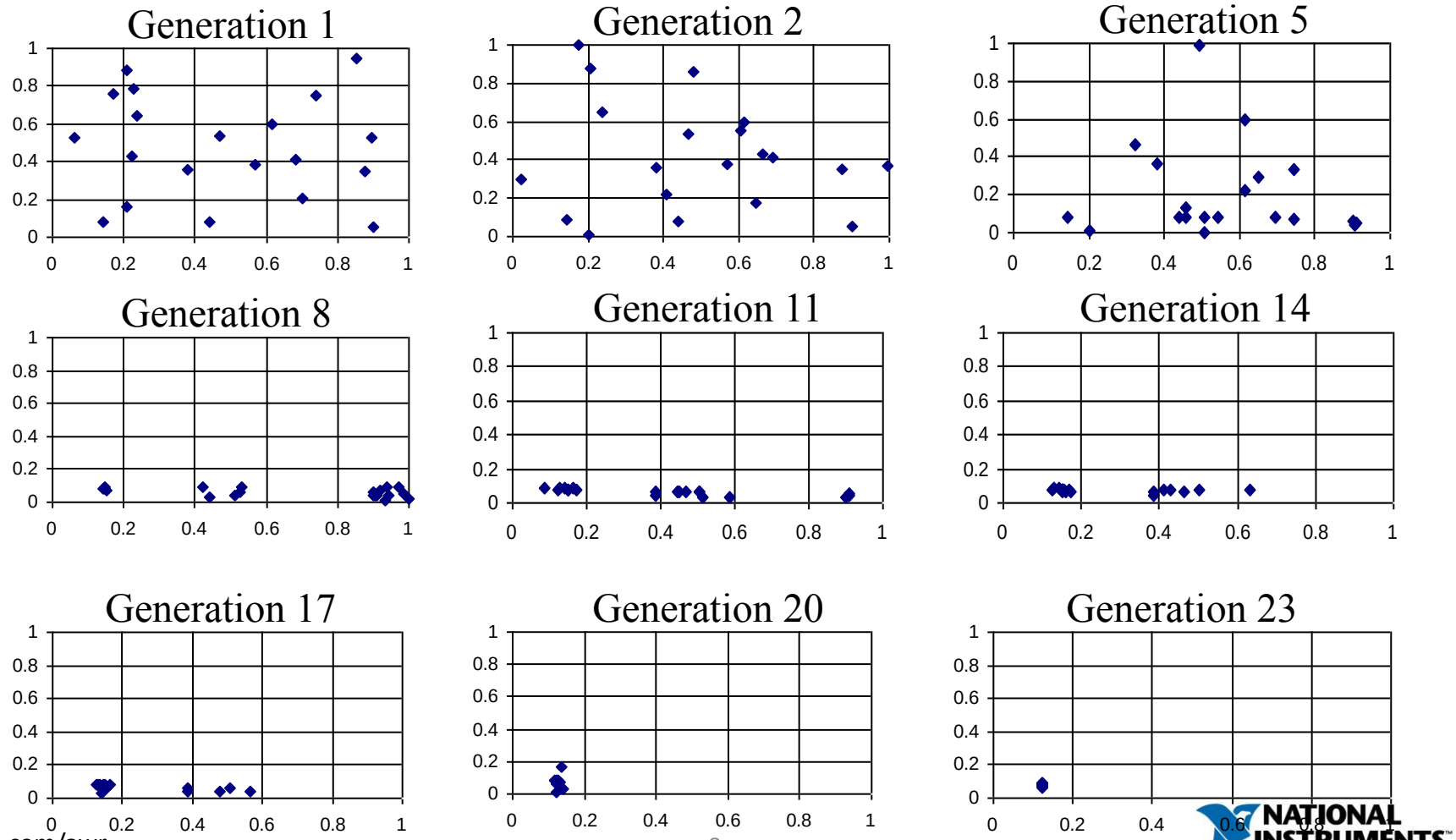
Linden, 1997

How Difficult is Antenna Design?



Genetic Algorithm Optimization

A Genetic Algorithm can focus in on most useful areas of search space



What is Antenna Synthesis?

- Imagine a system that automates the antenna design process for both Systems/RF Engineers and Antenna Experts
- Requires:
  - Expert system for antenna selection, fitness scoring, representation, etc.
  - Antenna optimization engine

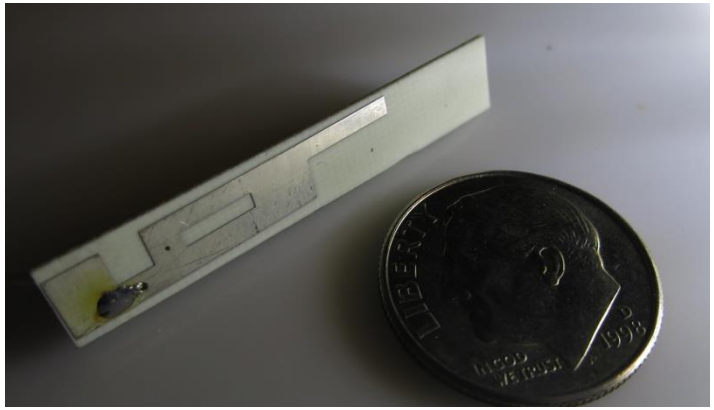
Antenna specs → **Synth** → Antenna Design

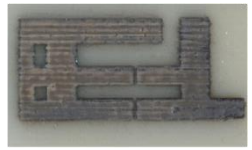
How It Works

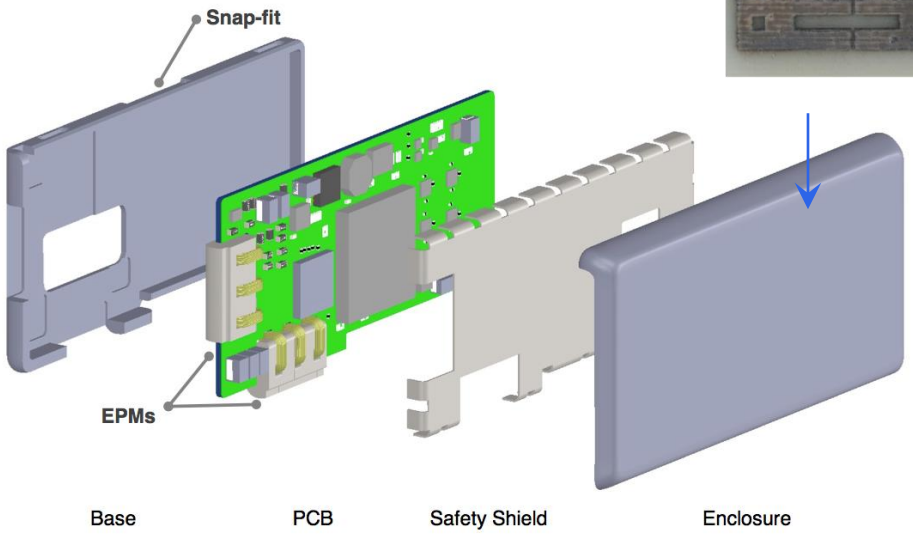
- Antenna performance requirements are defined by the user - not the model
- Advanced algorithm performs smart optimization, eliminating weaker solutions with each iteration
- EM solver used to provide accurate evaluation of candidate antennas

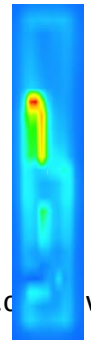
Design by Requirements: What you want is what you get

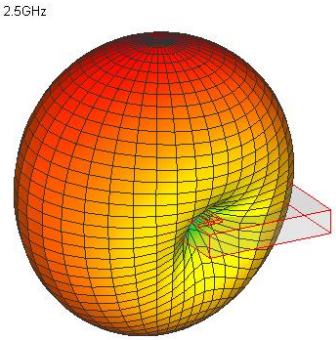
Google's Project Ara Smartphone











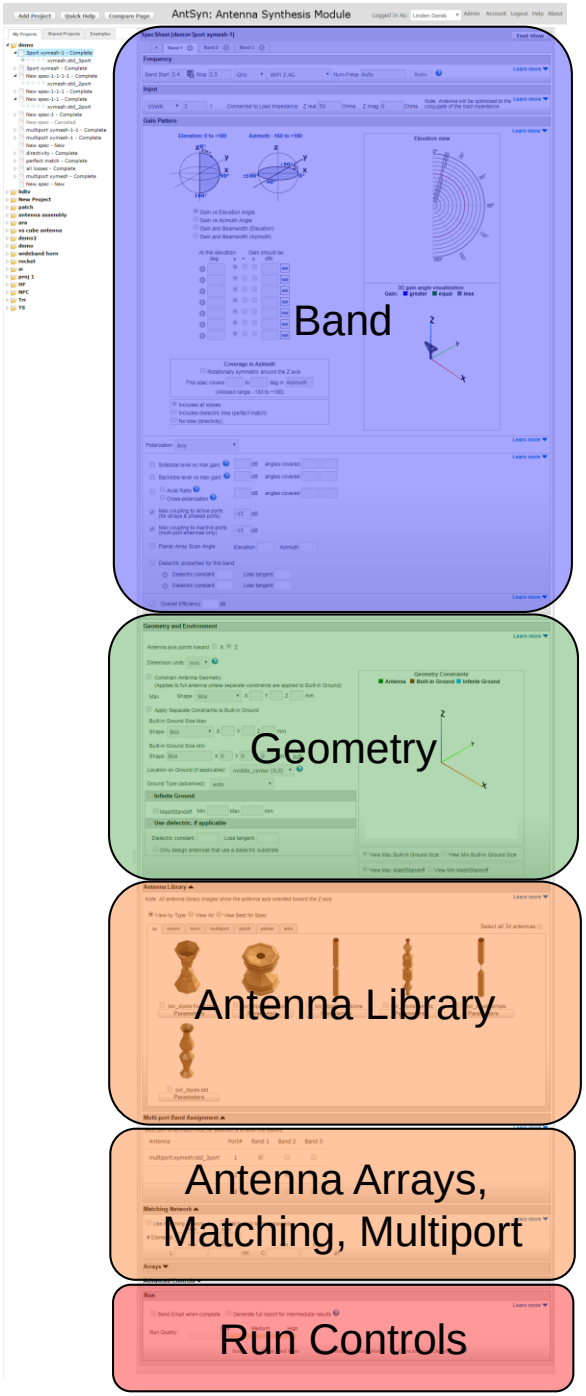
NATIONAL INSTRUMENTS

Antenna Synthesis Benefits

- All levels of engineer can develop optimum antennas
  - Senior engineers rapidly gain more insight
  - Less experienced designers can produce excellent designs
- Explore more design space with smart optimization while reducing local EM simulation loading
- Scalable with compute power
- Increases reliability of finding a solution quickly
  - Reduces risk, rework, and failed projects
- Easy to use and intuitive

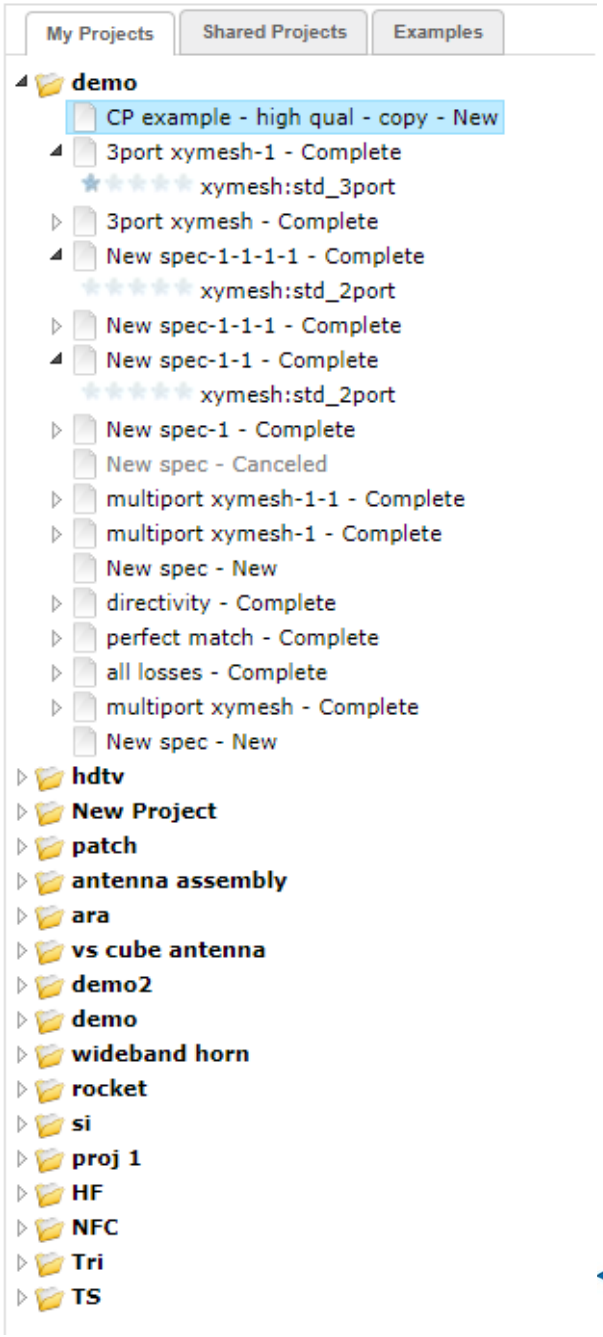
Spec Sheet Overview

- Spec sheets are used to collect antenna requirements
  - Band
    - Pattern
    - Input impedance and reflection
  - Geometry
    - Bounding box/cylinder
    - Separate ground specifications
    - Infinite ground
    - Mast/standoff
  - Antenna Library
  - Advanced: arrays, matching, etc.
  - Run controls



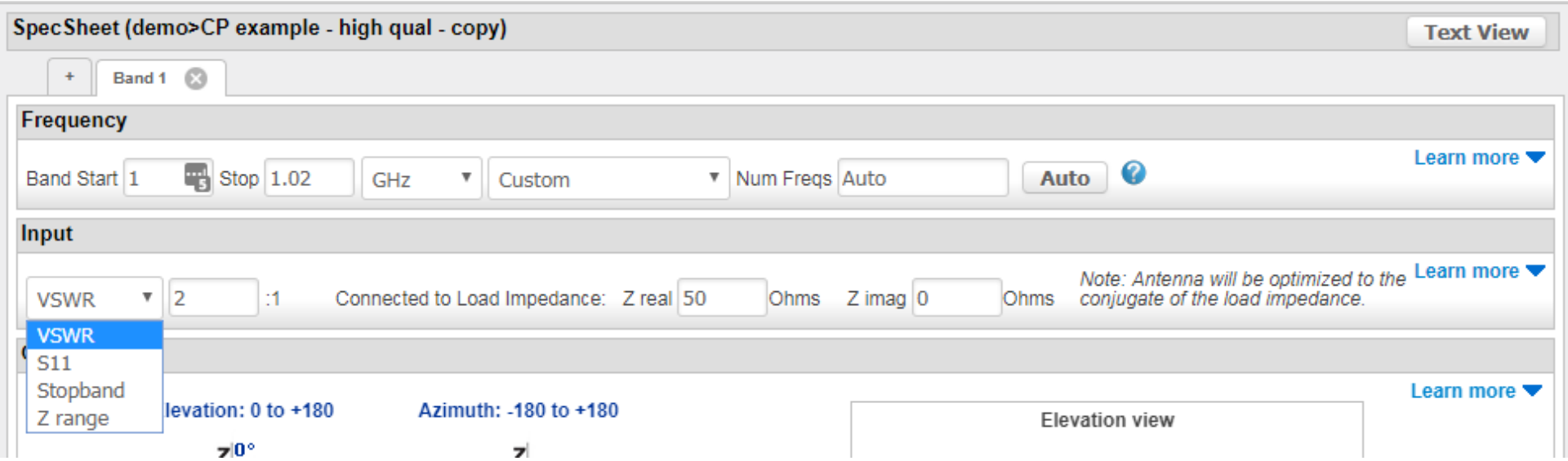
The AntSyn Spec Sheet

- Spec sheets are grouped into project folders

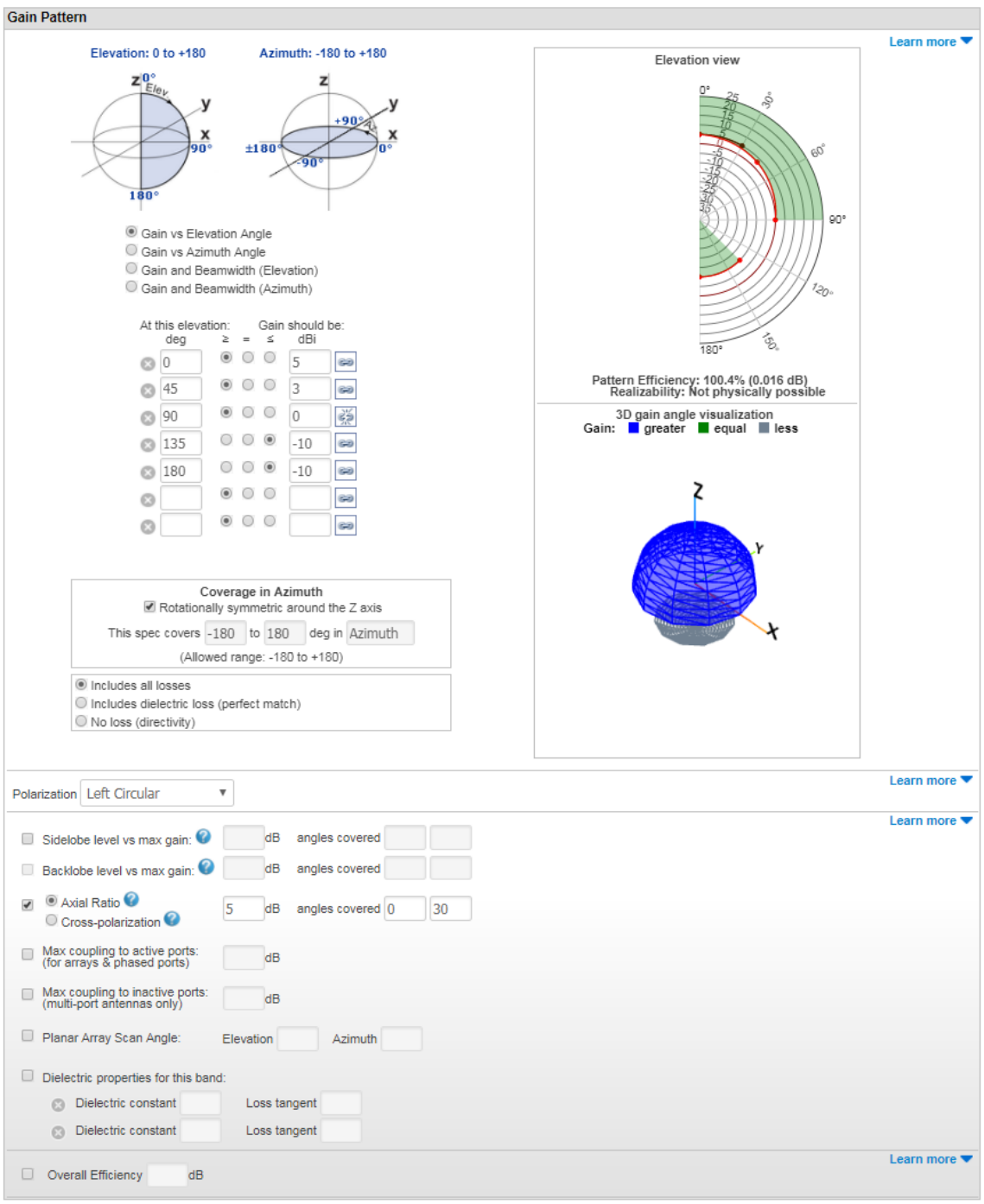


NATIONAL INSTRUMENTS

Bands, Frequencies, Input Impedance



Pattern



ni.com/awr

NATIONAL INSTRUMENTS

Geometry

Geometry and Environment

Learn more

Antenna axis points toward ○ X ◉ Z

Dimension units: cm

☑ Constrain Antenna Geometry
(Applies to full antenna unless separate constraints are applied to Built-in Ground)

Max Shape: Box X 30 Y 30 Z 60 cm

☑ Apply Separate Constraints to Built-in Ground

Built-in Ground Size Max

Shape: Box X 60 Y 60 Z 10 cm

Built-in Ground Size Min

Shape: Box X 30 Y 30 Z 0 cm auto

Location on Ground (if applicable): middle_center (0,0)

Ground Type (advanced): auto

☐ **Infinite Ground**

☐ Mast/Standoff Min Max cm

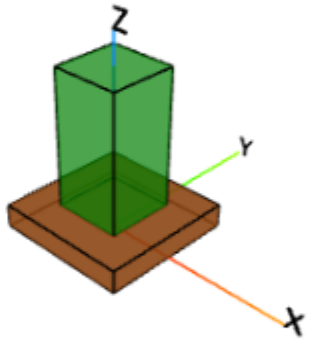
☐ **Use dielectric, if applicable**

Dielectric constant: Loss tangent:

☐ Only design antennas that use a dielectric substrate

Geometry Constraints

Antenna Built-in Ground Infinite Ground

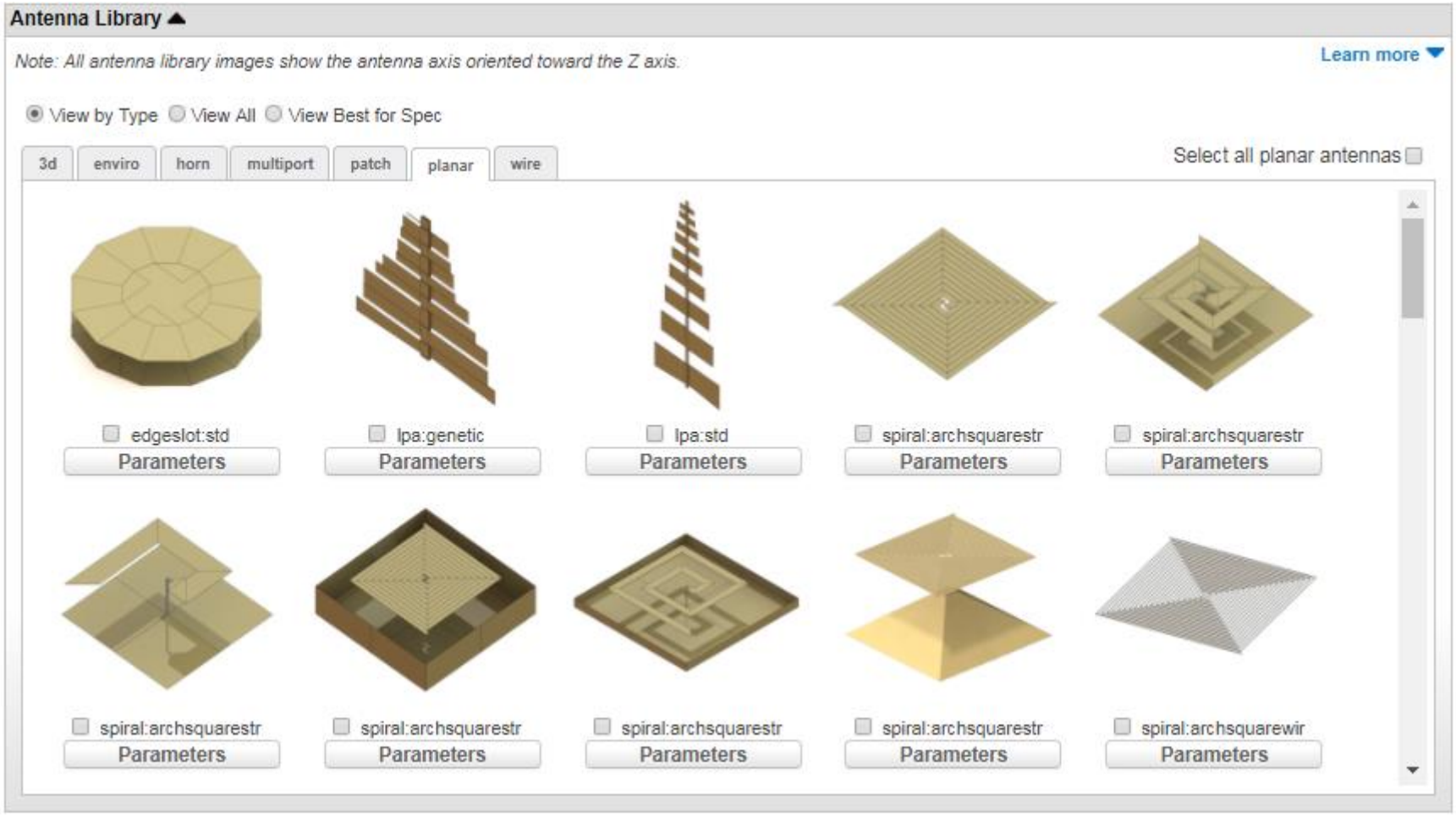


◉ View Max Built-in Ground Size ○ View Min Built-in Ground Size

◉ View Max Mast/Standoff ○ View Min Mast/Standoff

NATIONAL INSTRUMENTS

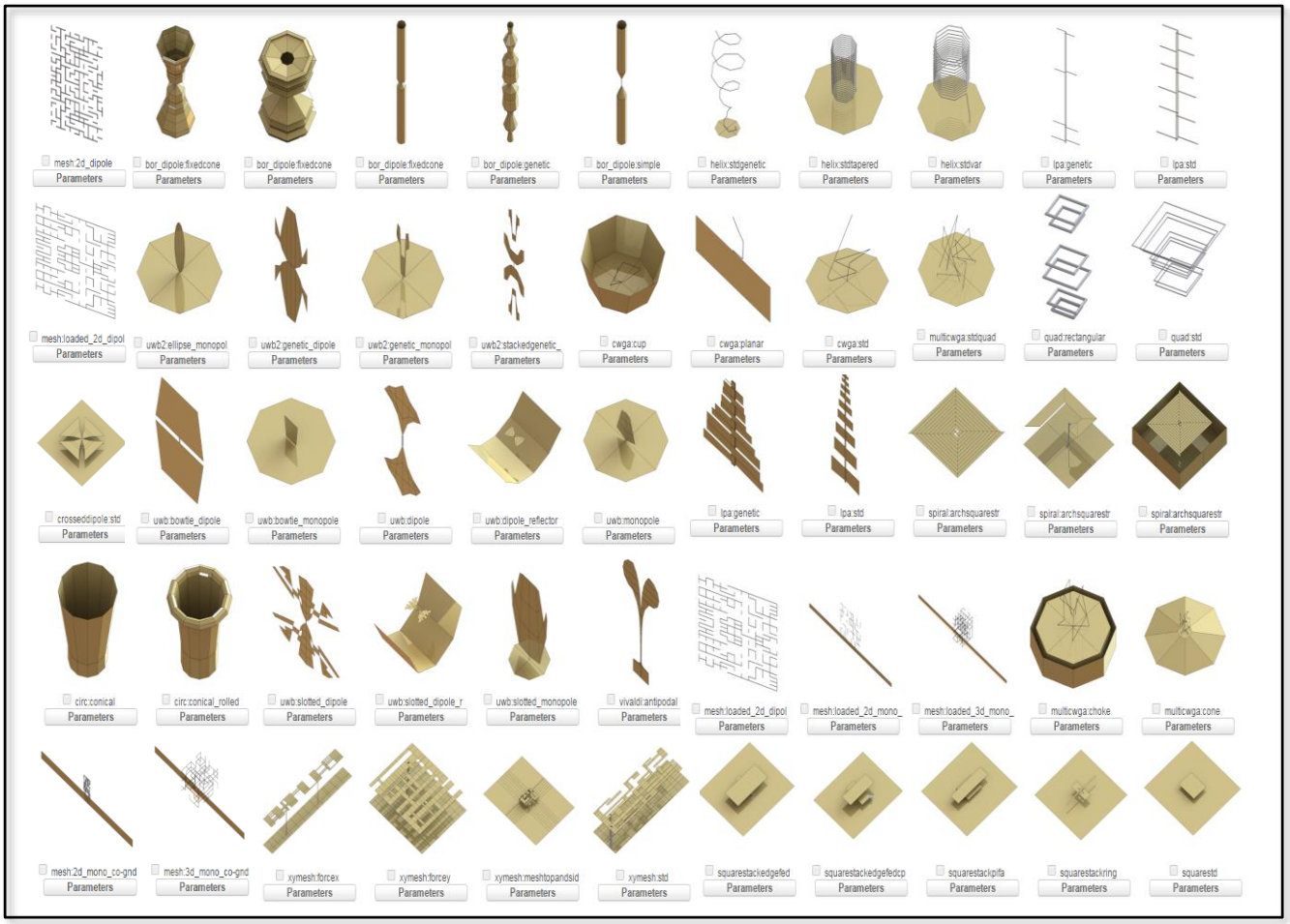
Antenna Library



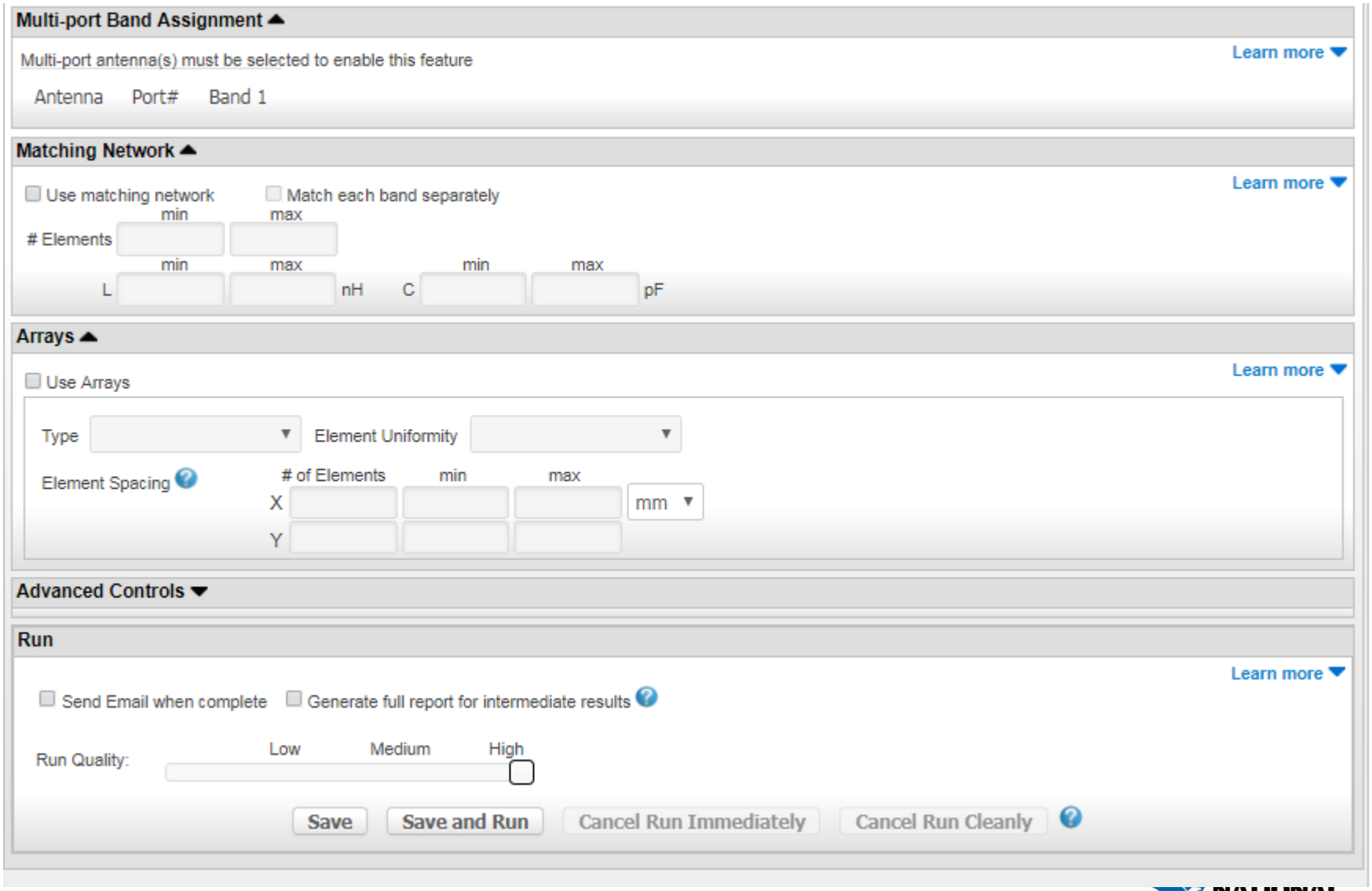
Antenna Library

- 189 Antenna Styles and Growing

- Wideband 3d Dipoles
- Horns (circular, square)
- Multi-port antennas (e.g., crossed dipoles)
- Patch antennas
- Edge-slot antenna
- LPAs (wire and planar)
- Wire collinear-dipole arrays
- Crooked-wire genetic antennas (CWGAs)
- Helices & quadrifilar helices
- Wire mesh antennas
- Branching or multi-wire CWGAs (monopoles & quadrifilars)
- Quad antennas
- Yagi antennas
- Planar mesh antennas (e.g., PIFA-like internal antennas)
- Vivaldi-style antipodal antenna
- UWB planar dipoles and monopoles
- Square spirals (wire and planar)

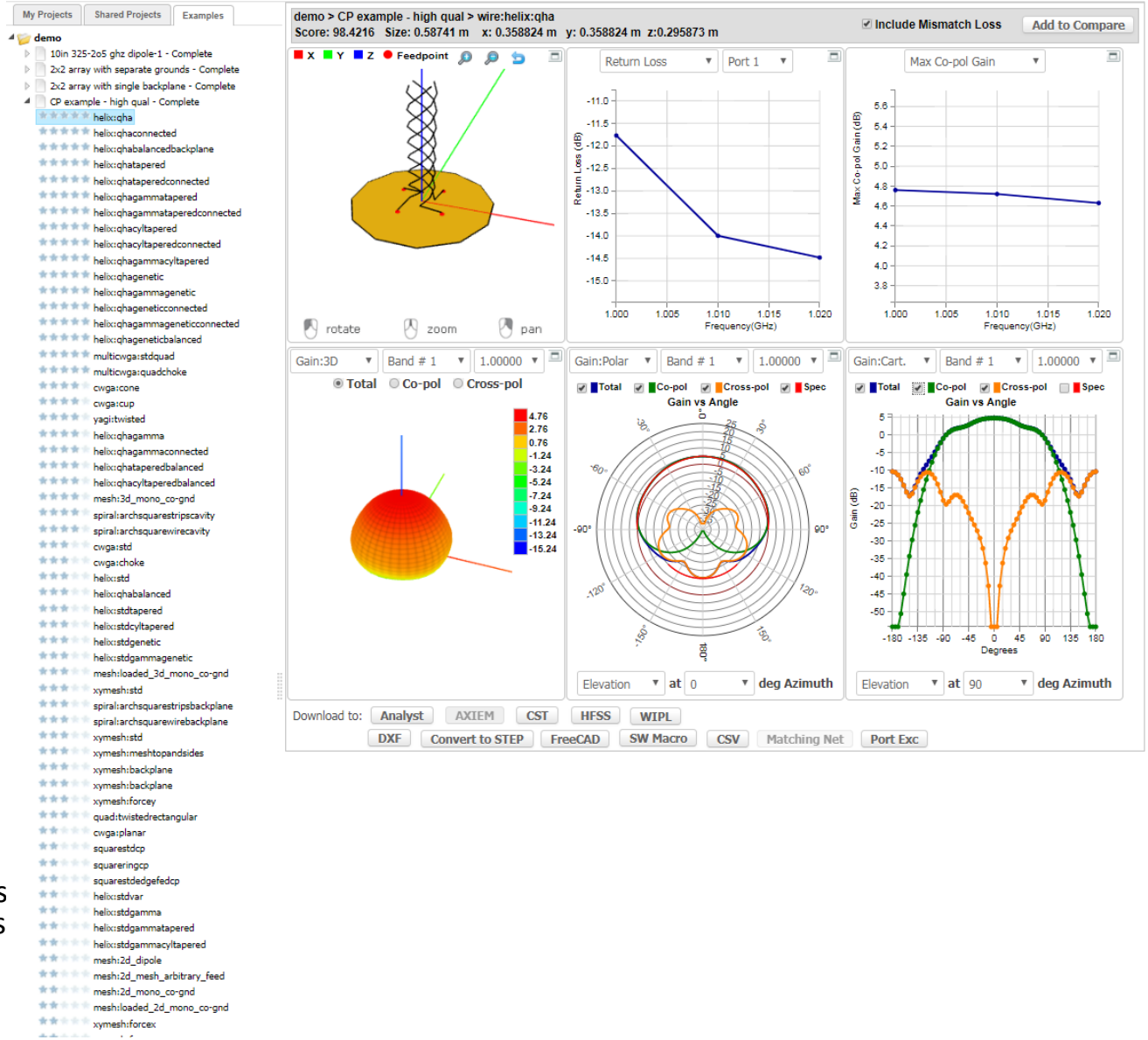


Advanced: multi-port, matching, arrays



Results

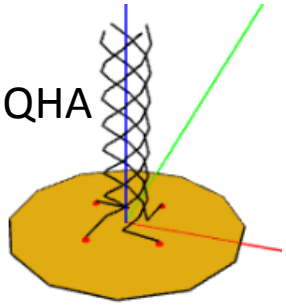
- When spec sheet is run, AntSyn returns one or more optimized antenna designs
- Star ratings give qualitative measure of performance vs specs for quick overview of performance
- Results are viewed using a customizable dashboard allows rapid evaluation
  - 3D rough model
  - Input performance vs freq in several formats, including:
    - VSWR
    - Return loss (dB)
    - Z real, Z imaginary
    - Smith chart
  - Max gain vs freq
  - Pattern cuts
    - 3 panels, user settable
    - Total, Co-pol, Cross-pol in any combination
  - Qualitative star-rating helps to identify good performers quickly
- Download to many simulator and CAD formats available

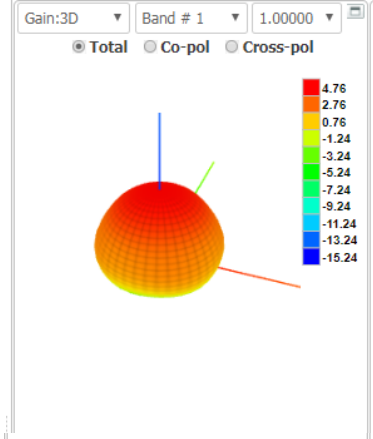


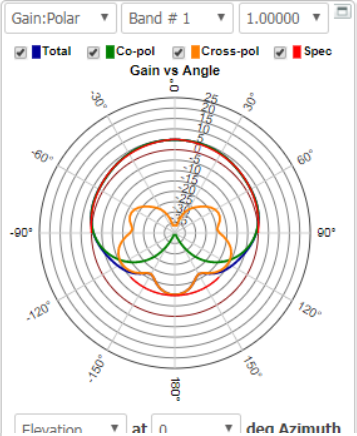
Results

- These three antennas came from 1 run, along with 68 others

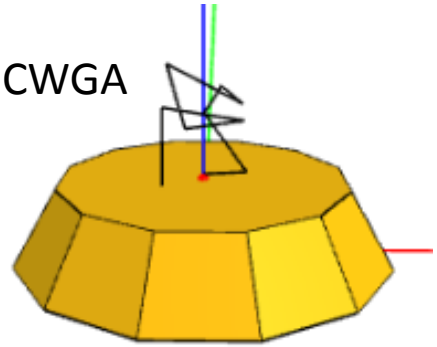
QHA

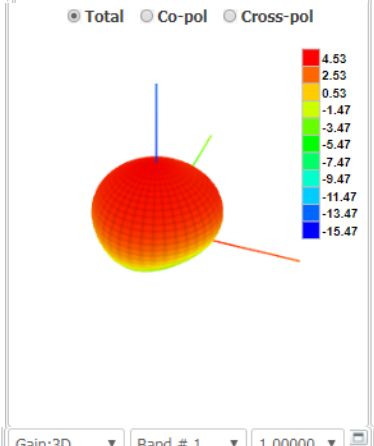


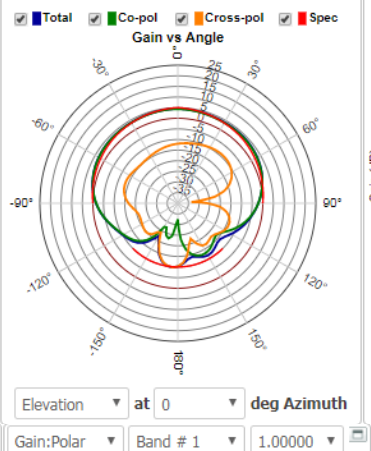


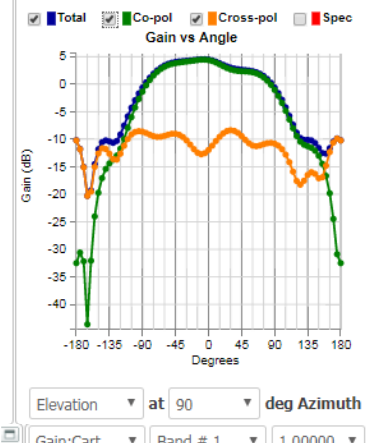


CWGA

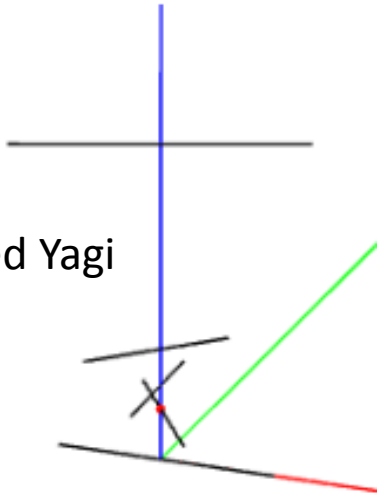


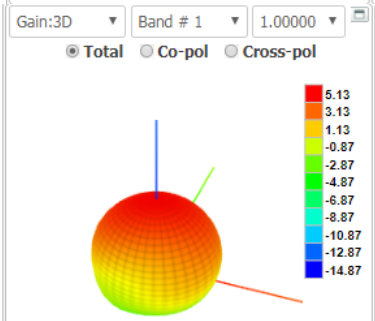


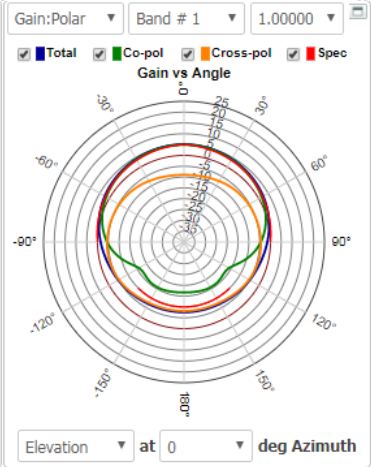


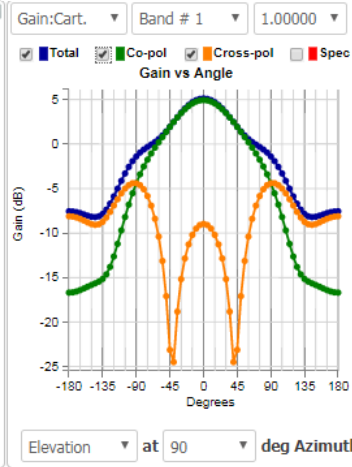


Twisted Yagi



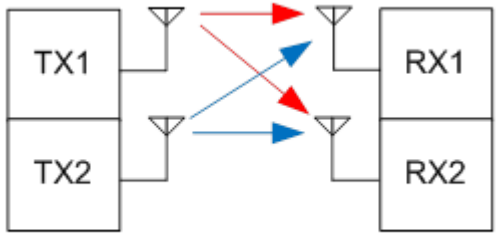






IoT Example

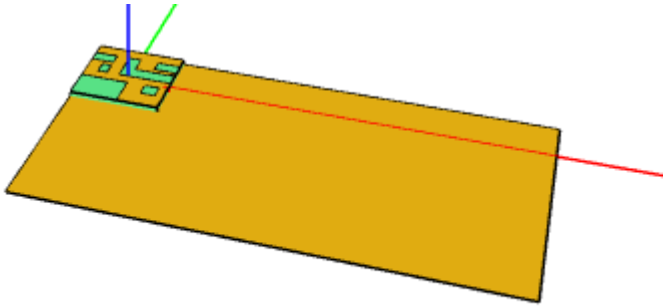
- Dual-band WiFi
  - 2.4 and 5 GHz bands
- IoT device package
  - Compact, planar geometry
  - Approx. size of standard business card, 90mm x 50mm
  - Antenna integrated with electronics
  - Antennas placed along long edge
- Multiple-input Multiple-output (MIMO)
  - 2+ ports/antennas for transmit and receive on each device
  - Needs isolation between ports to create de-coupled channels

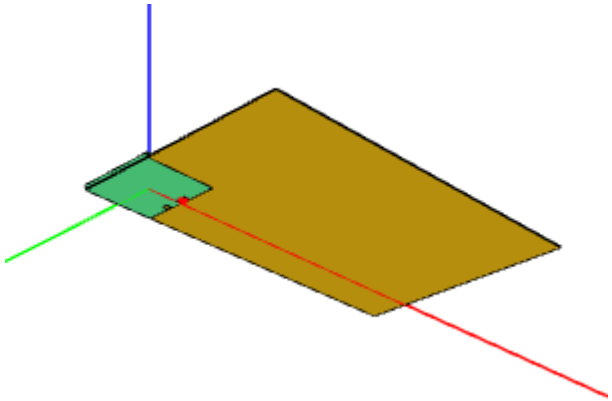


MIMO = MULTIPLE INPUT, MULTIPLE OUTPUT

Iteration 1: Single-port antenna on dielectric

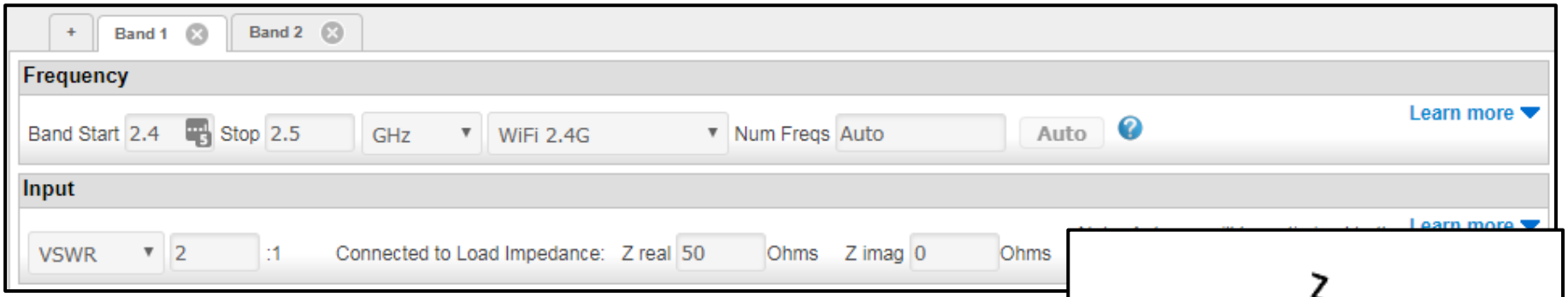
- Dielectric
  - Tends to constrain fields for better isolation
  - Allows more miniaturization
  - Usually decreases efficiency
- Synthesize single-port antenna on dielectric, add 2 to a single substrate & calculate coupling
- Generic mesh antenna type used
  - PIFA-style, with short and feed
  - Ground is cut back underneath to give radiator access to free space
  - 50-ohm antenna: no matching needed

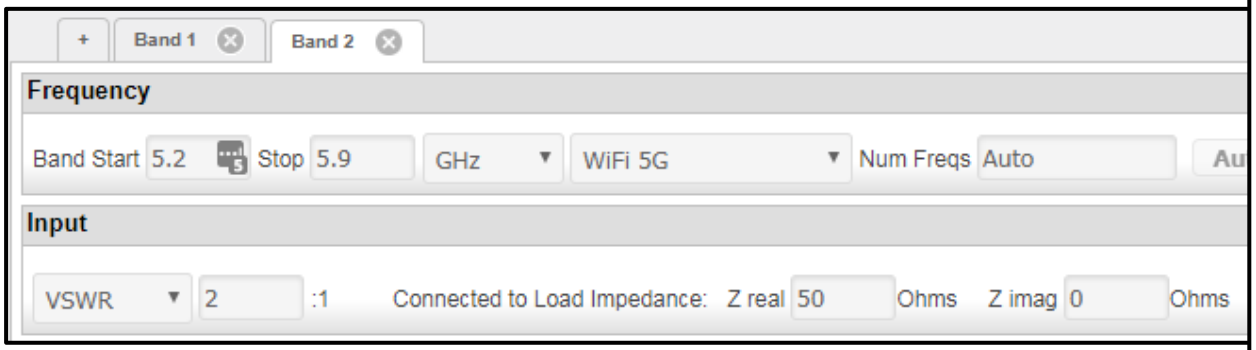


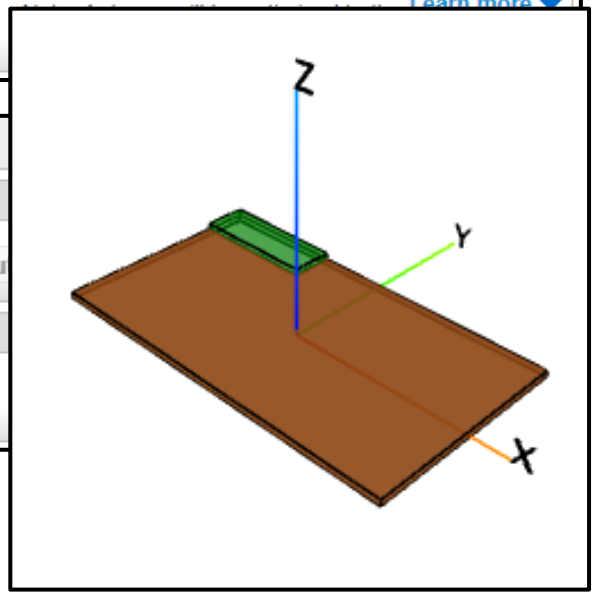


Single-port Antenna Specification

- VSWR & efficiency
- “planar:xymesh” antenna, 30 x 10 mm x 1.5mm, corner of ground

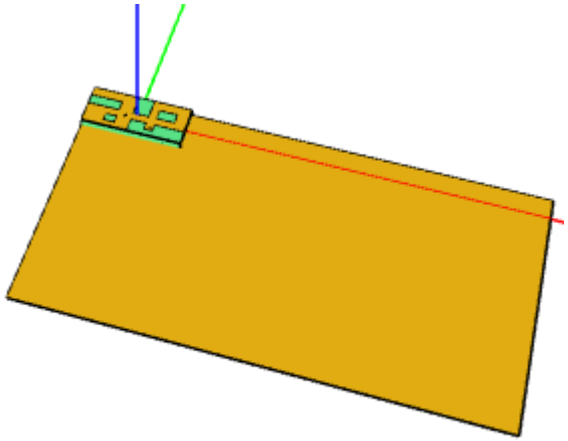


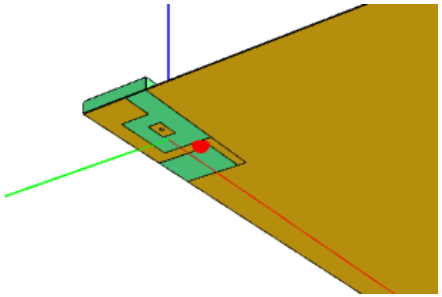


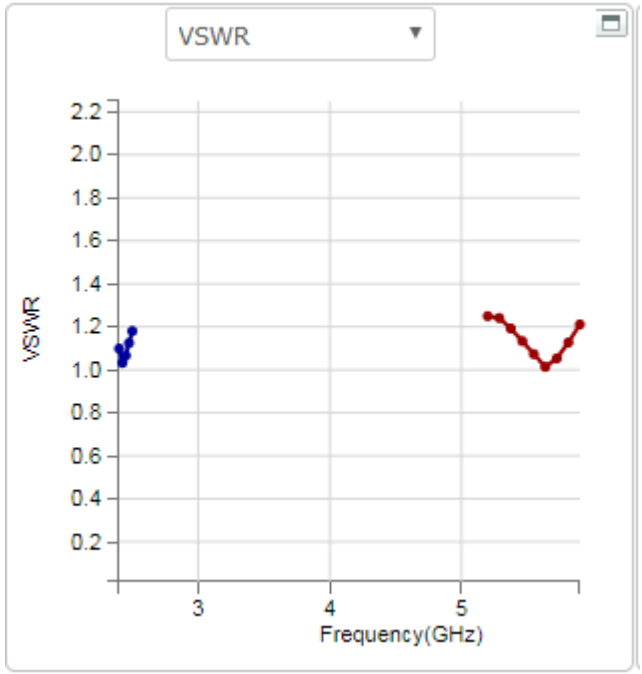


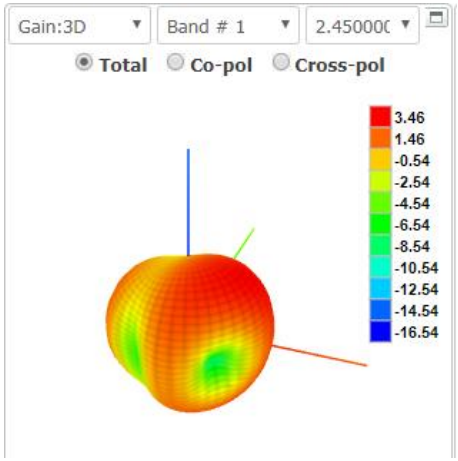
Single-port Antenna Results

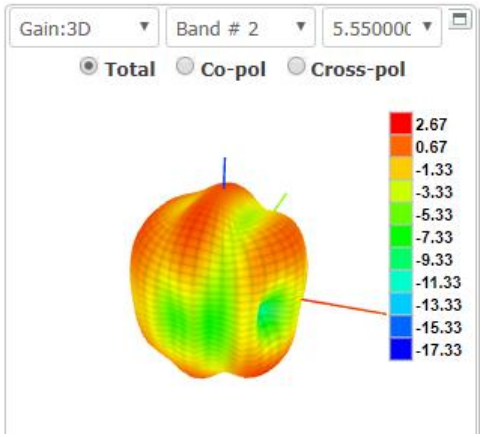
- Overall envelope: 90 x 50 mm, 1.5mm thick
- Antenna is 20 X 8.5 mm, 1.5 mm thick, efficiency: -0.2 dB





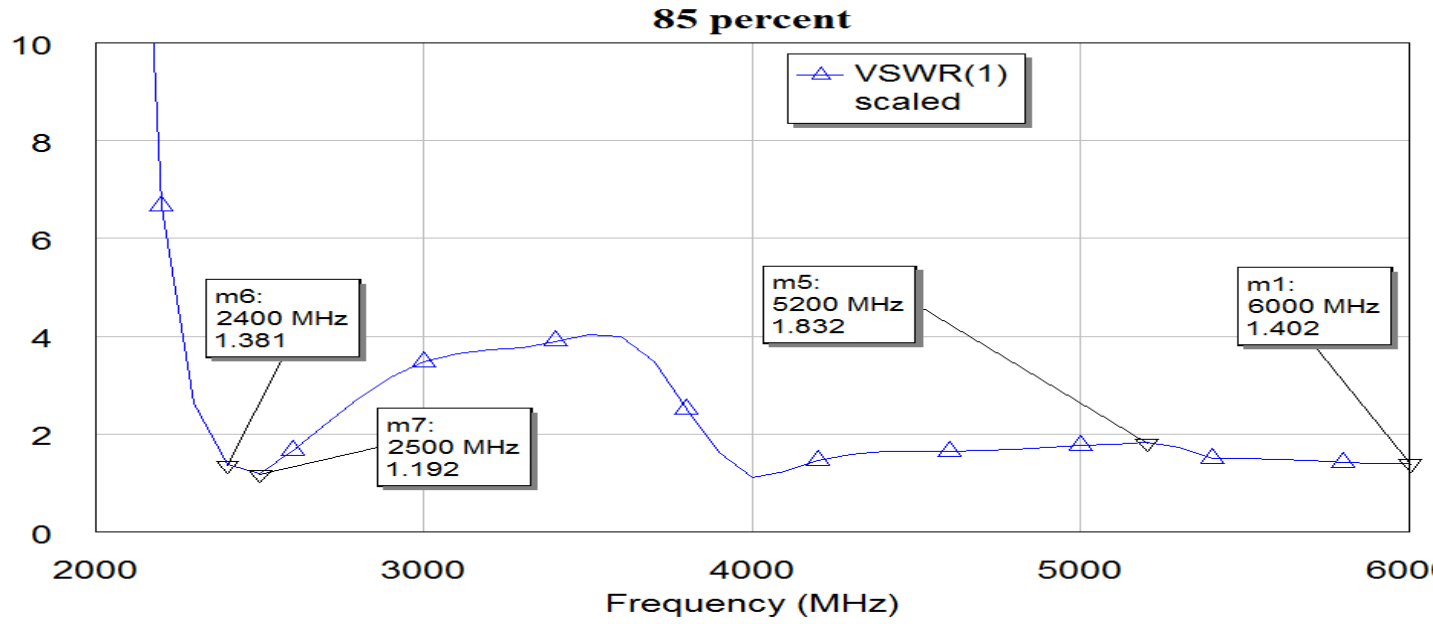






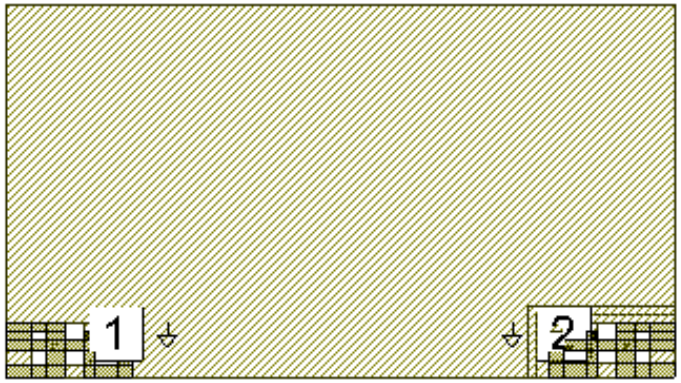
Single-port Antenna Analysis

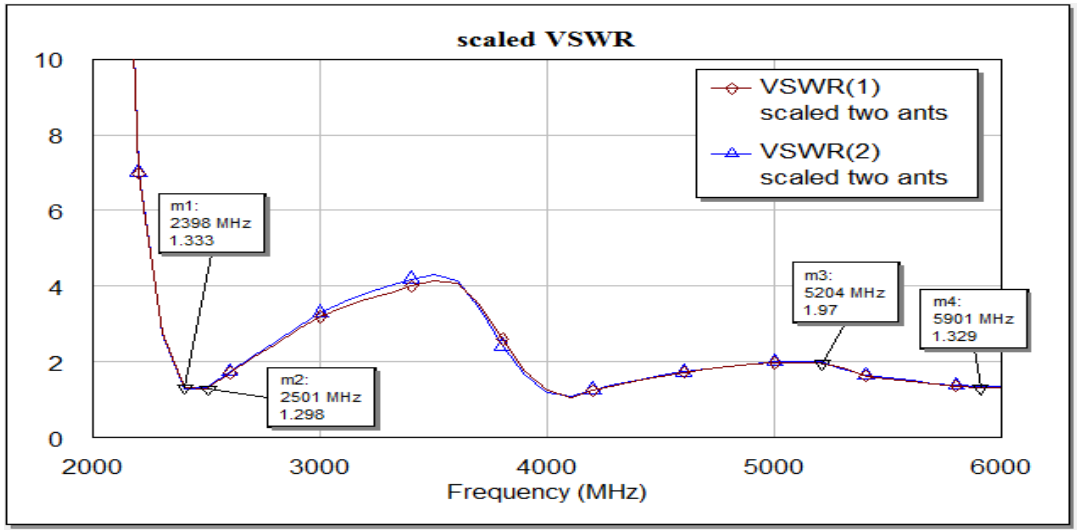
- Imported into Microwave Office, resimulated in AXIEM (2.5D EM simulator)
  - Infinite sheet of dielectric vs AntSyn's finite sheet,
  - Reduced the antenna resonant frequencies
- Antenna re-tuned
  - Scaled 15% smaller, 17 x 7.2mm
  - Thinner substrate (0.9 mm)

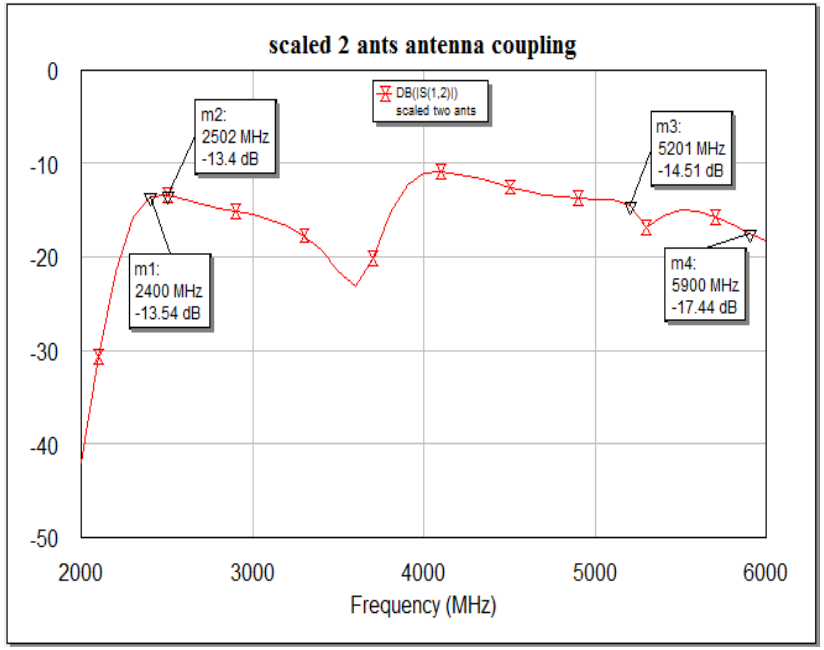


Single-port Antenna Analysis

- Two of these antennas on same long edge have good VSWR and coupling level
- This antenna does not work in center of the edge





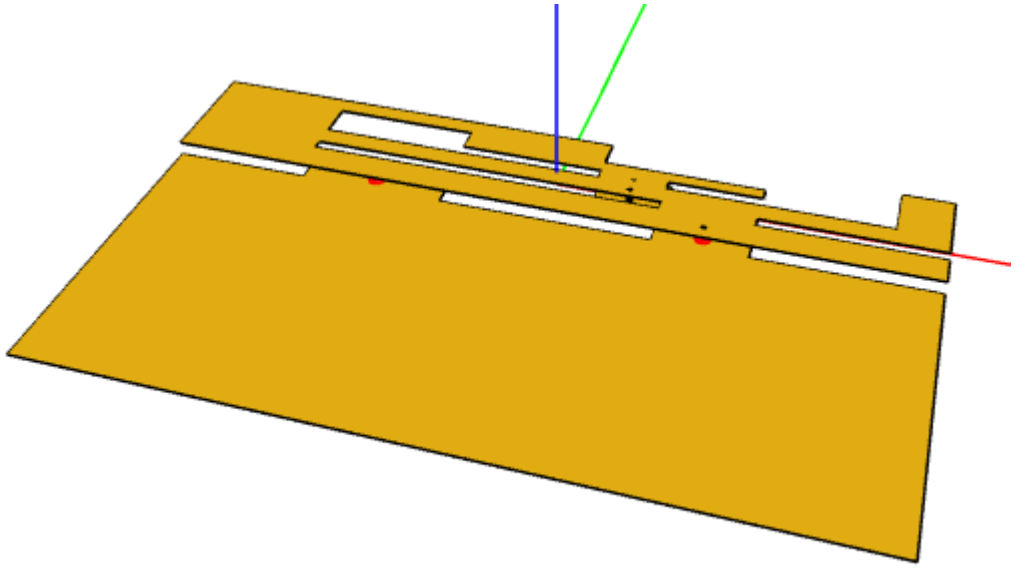


Single-port Antenna Analysis

- This approach worked for 2 antennas
- New design needed for a third port in center of edge
- Would rather optimize a complete design directly, versus hope it works once multiple antennas are integrated

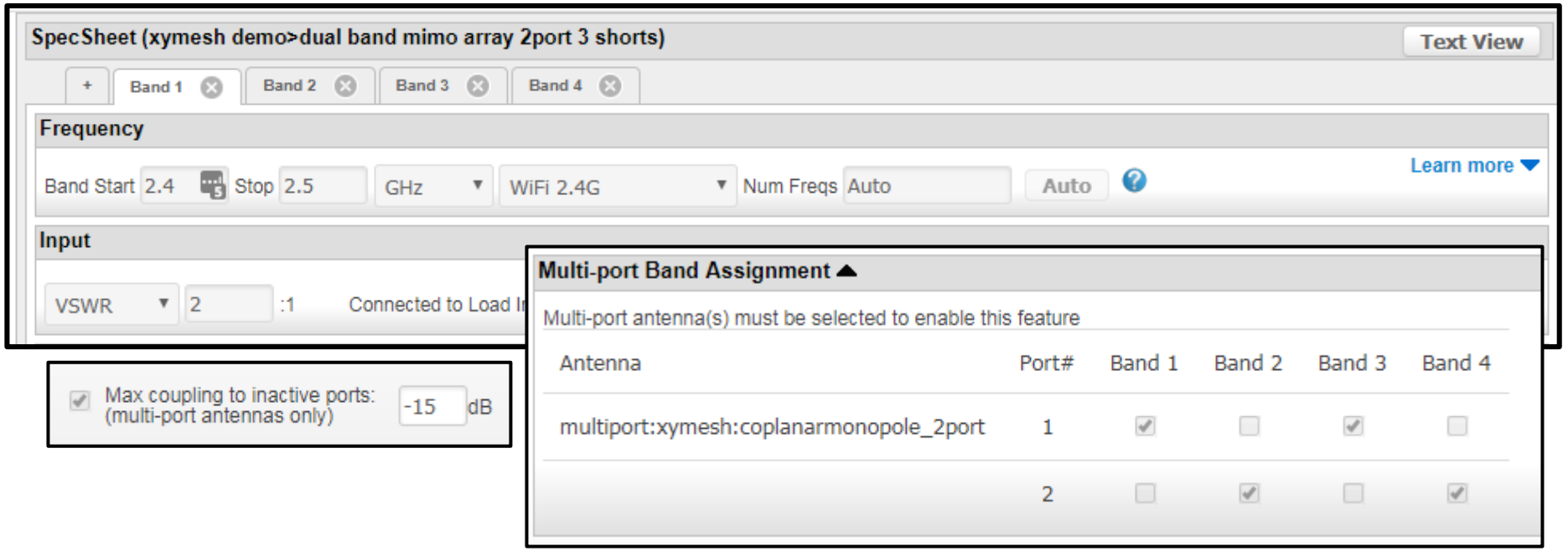
Iteration 2: 2-port antenna, no dielectric

- Direct design of 2-port antenna before attempting 3-port design
- No dielectric: increases bandwidth, efficiency, packaging usage, simulation speed
- 50-ohm ports

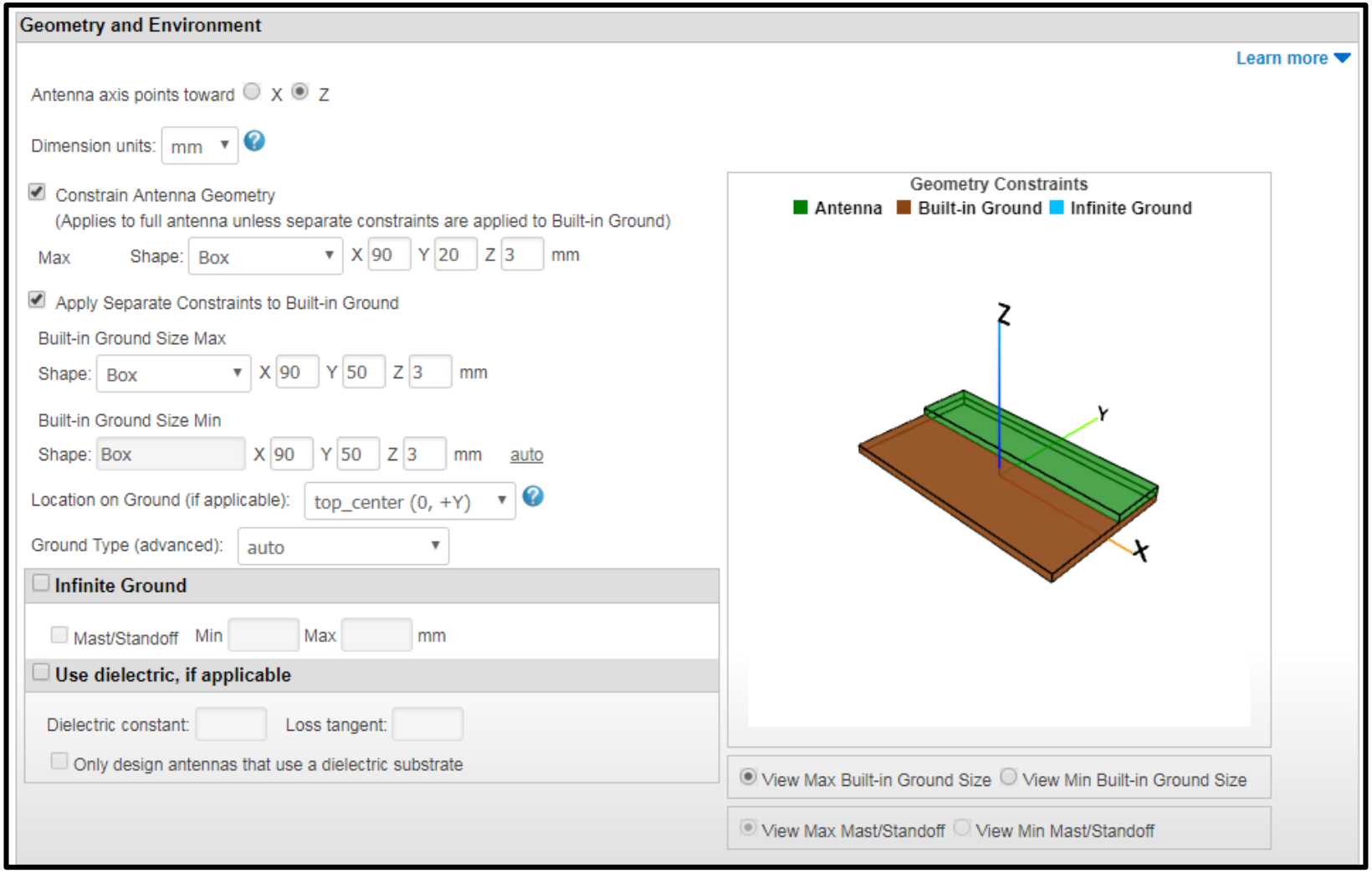


2-port Antenna: Specification

- AntSyn spec: multiport antenna used, so more “bands” used
  - Band 1: 2.4GHz WiFi, port 1 active
  - Band 2: 2.4 GHz WiFi, port 2 active
  - Band 3: 5 GHz WiFi, port 1 active
  - Band 4: 5 GHz WiFi, port 2 active

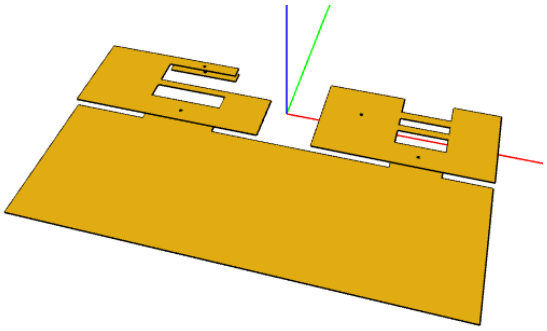


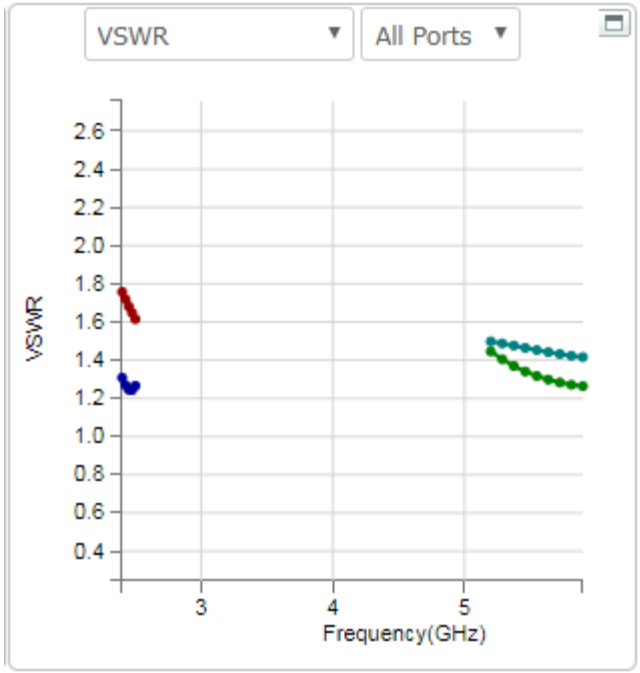
2-port Antenna: Specification

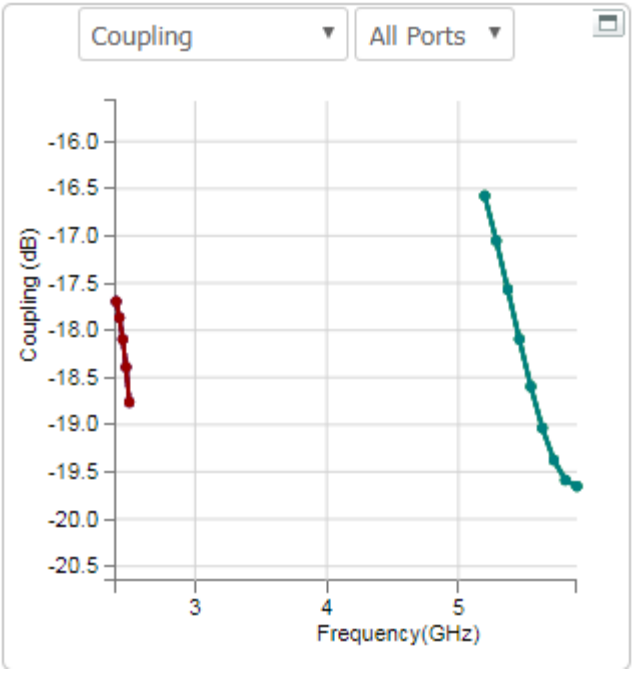


2-port Antenna: Results

- Good VSWR and coupling results
- Though optimized as a single 2-port antenna, AntSyn removed connections between ports

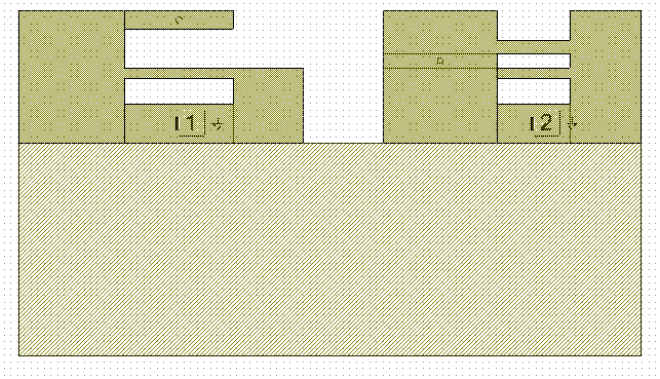


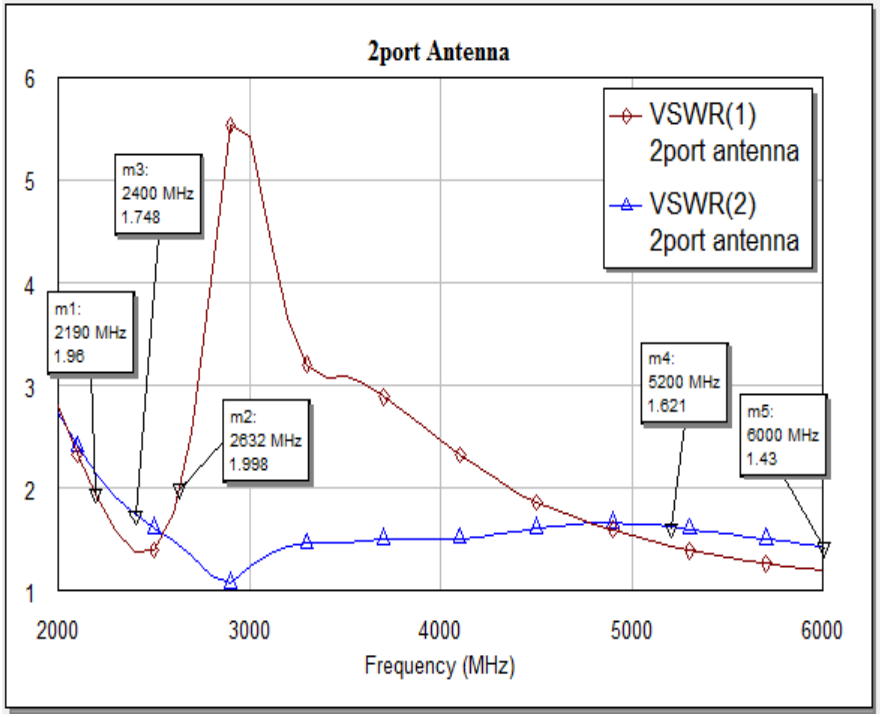


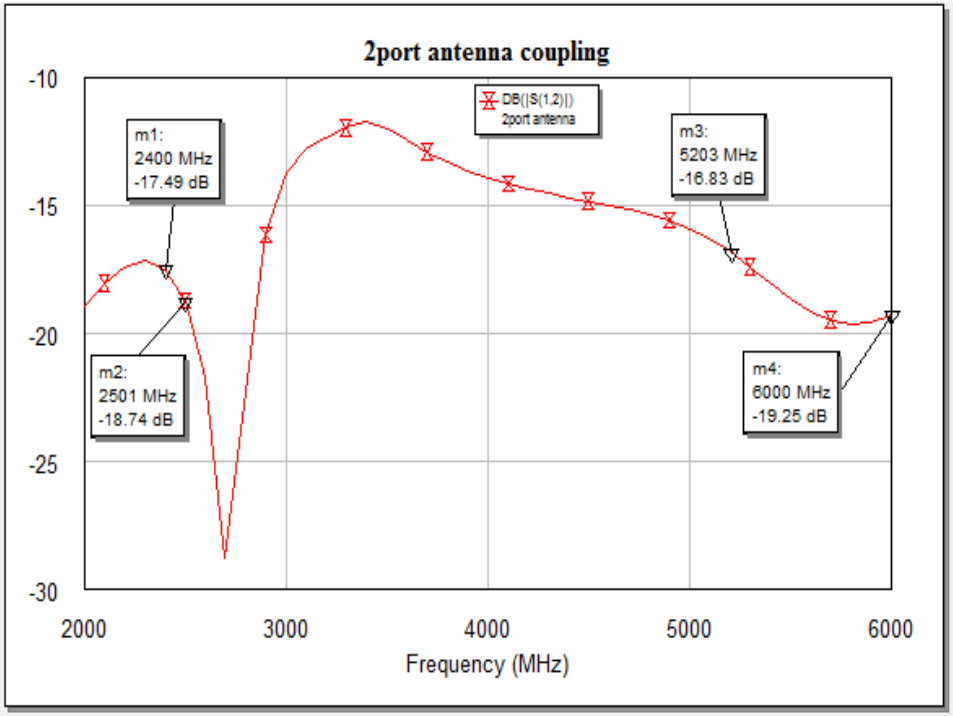


2-port Antenna: Analysis

- AXIEM simulation of VSWR and Coupling match well with AntSyn

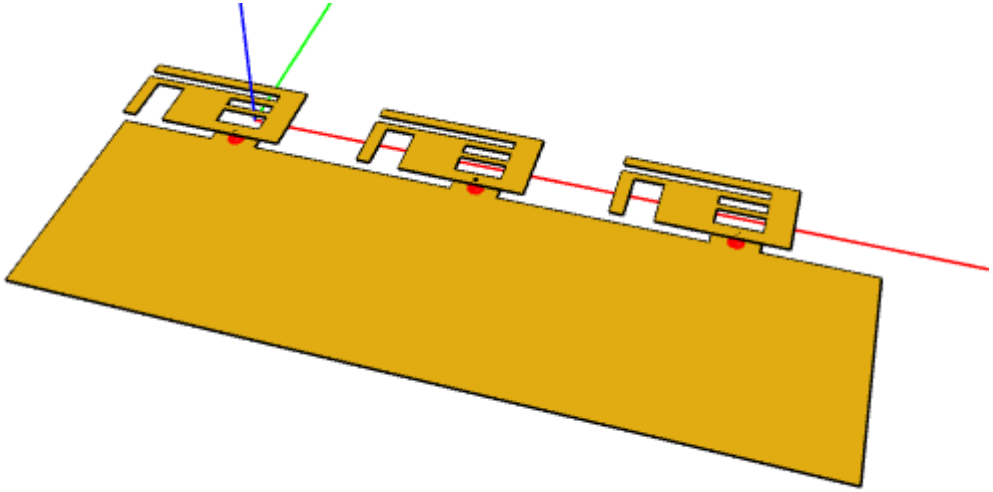






Iteration 3: 3-port antenna array

- 3-port single antenna is harder to optimize due to increased degrees of freedom
- 2-port antenna looks a lot like an array of two elements, what if we design a 3-element array?



3-port Array: Specification

Geometry and Environment

Learn more

Antenna axis points toward ○ X ◉ Z

Dimension units: mm

☑ Constrain Antenna Geometry
(Applies to full antenna unless separate constraints are applied to Built-in Ground)

Max Shape: Box X 30 Y 20 Z 4 mm

☑ Apply Separate Constraints to Built-in Ground

Built-in Ground Size Max

Shape: Box X 30 Y 50 Z 1 mm

Built-in Ground Size Min

Shape: Box X 30 Y 50 Z 1 mm auto

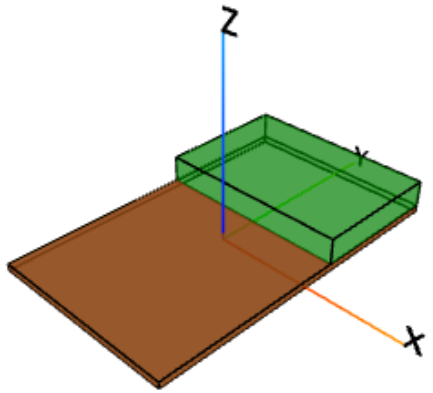
Location on Ground (if applicable): top_center (0, +Y)

Ground Type (advanced): auto

☐ **Infinite Ground**

Geometry Constraints

Antenna Built-in Ground Infinite Ground



Arrays

☑ Use Arrays

Type Planar Element Uniformity Uniform ☑ Single Backplane

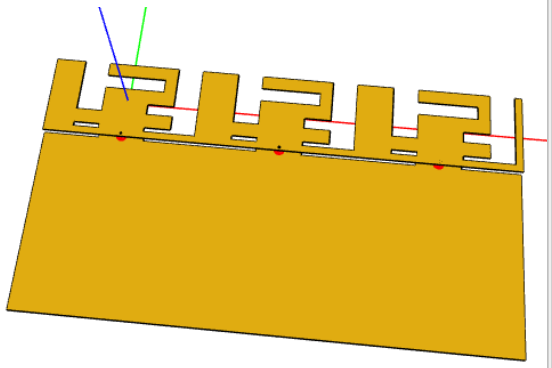
Element Spacing	# of Elements	min	max	
X	3	30	30	mm
Y	1	50	50	

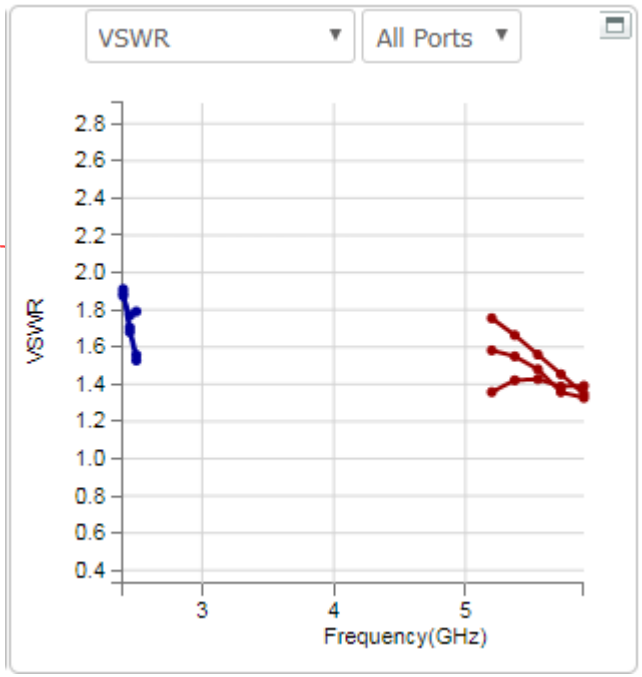
☑ Max coupling to active ports: (for arrays & phased ports) -12 dB

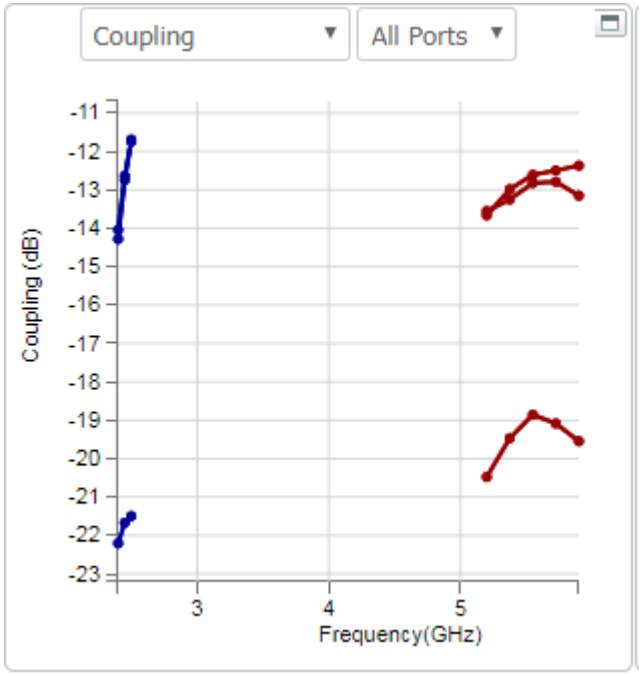
NATIONAL INSTRUMENTS

3-port Array: Results

- Overall envelope is 90 mm x 50 mm x 1.3 mm
- Elements are 30 mm x 15.3 mm x 1.3 mm thick
- Elements are actually connected across all the feedpoints, though their isolation is good

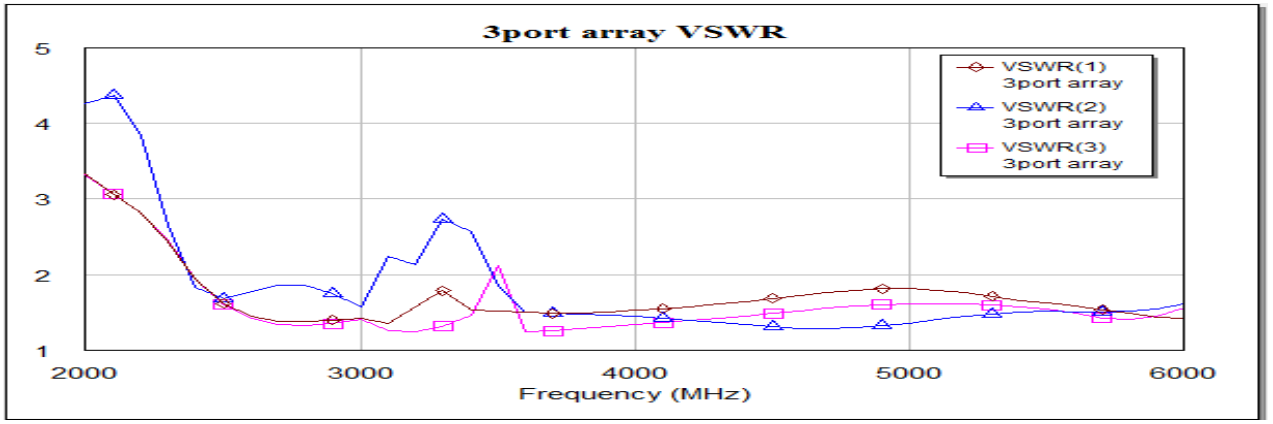


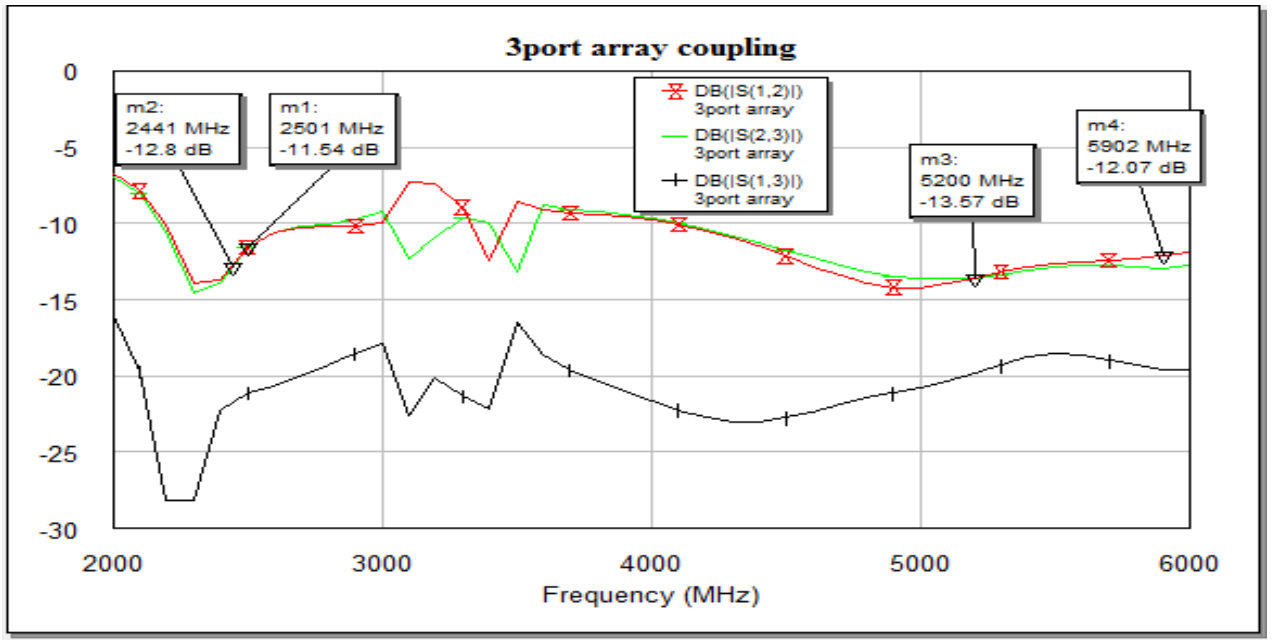




3-port Array: Analysis

- AXIEM, results match well with AntSyn
- Antennas are reasonably broadband
  - Center antenna has slightly worse VSWR between bands, still < 3
- Coupling is below -11.5 dB across bands of interest



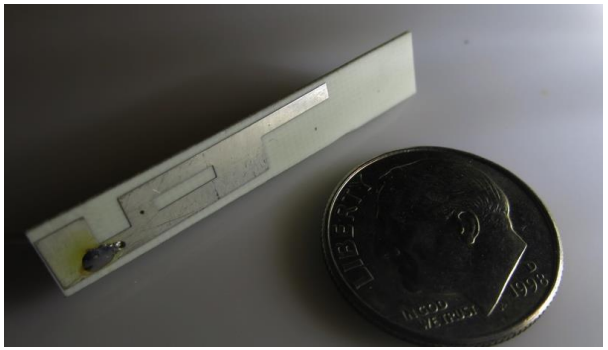


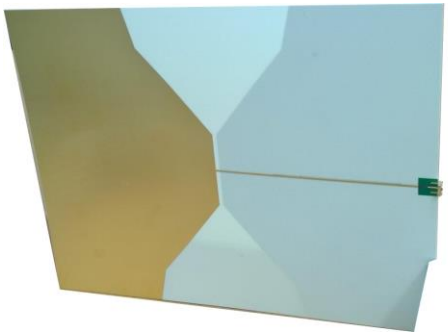
IoT Example - Conclusions

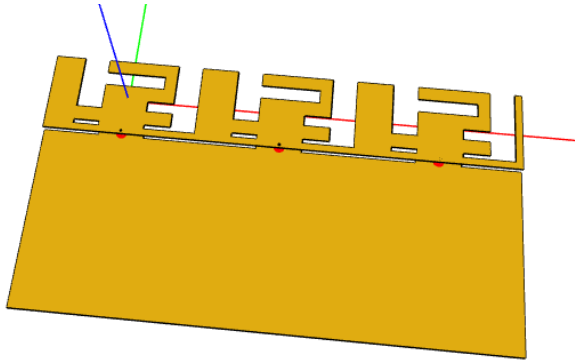
- Good results from each approach
- Results from AntSyn match well with AXIEM
- Next steps
  - Miniaturization
    - How small can the antennas be, with and without dielectric?
    - What is the quantitative tradeoff for using dielectric?
    - What is the tradeoff between size and isolation?
  - Adding more ports/antennas
    - How many ports are feasible in a given space?
    - What is the best geometric configuration? Antenna type?
    - Which is better: an N-port antenna or an array?

Antenna Synthesis Summary

- Quickly create high-performance designs with multiple competing criteria
  - Increased performance and/or efficiency can be achieved in many cases
  - Higher confidence in achieving superior result
  - Automated discovery of design principles from which insight can be gained
  - Supports a wide (and growing) range of specifications & applications
- Significantly faster and lower-cost design process
  - Less time needed to begin new design efforts
  - Ability to rapidly run what-if design scenarios and trade studies
  - Greater agility and responsiveness to new requirements
  - All of the above lead to cost savings as well







NATIONAL INSTRUMENTS

Thank You for Your Attention