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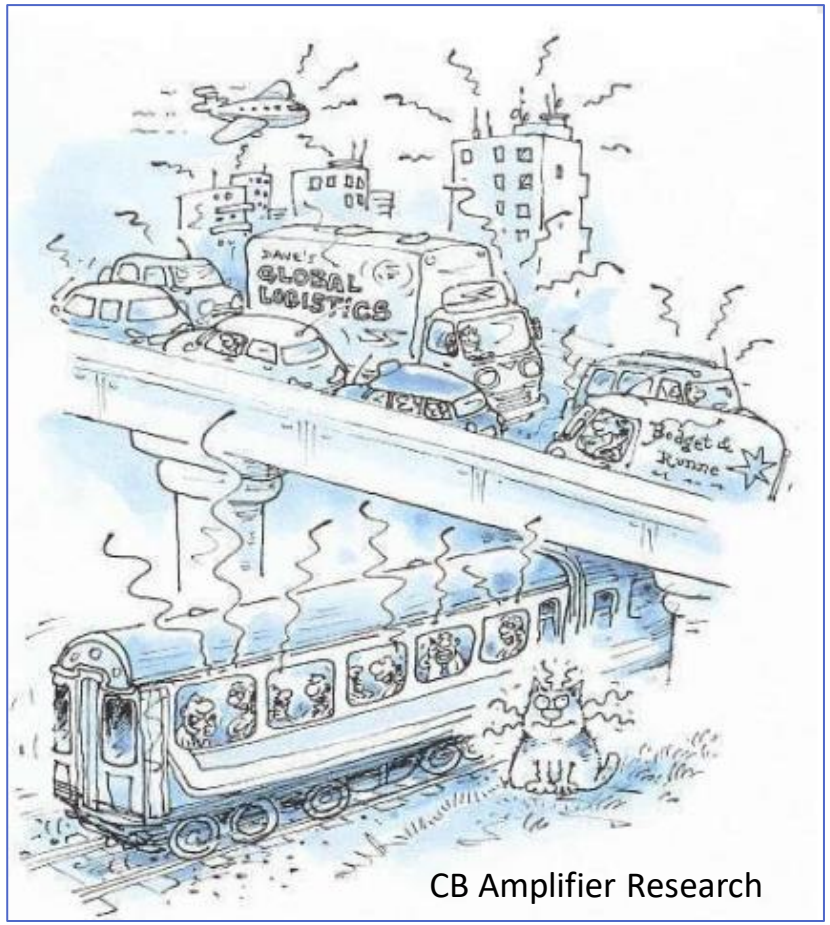
# Dual Reverberation Cavities for I/O Connector EMI Performance

Gary Biddle

# Table of Contents

# Introduction

Real World




CB Amplifier Research

**EMI** is **E**lectro**M**agnetic **I**nterference

EMI is **electromagnetic energy** that emanates from electrical source/device by conducted or radiated emissions into surrounding environment. If emissions interact and disables other devices, the interference is an intolerable disturbance.

**The Solution** is **EMC**

EMC is **electromagnetic compatibility** that mandates any emission must not interfere at all with any other device in the environment. This is achieved two ways:

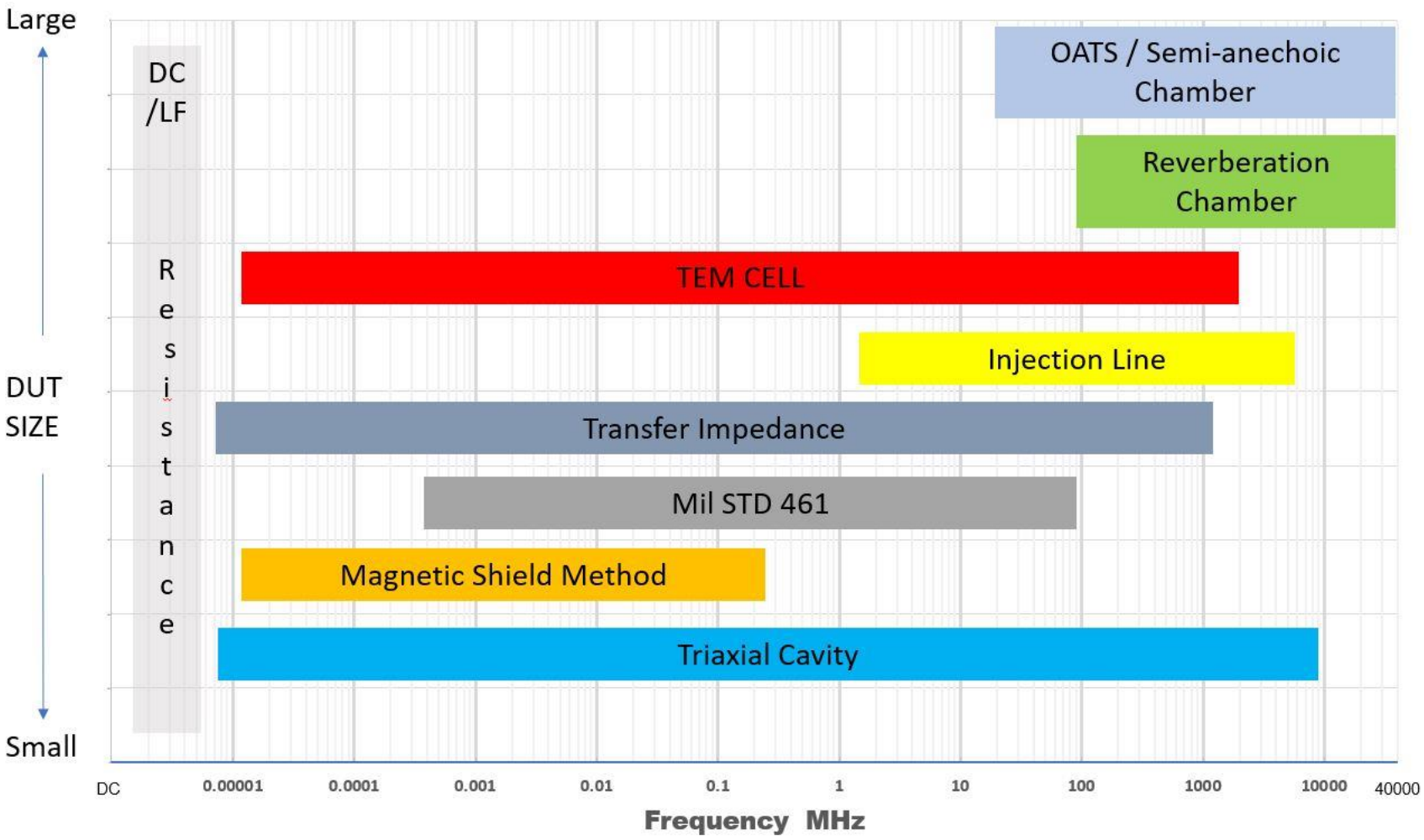
[1] Emission Levels ->Limit radiated energy from devices.

[2] Immunity levels ->Mitigation requirements to limit external energy from penetrating device shielding.

**EMC Test Standards**

The Test Standards are a compendium of domestic and international measurement practices across a wide range of applications voted into law by experts in the industry and enforced by governments.

# EMC Test Methods … [DC to 40 GHz]



# EMC Testing -> Two Branches

## Radiated Emissions

Product Compliance

- Domestic usage
  - Device does not interfere TV
  - Phones, radios, computer, etc work in same room
- Industrial environment
  - Integrity of data centers
  - Manufacturing equipment

## Susceptibility Immunity

Product Protection

- Important in applications where an interference would be life threatening:
  - Hospital
  - Air travel
- Hostile Environments:
  - Warfare
  - Industrial settings

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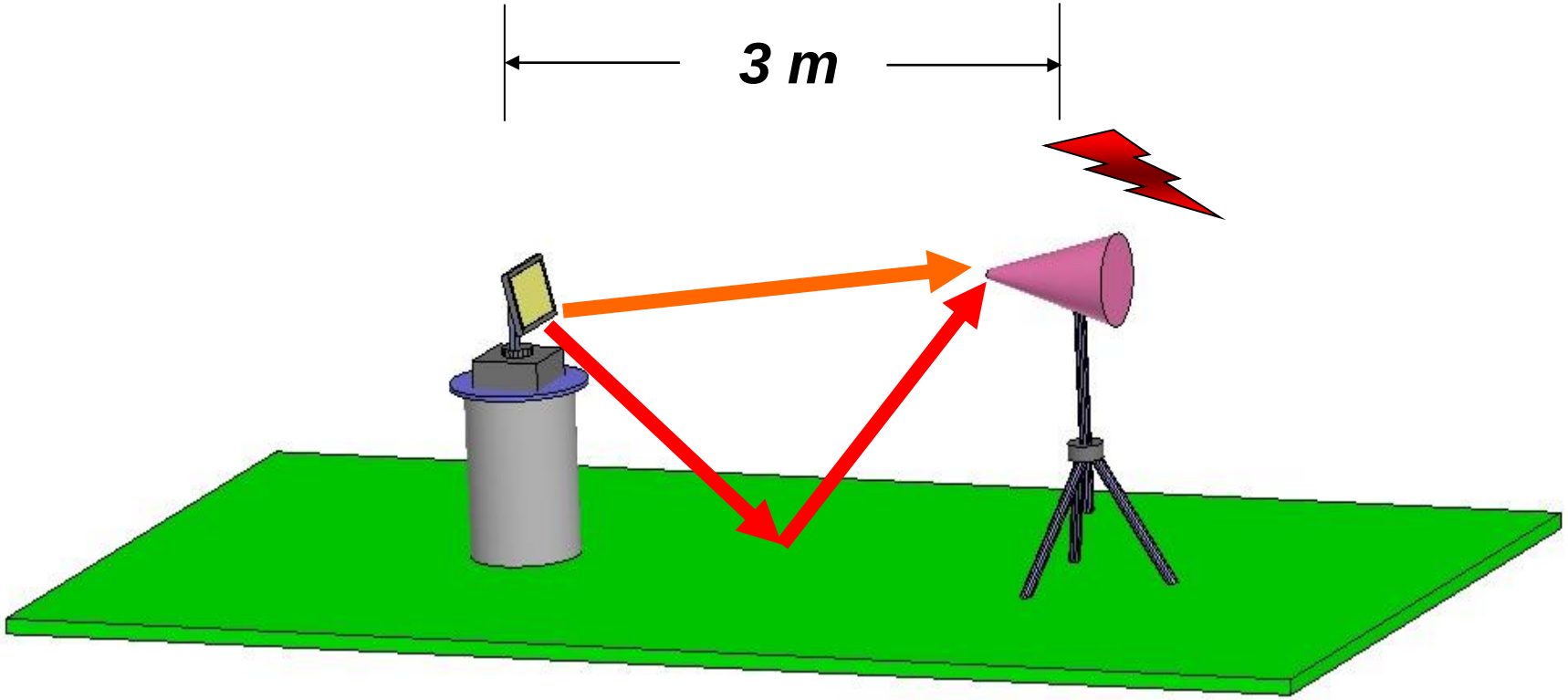
# OATS "Benchmark Method"

## *Open Area Test Site*

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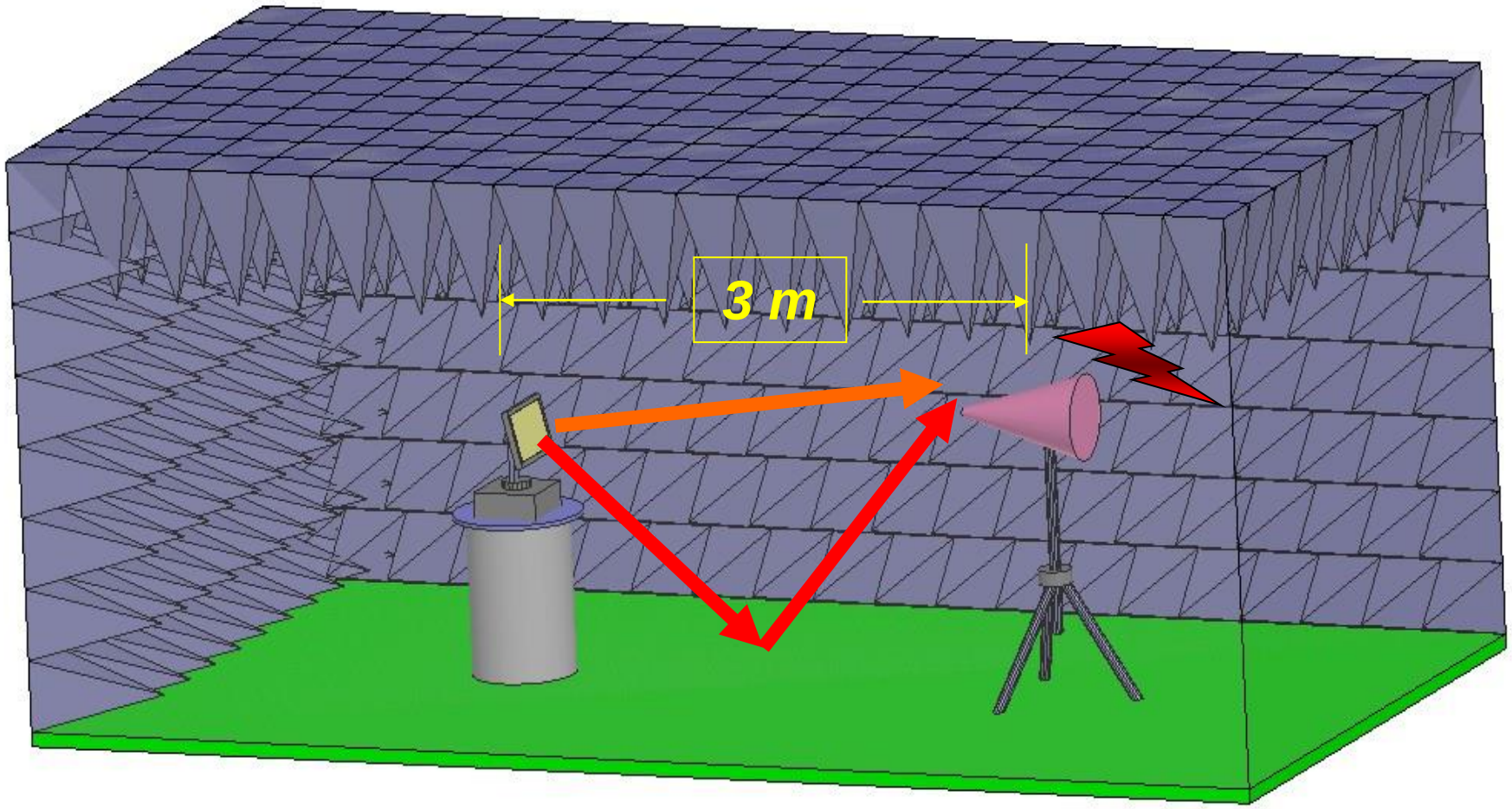
# Semi - Anechoic Chamber

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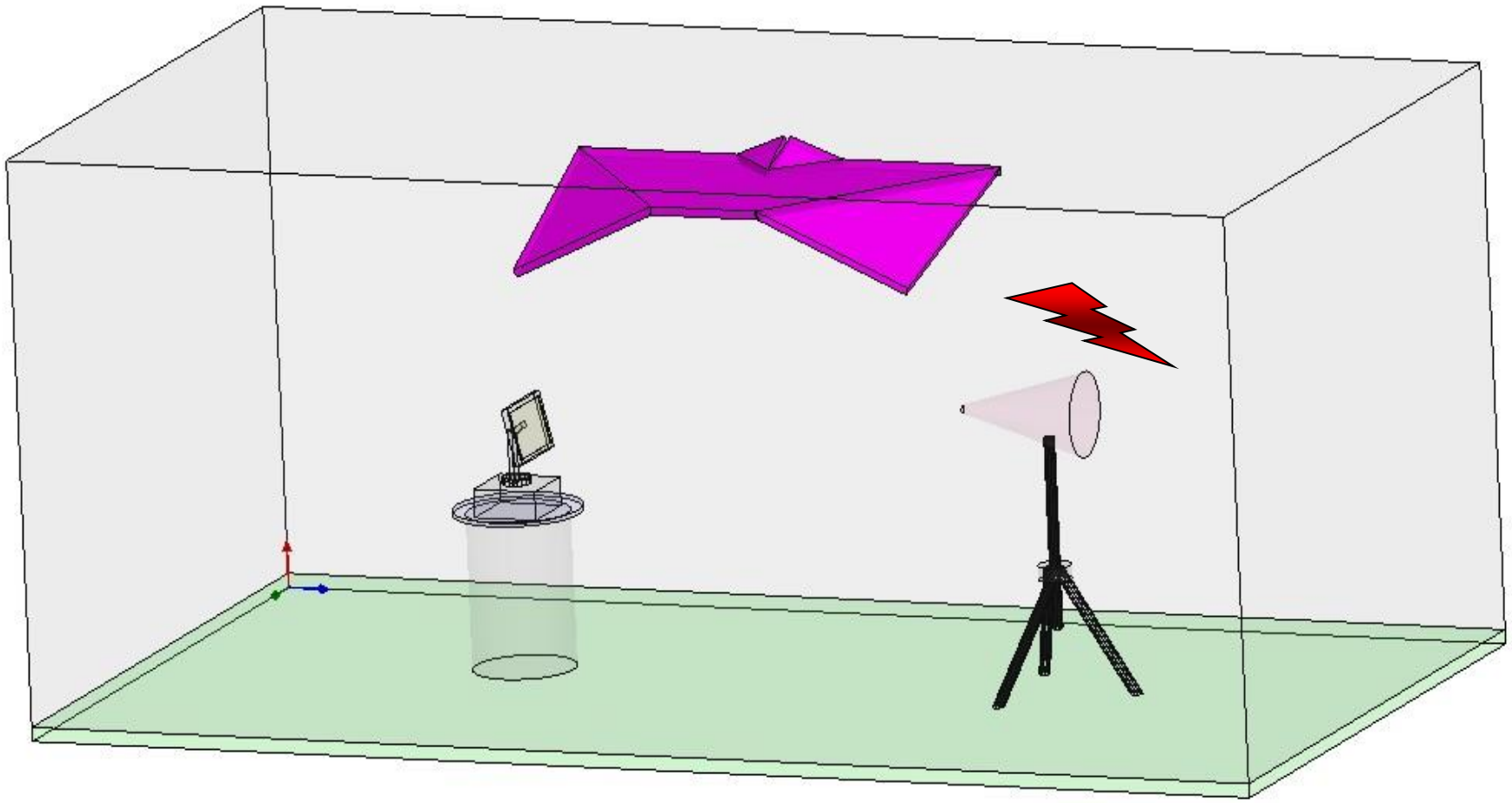
# LRC

## *Large Reverberation Chamber*



# Large Reverberation Chamber ... [ LRC ]

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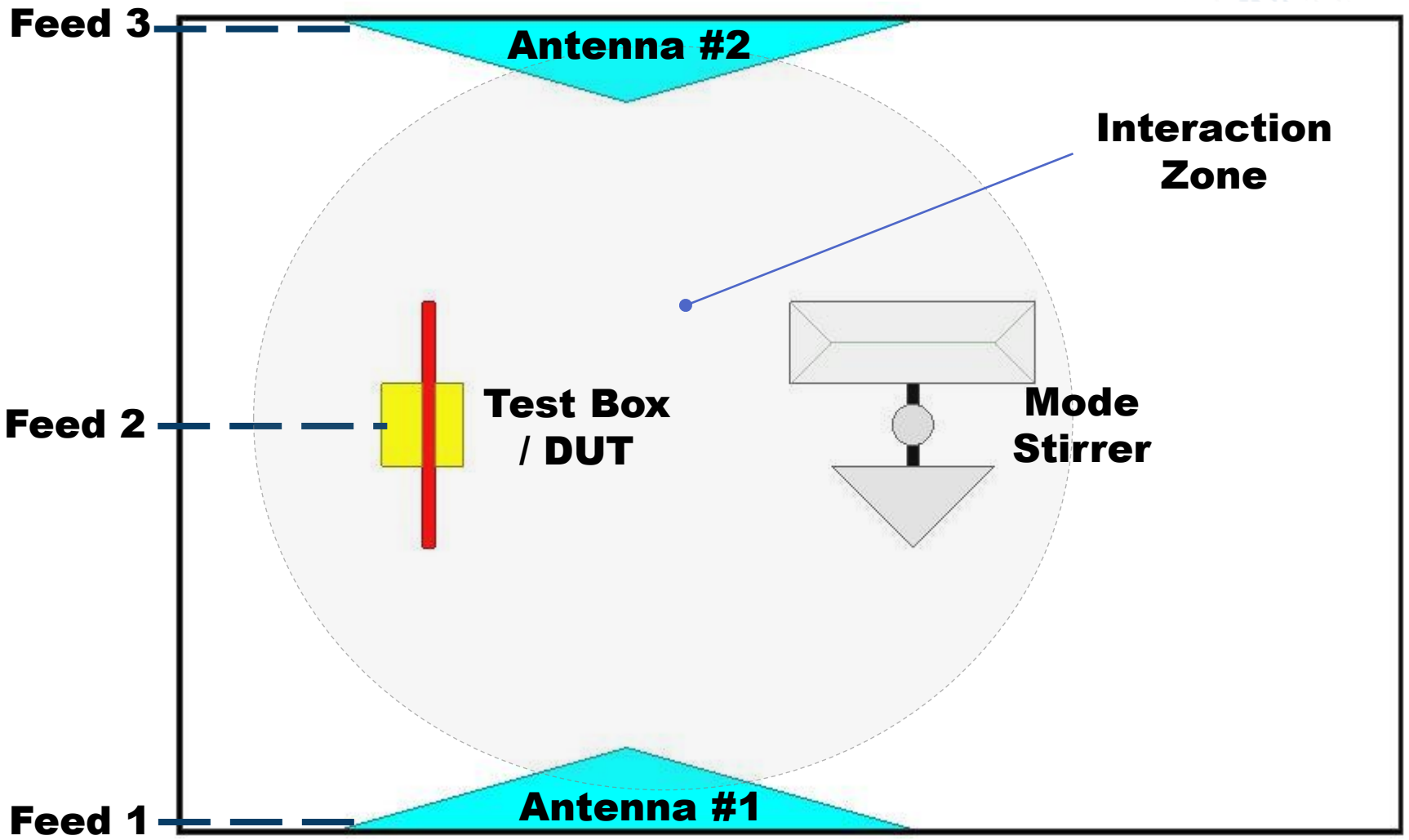
## Why LRC ???

- Parallel attributes to an OATS setup
- Well established basis of mode stirred theory
  - ❑ Myron L. Crawford NBSIR 81-1638
  - ❑ IEC 61000-4-21 Reverberation Chamber Test Methods
- Isolation from ambient background noise
- Large test frequency range
- Fast and accurate
- Removes the spatial dependence of the DUT [repeatability]
- Ultimate goal is to correlate to an OATS measurement.

# LRC Layout




Points of Interest:

1) 61000-4-21 format
2) Mode stirrer determines spatial dependence
3) Test Box is the vehicle to corelate LRC / OATS
4) Supports both Emissions/Immunity

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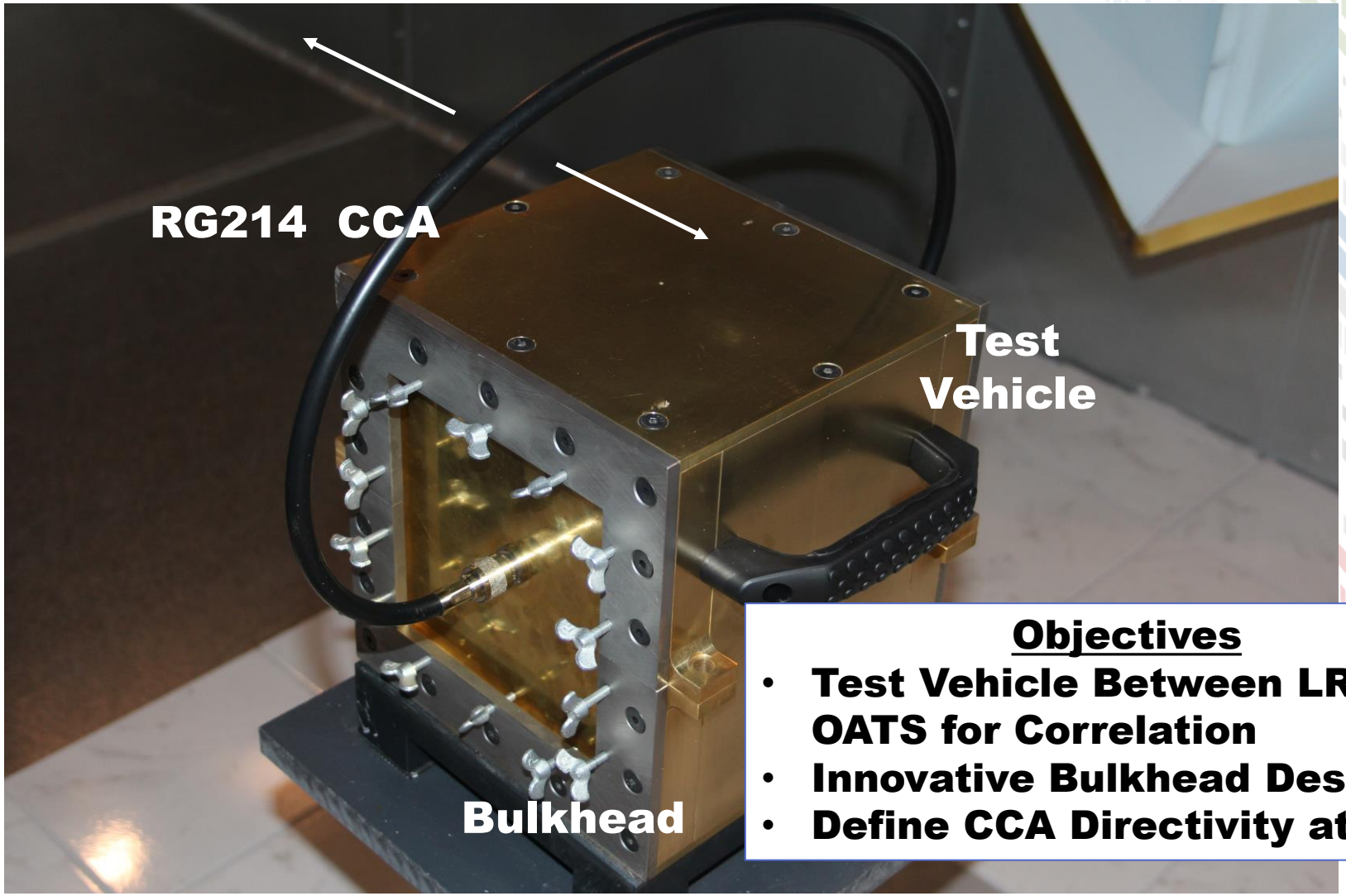
# Samtec Reverberation Chamber


- CCA Box [Test Vehicle to Compliance Site]
- Antennae
- Mode Stirrer

# CCA Test Box Vehicle




**Objectives**

- Test Vehicle Between LRC & OATS for Correlation
- Innovative Bulkhead Design
- Define CCA Directivity at OATS

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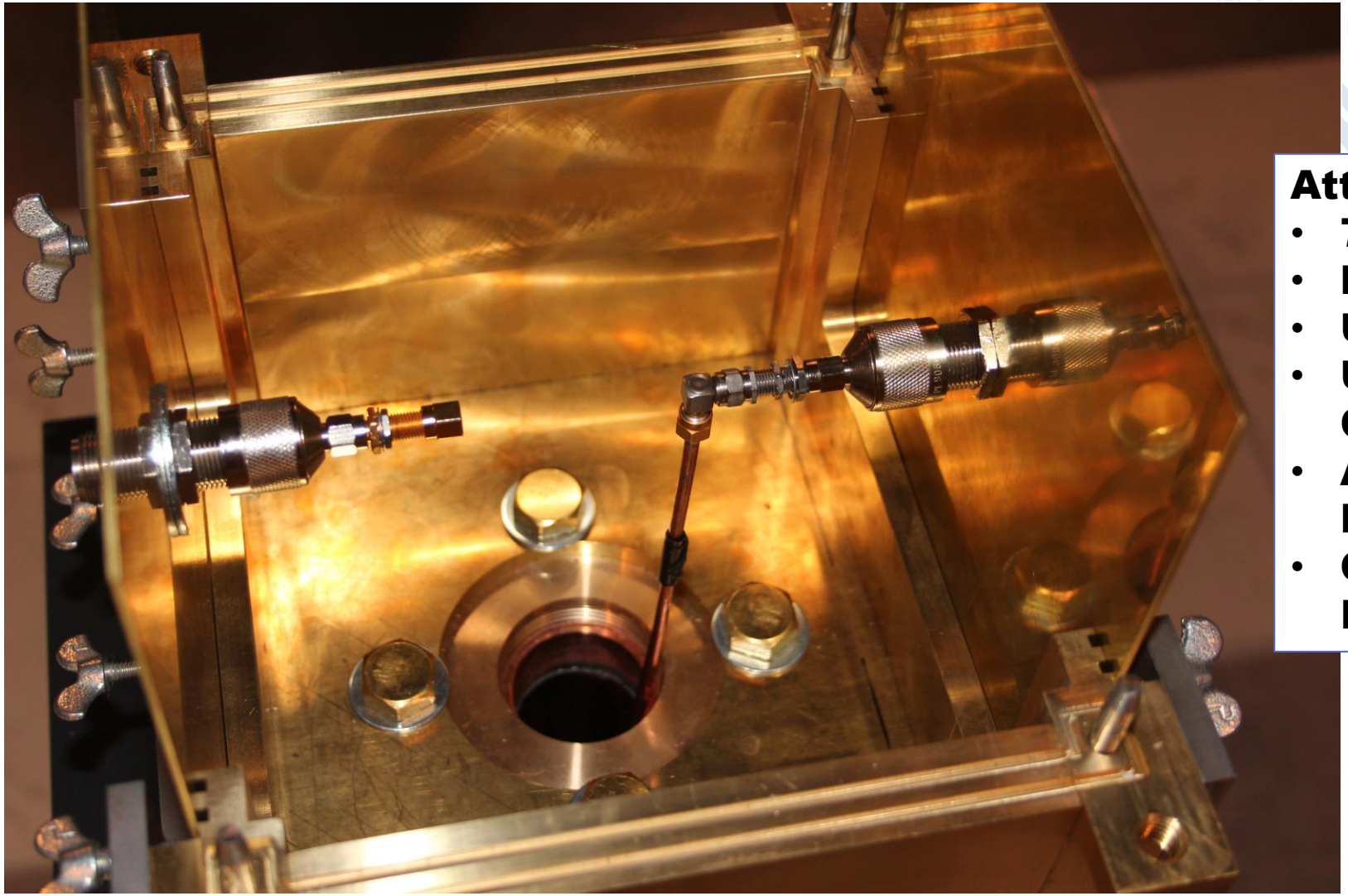
# View Inside Box



**Attributes**

- 7 “ Cube Space
- Portable [4 bolts]
- Utilize Absorber
- Utilize Elastomer Cord
- Allow TD or FD DOEs
- Goal > +100 dB Isolation

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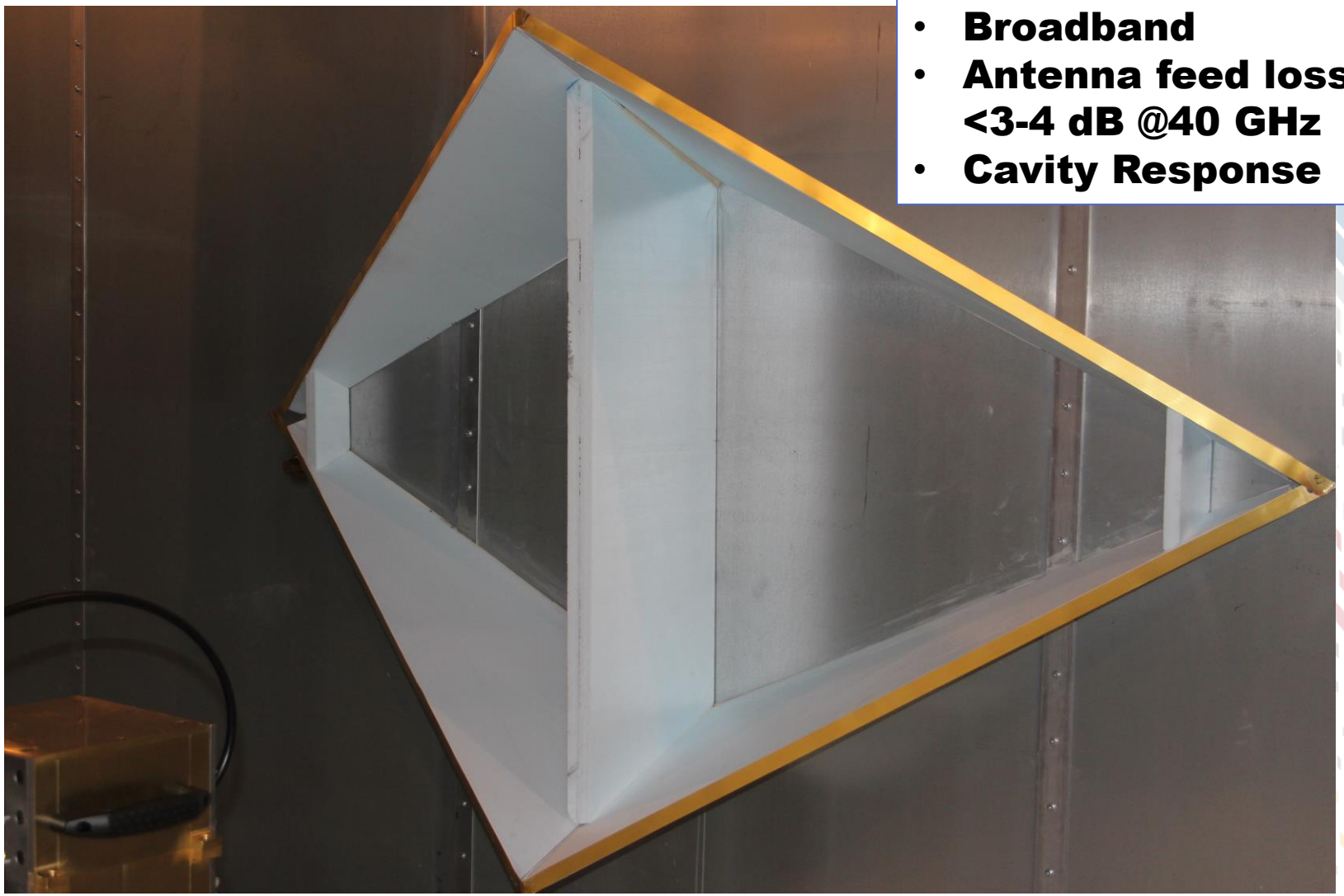
# Antenna



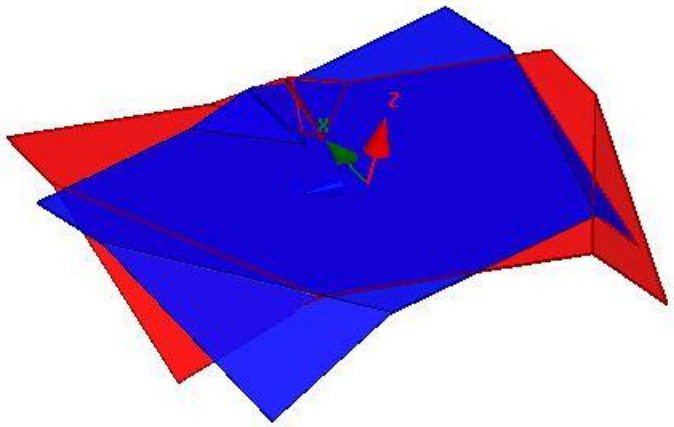
**Attributes**

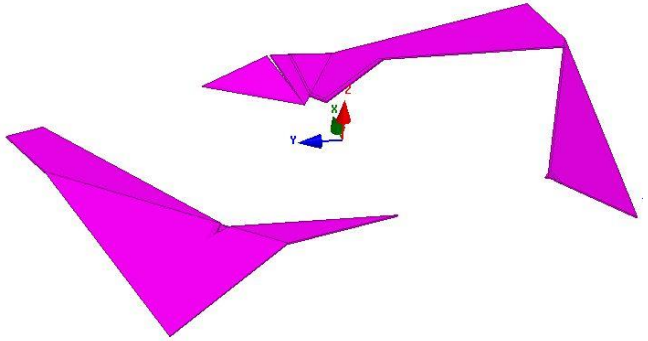
- **Permanent**
- **Broadband**
- **Antenna feed loss <3-4 dB @40 GHz**
- **Cavity Response**

# New Mode Stirrer Design

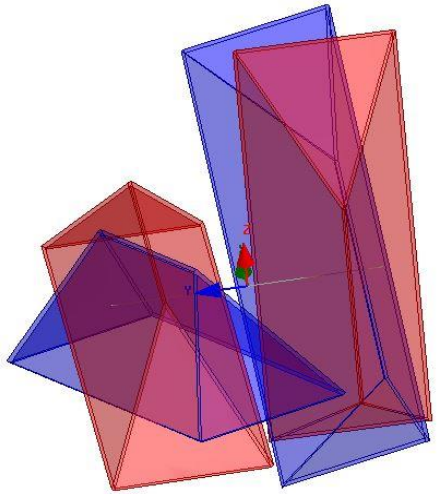
## DELTA CHANGE IN SPATIAL GEOMETRY

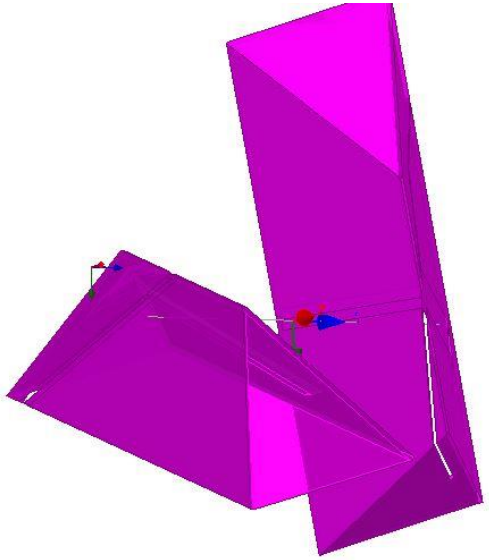
**Mil-C 38999**



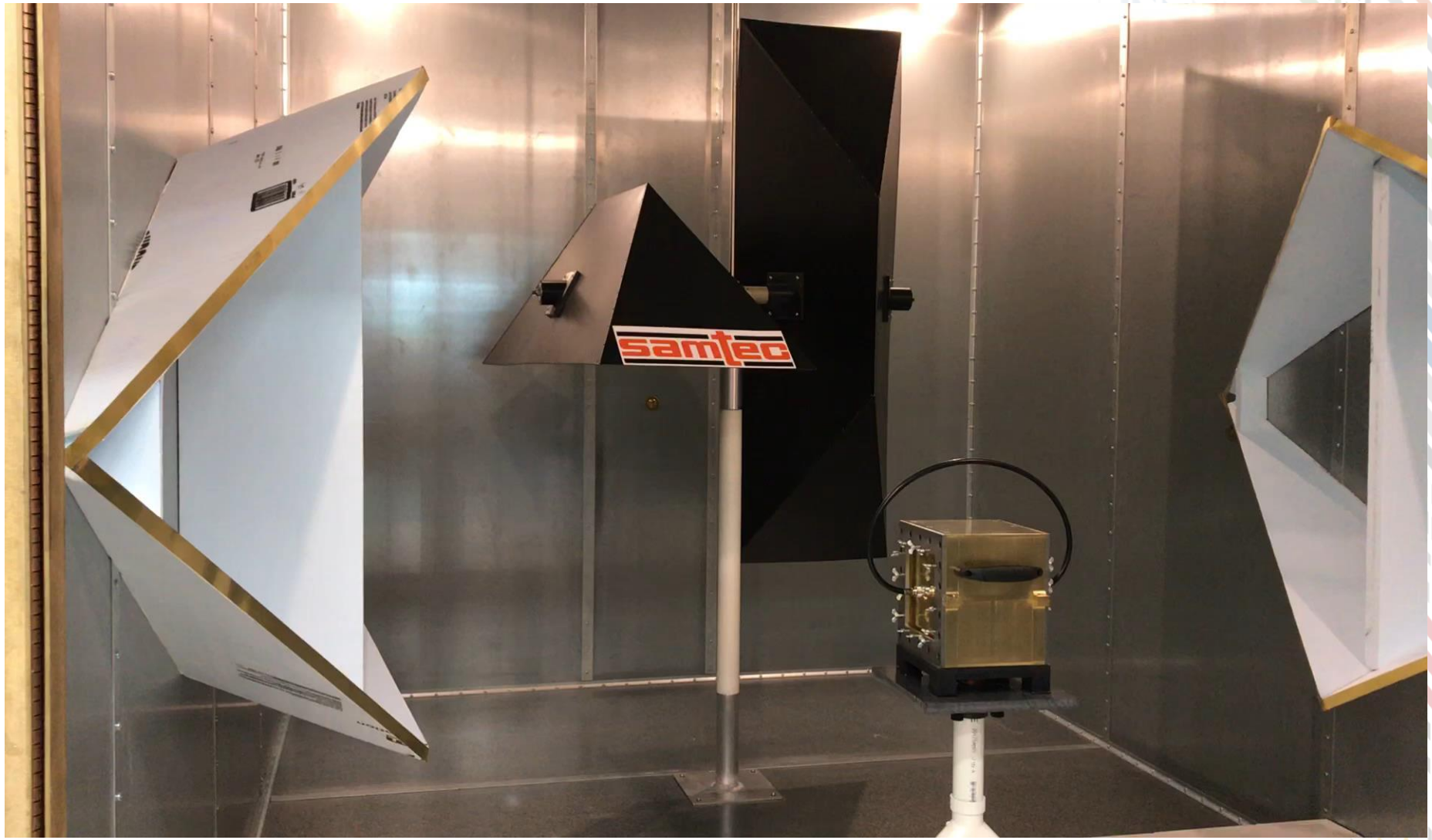


**Samtec 2 Axis**





# Video … Rotation 2 axes




**Simultaneous rotation about 2 axes**

# Dual Reverberation Chambers ... [DRC]

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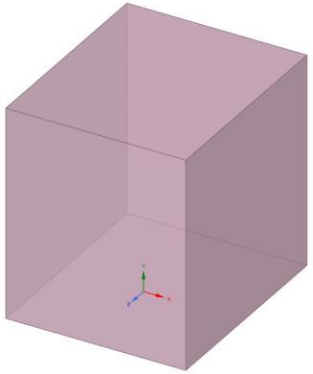
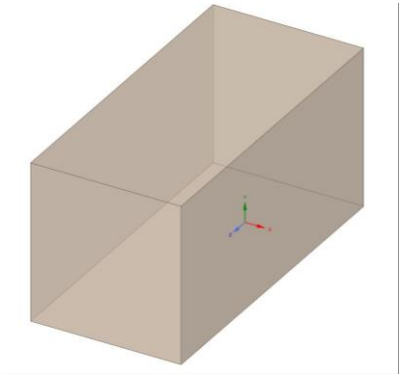
## Why DRC ???

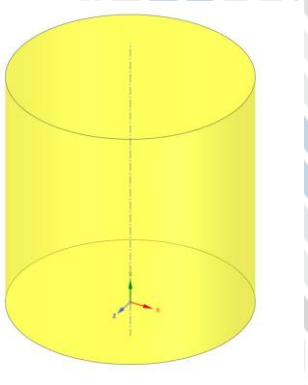
- Evaluate Power Transfer thru DUTs [FOCUS]
  - -- aperture, connector shell, IO port assembly
  - -- material sheet, screening, gasket
- Uses LRC theory, fast and accurate, isolation, large freq span, etc....
- Benchtop setup... smaller size... therefore better suited for simulation to support test development.
- Very difficult to do with OATS or LRC setups.

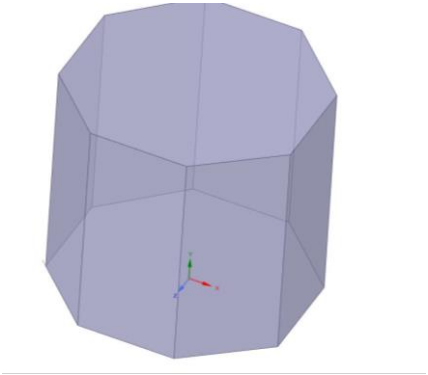
# Design Options for Dual Cavities

## Resonator Cavity Shape



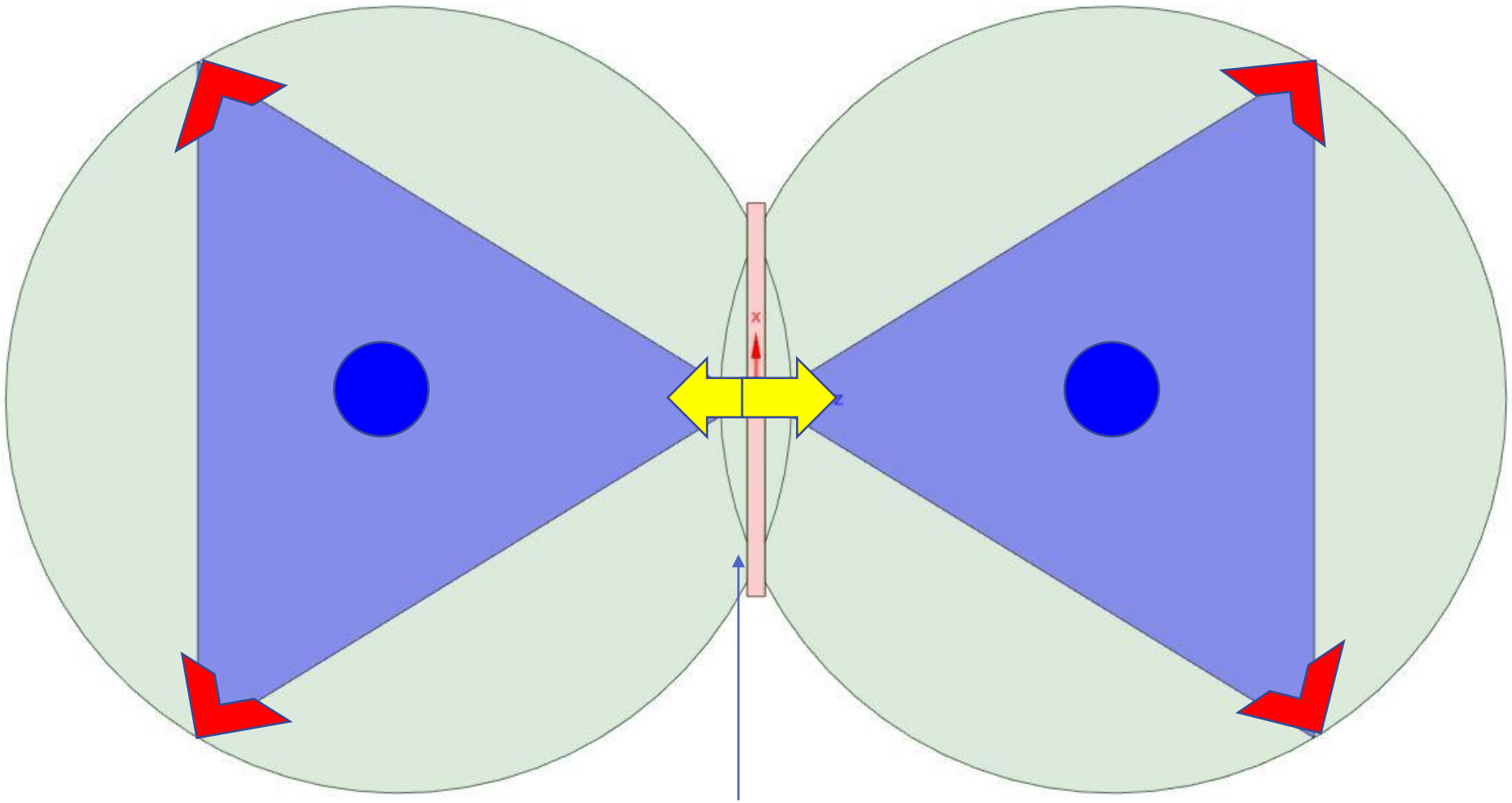






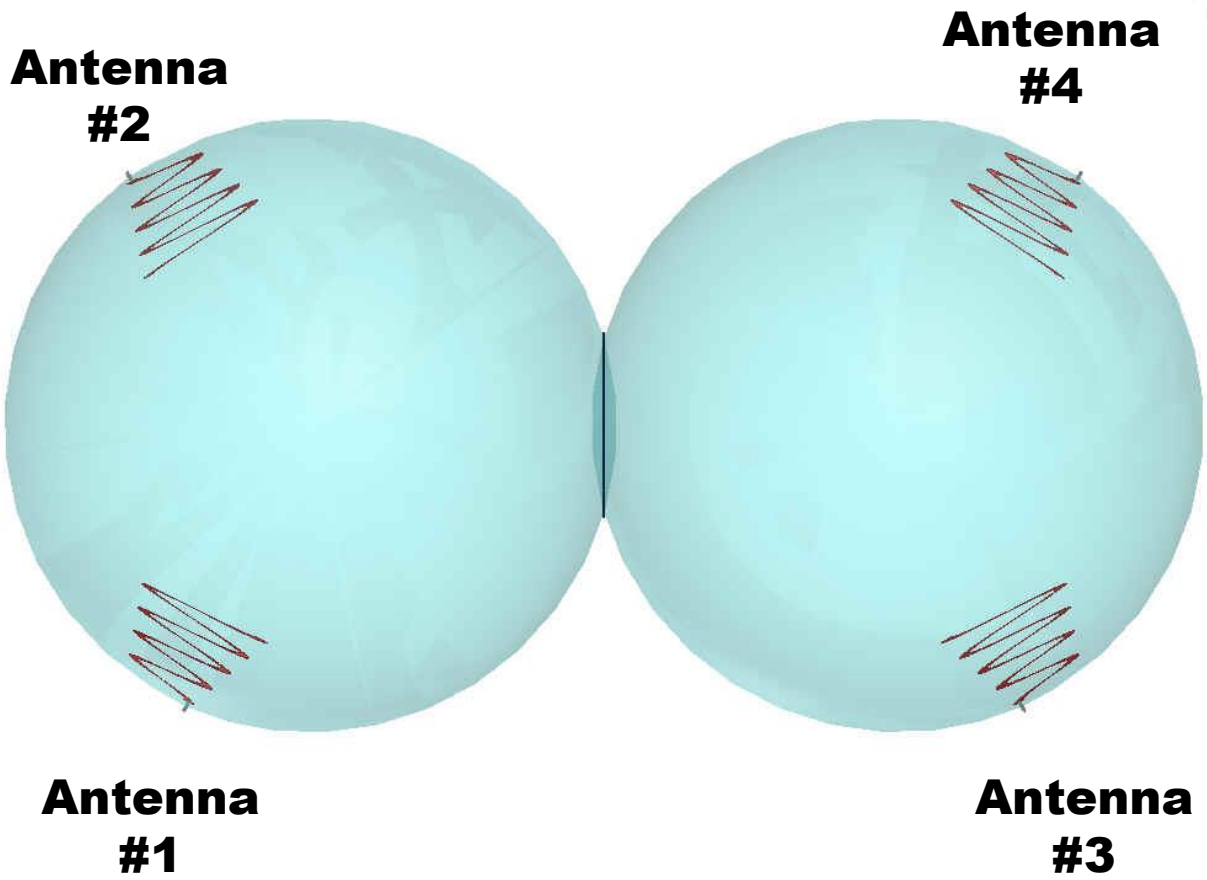
# Design Options for Dual Cavities

## Spherical Cavity Resonator Setup




**BULKHEAD for DUT**

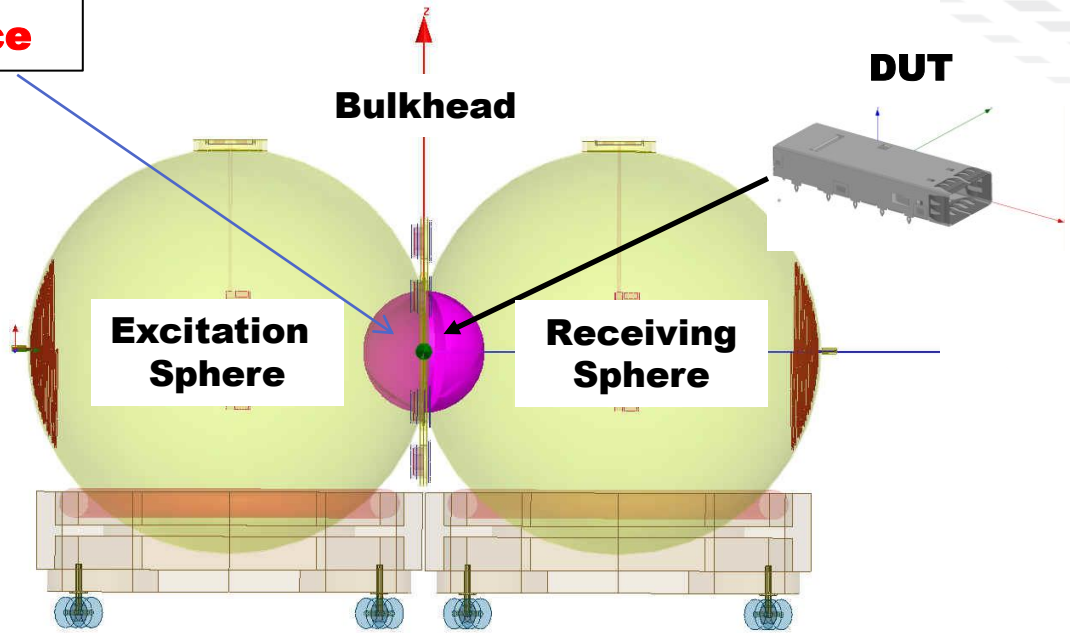
# 4 port Measurement



# Measurement Setup

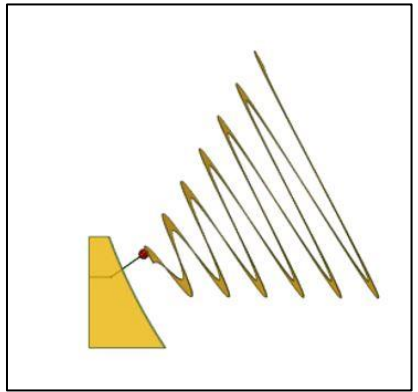
**Test Zone**
**&**
**Simulation Space**

**Plane wave Excitation Mode Stirred Theory**




**Simulated TRP On Inner Sphere**

**Helix Antenna**



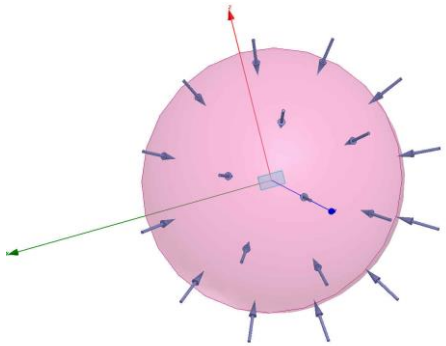
**Measurement based on energy density in spheres.**

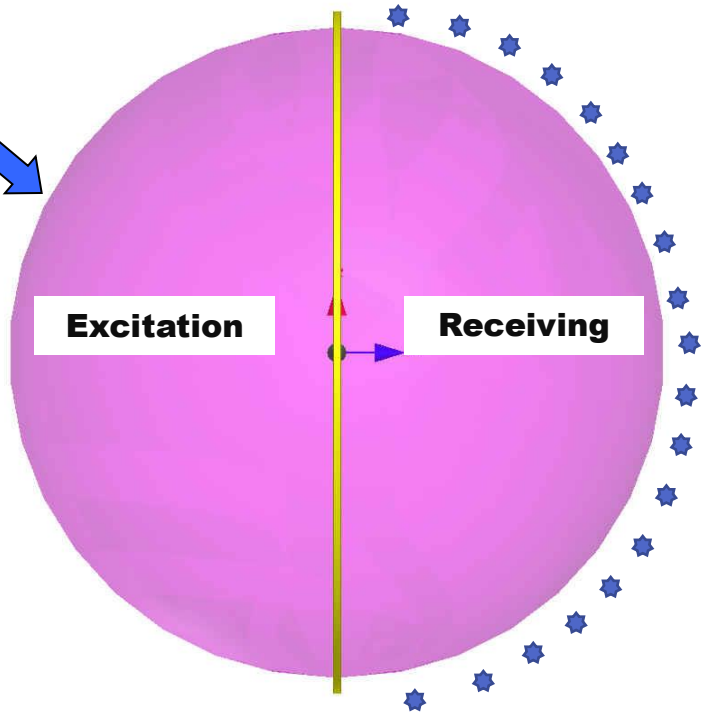
# Simulation Setup

**Incident Plane Waves on Boundary**

**Power Summing Absorbing Boundary for TRP**

**Plane wave Excitation**






**Simulation space provides visual details.**

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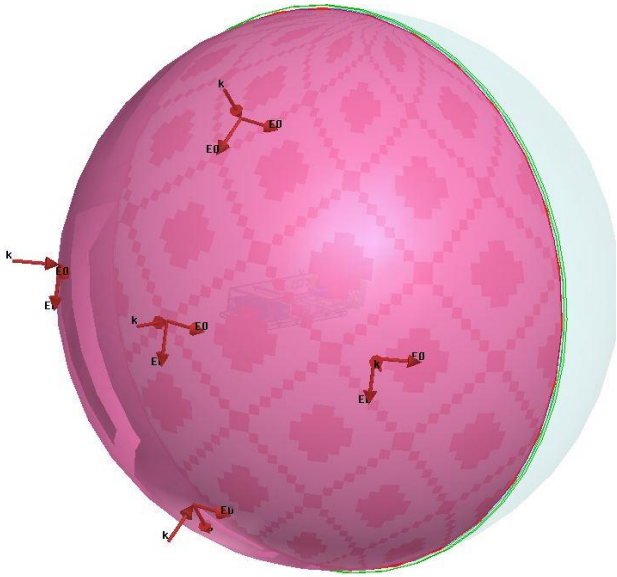
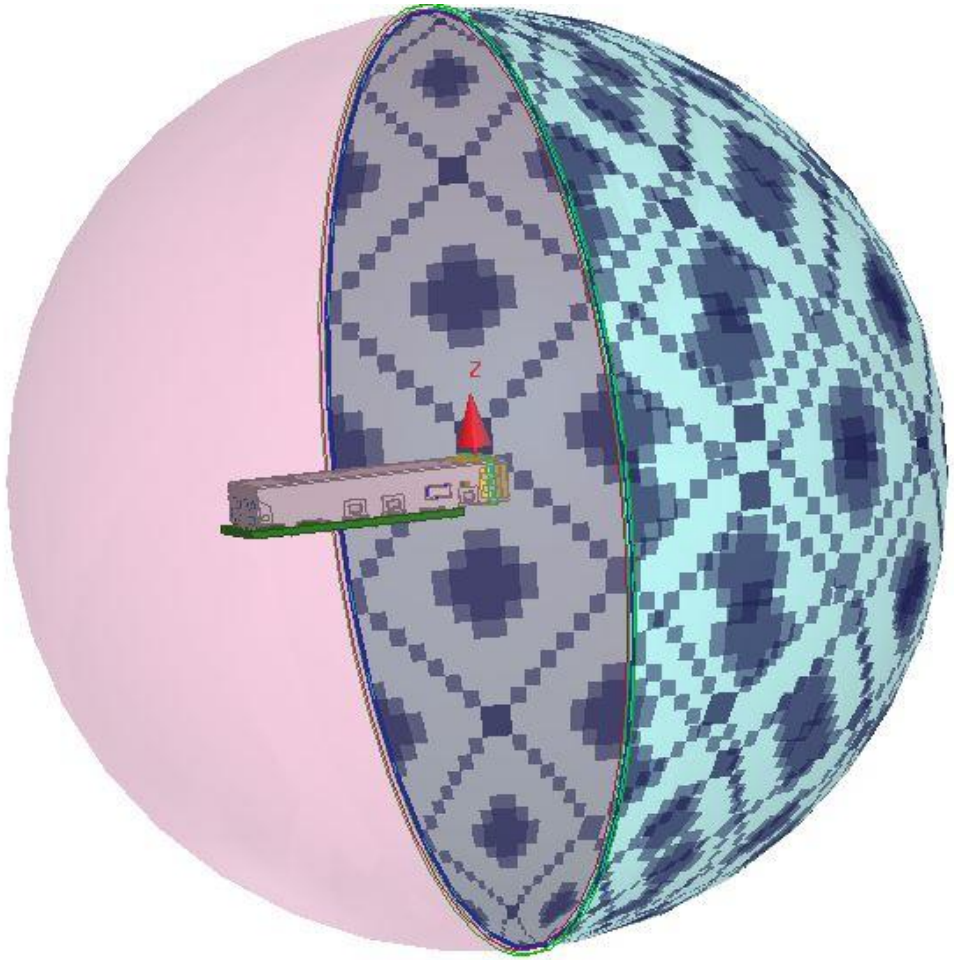
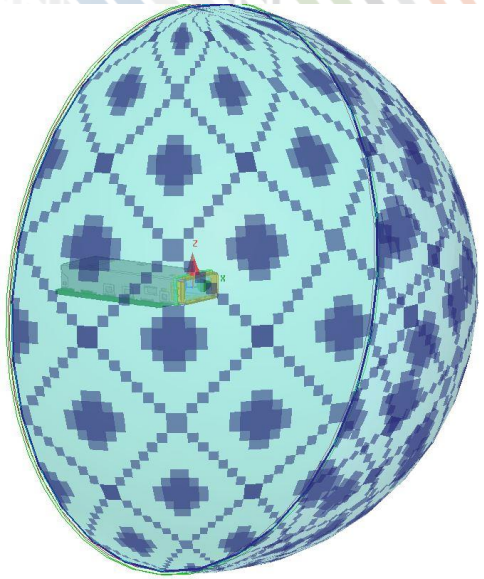
# HFSS illuminates DUT with Plane Waves

**Incident Plane Wave Excitation**



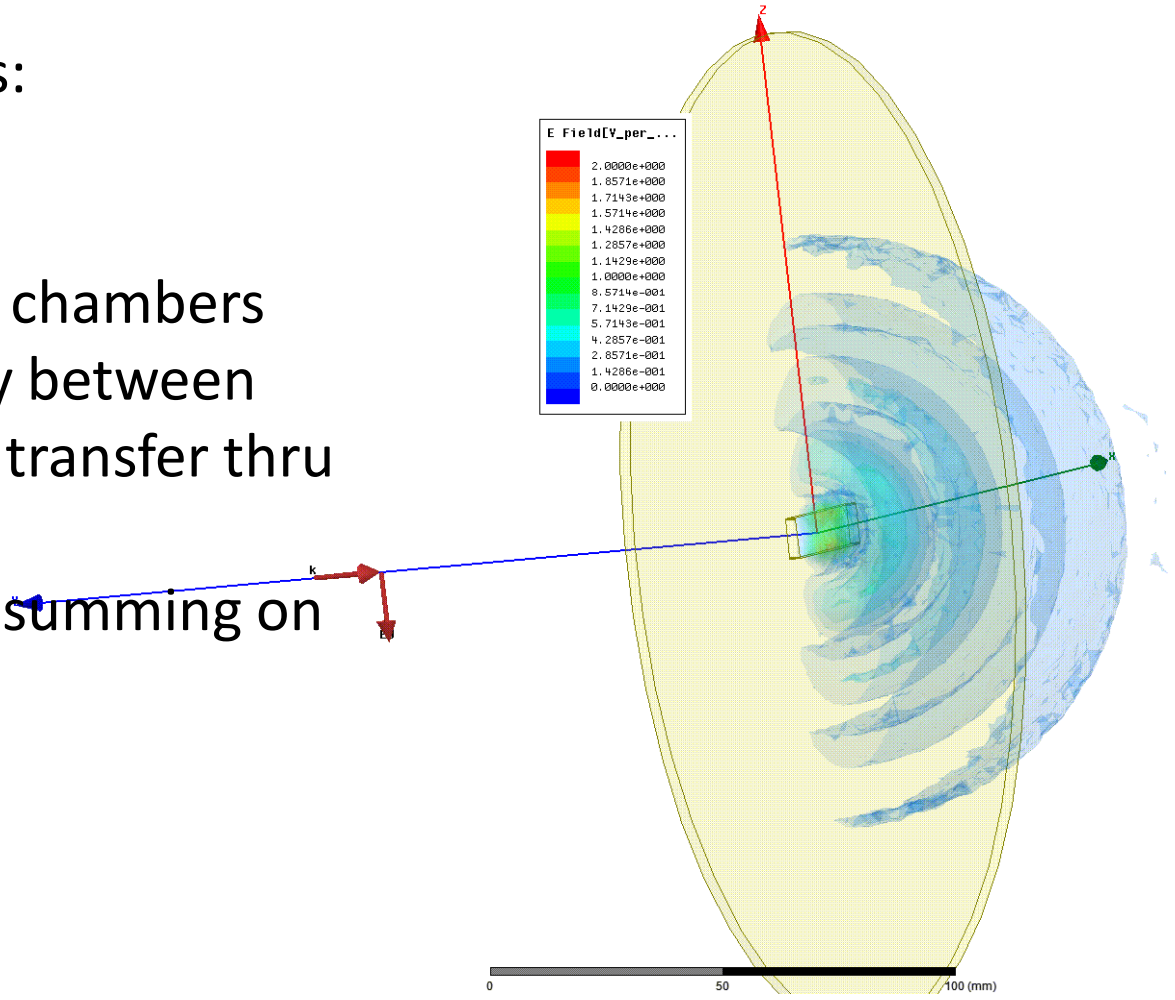


**Power Sum on Absorbing Boundary**

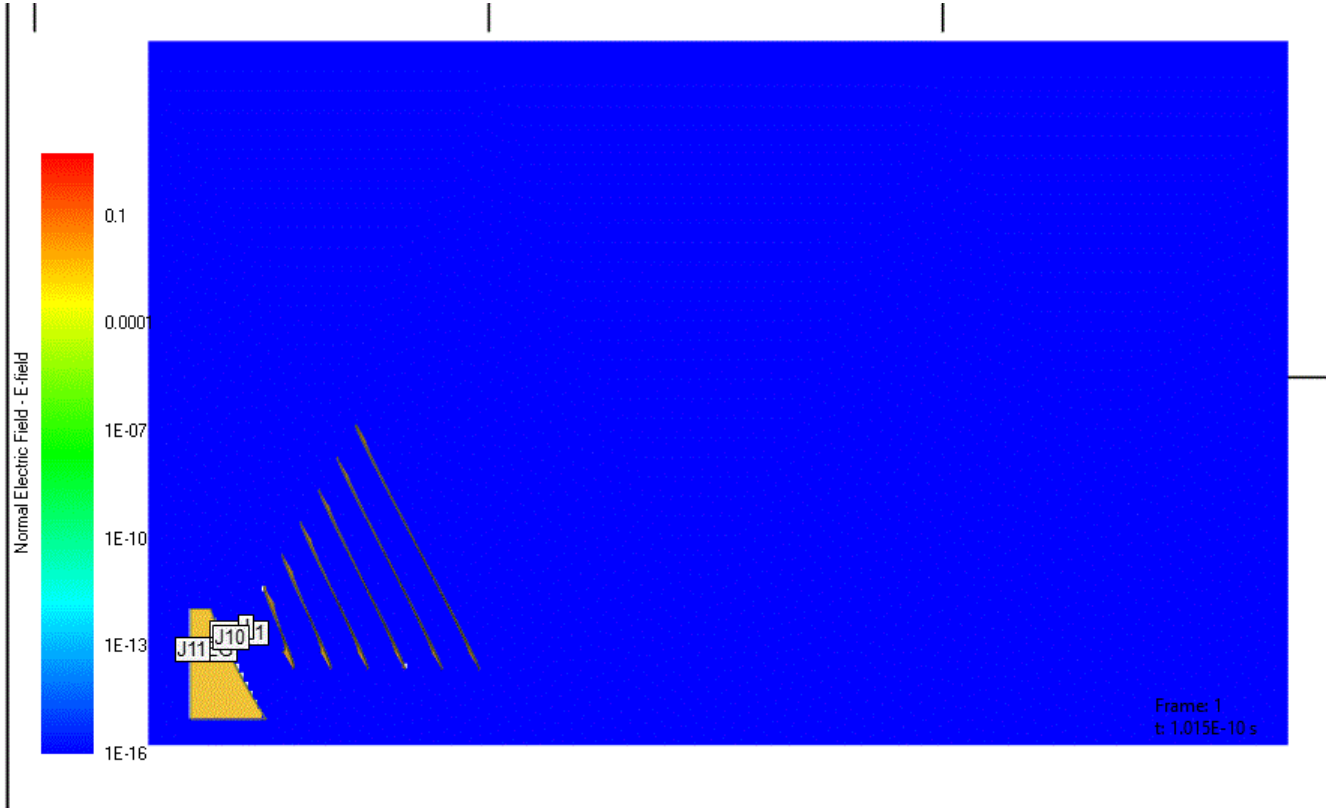


# Simulated Power Transfer thru Aperture … TRP

- Requires two chambers:
  - ❑ Excitation
  - ❑ Receiving
- DUT is placed between chambers
- Ratio of energy density between chambers is the power transfer thru DUT.
- HFSS computes TRP by summing on boundary.

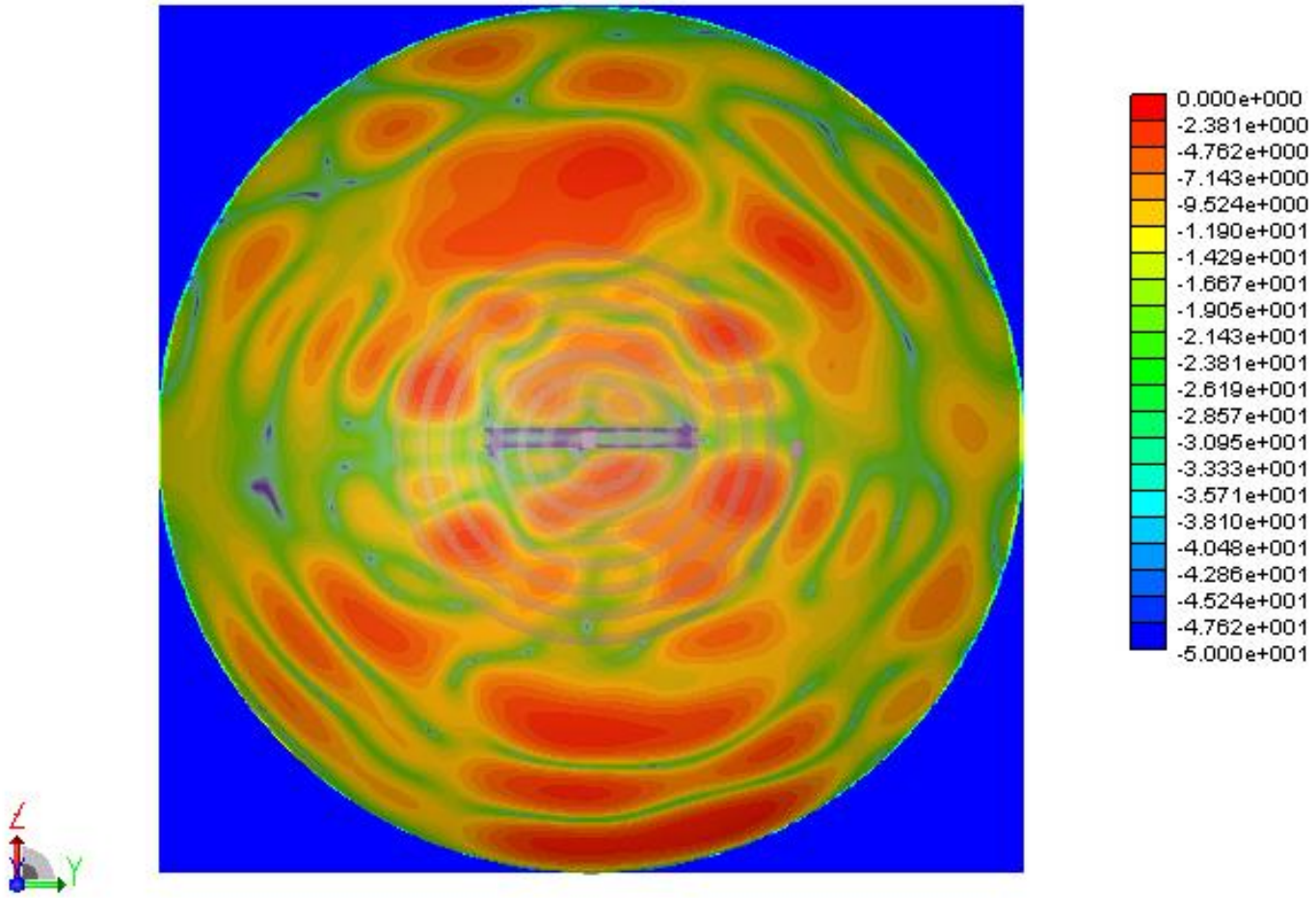


# Free Space Animation of Helix Antenna at OATS




**EMA3D Simulation Support**

# Field Pattern of Helix Antenna Inside Resonator Cavity




Ey on YOZ Plane

**EMA3D Simulation Support**

# Dual Reverberation Chambers

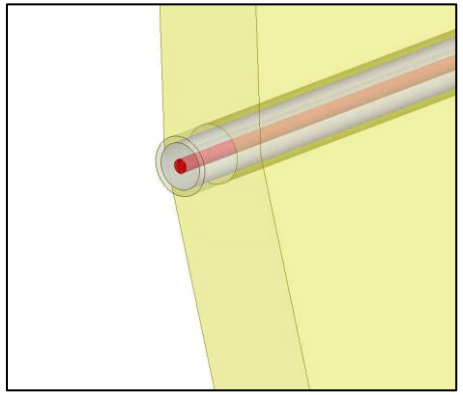
# Accessibility to change DUTs

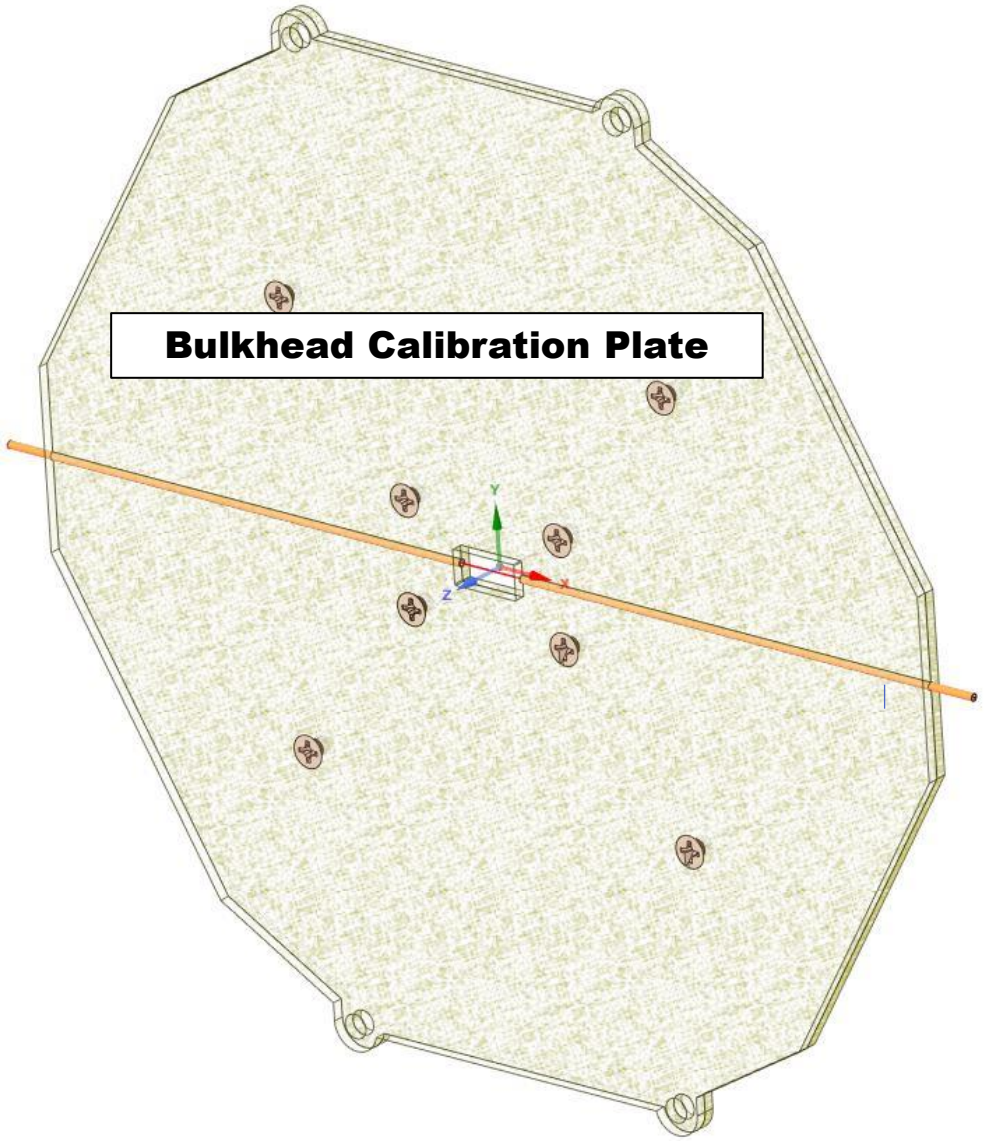
# Correlation: Driven Aperture Standard

**Simulation vs. Measurement:**

- **Ref Planes Identical**
- **RL, IL, Att, TRP**
- **Determine Calibration Factors**

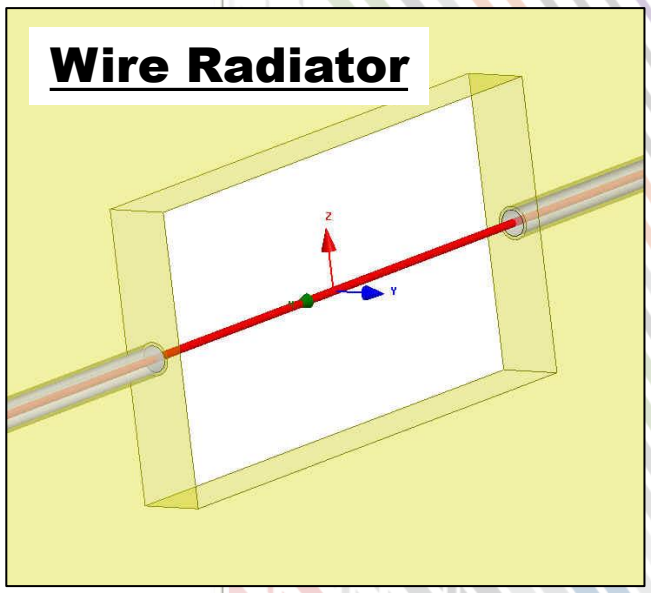
**50 ohm Port**






Ansys
2021 R2

**Wire Radiator**



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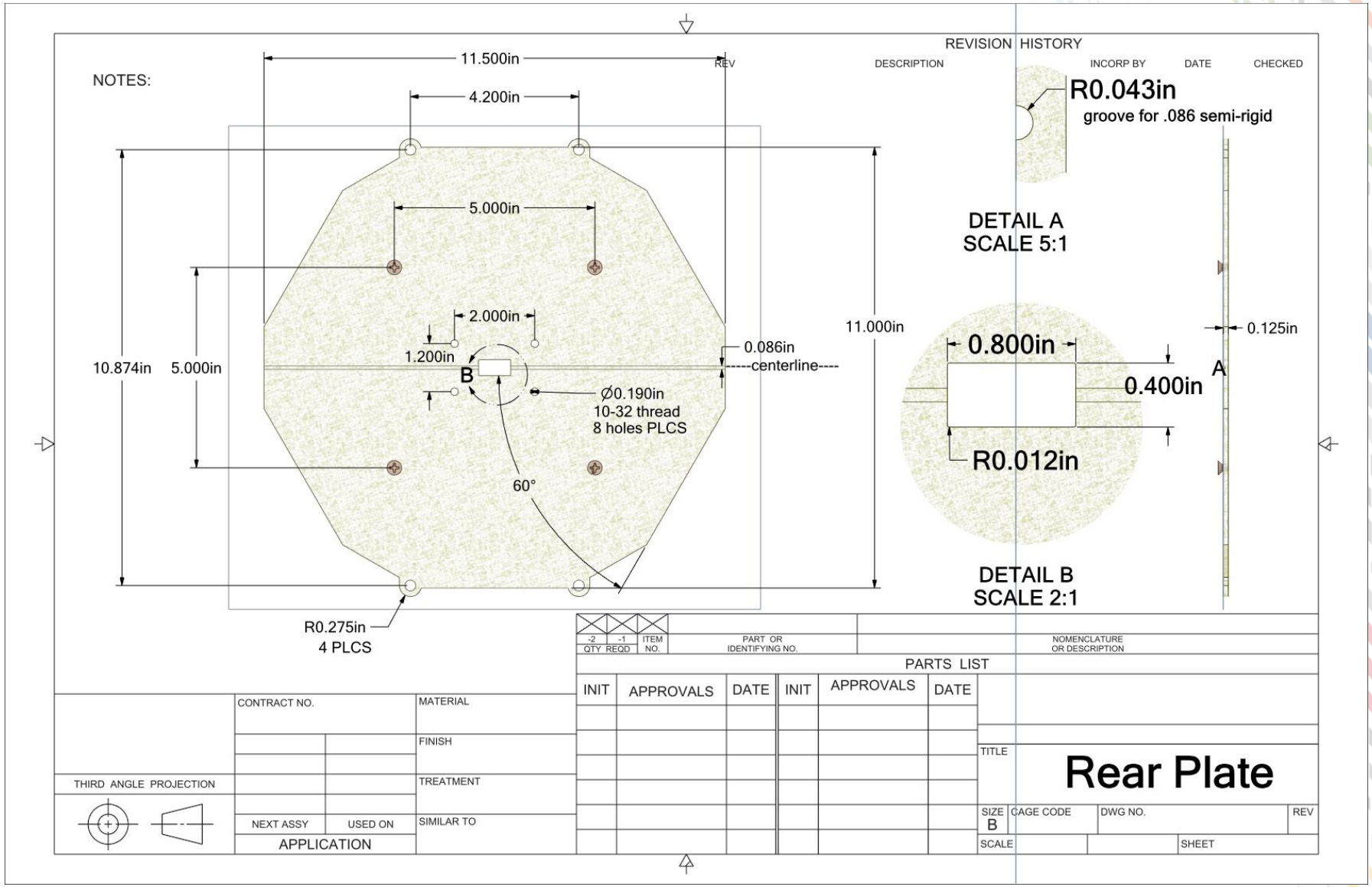
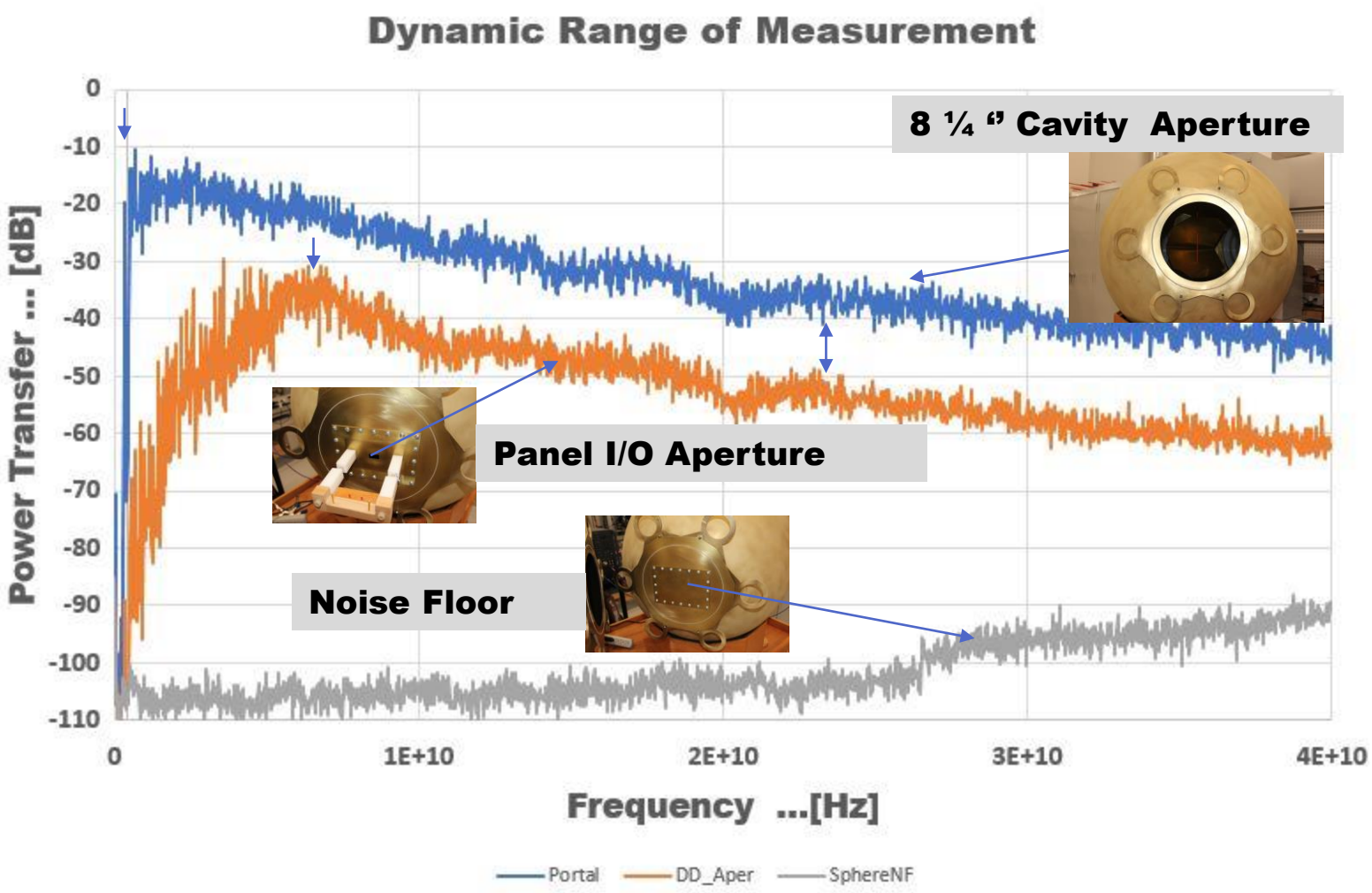
# DRC Calibration/Correlation Plate

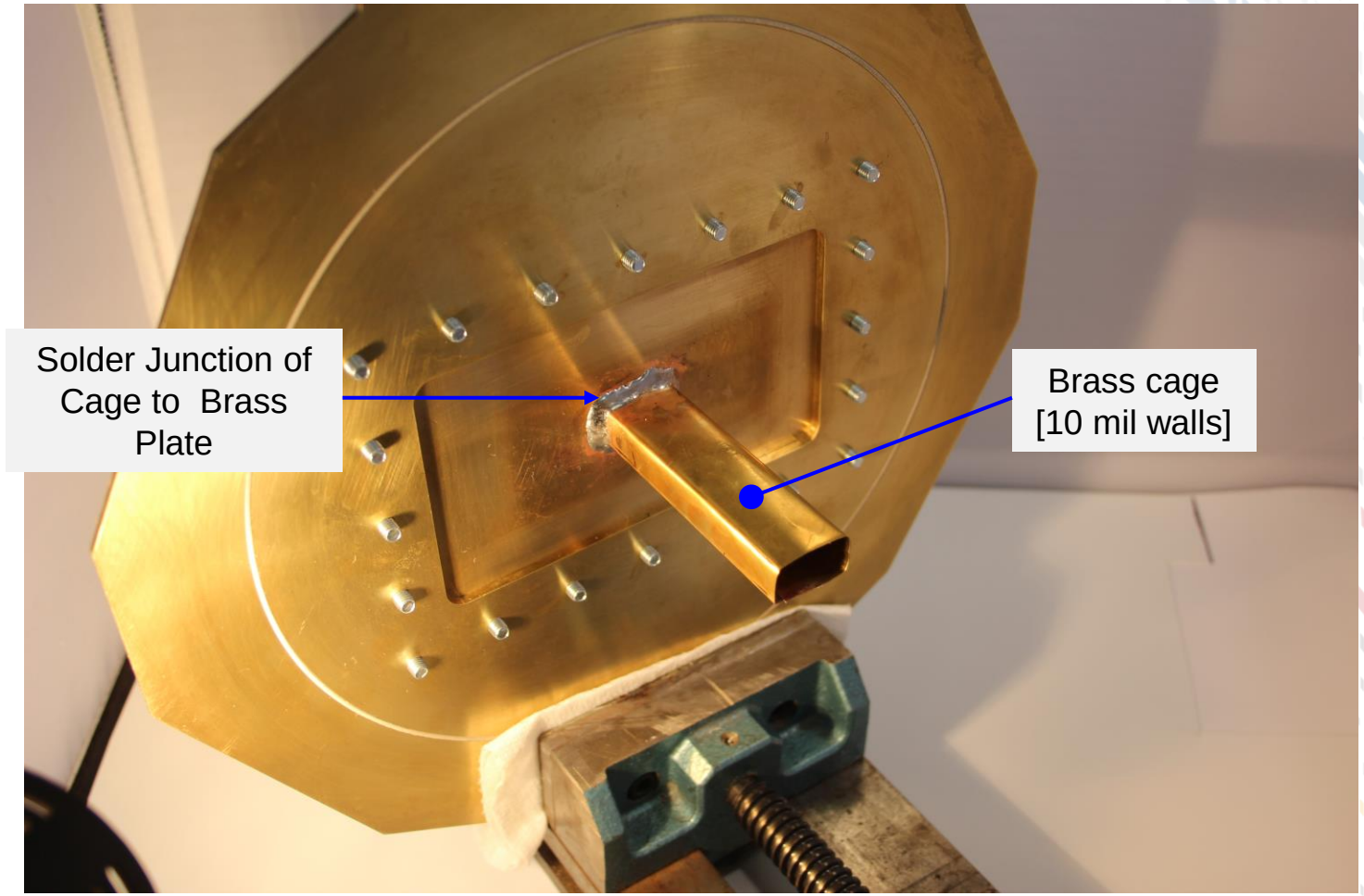


# Useful Measurement Examples

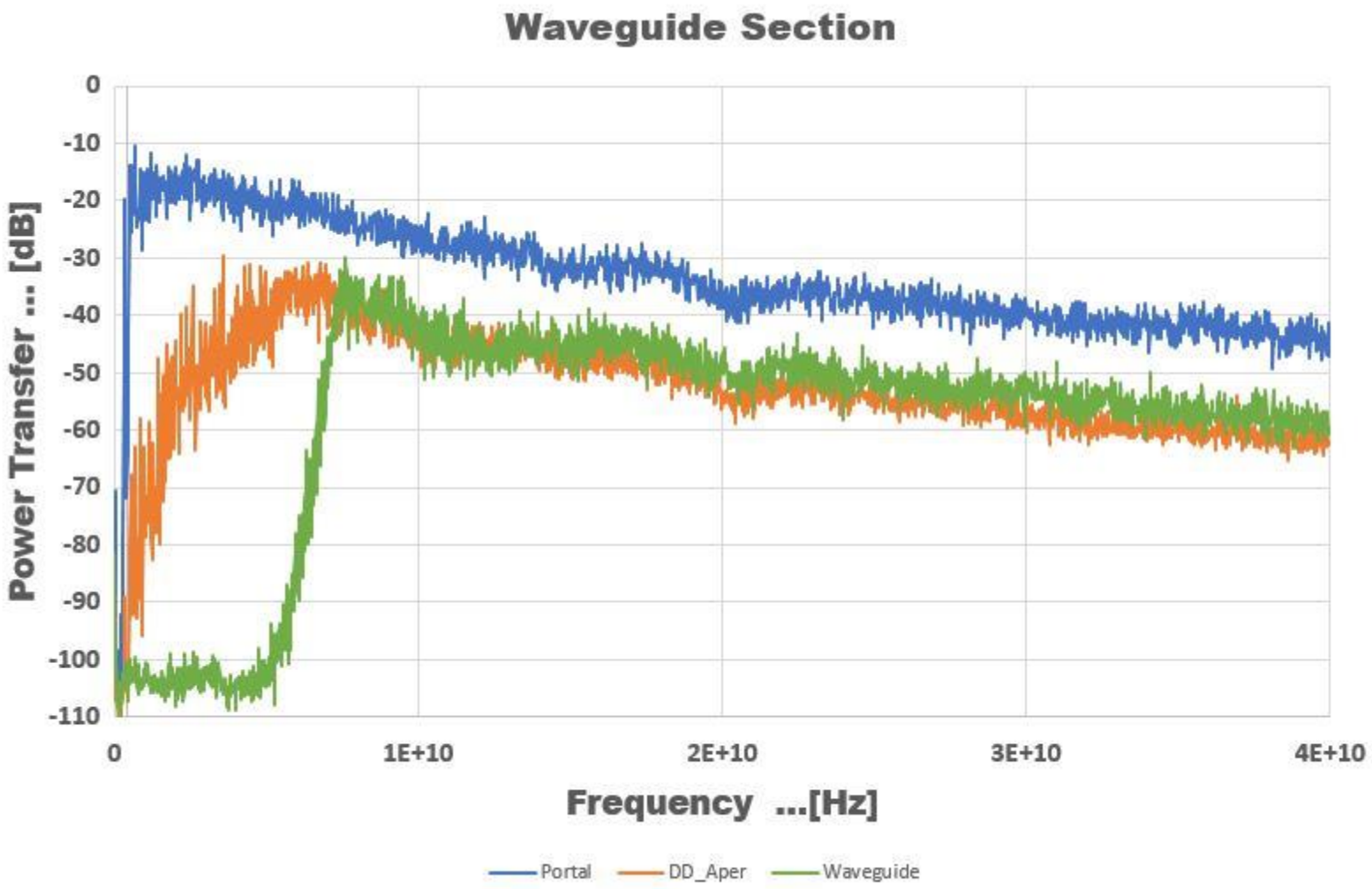
## #1 DRC Apertures / Noise Floor Plate



# #2 Rectangular Waveguide Section

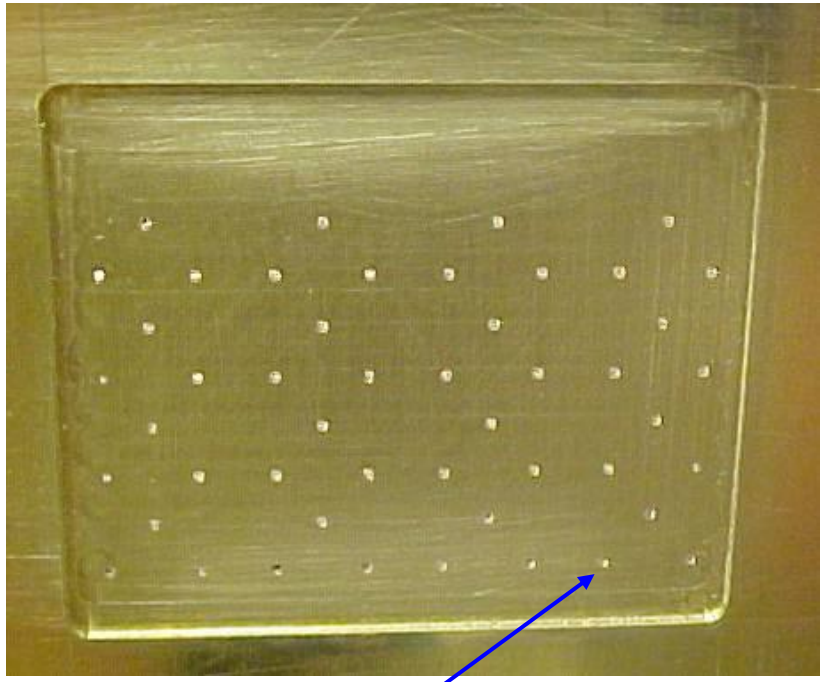


# Waveguide Section Example

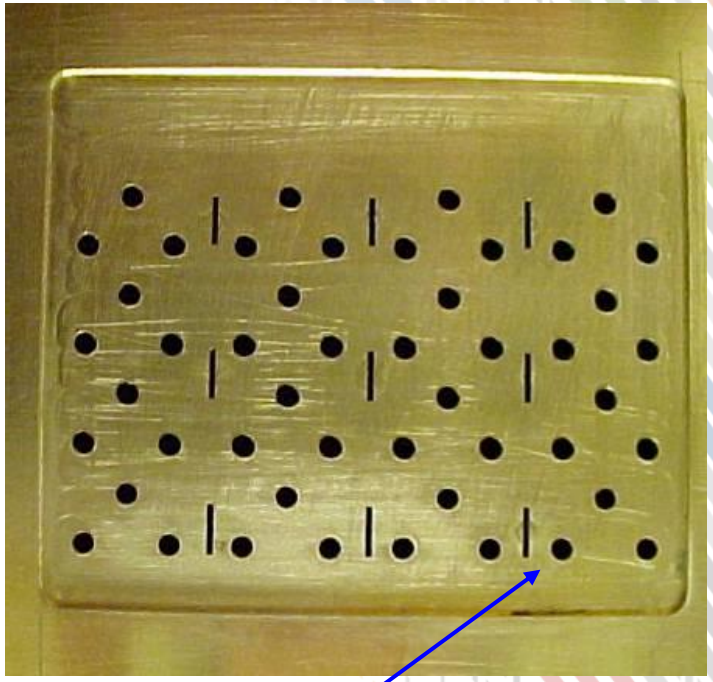


# #3 Ventilation Hole Pattern vs. EMI

**Progressively increasing ventilation hole DIAs while measuring EMI**

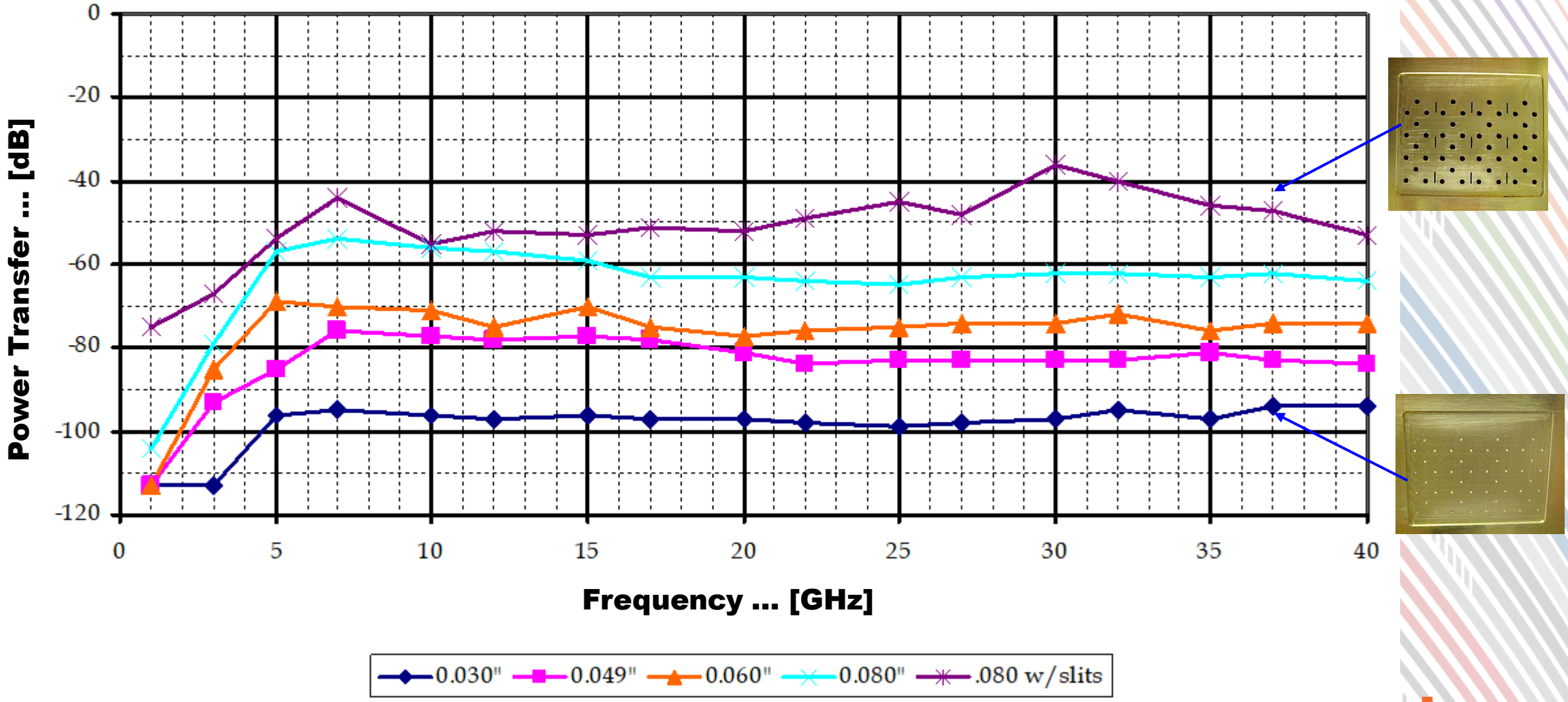


Initial Hole Size is
30 mil DIA



Final Hole Size is
80 mil DIA w Slits

# Power transfer for increasing Hole DIAs

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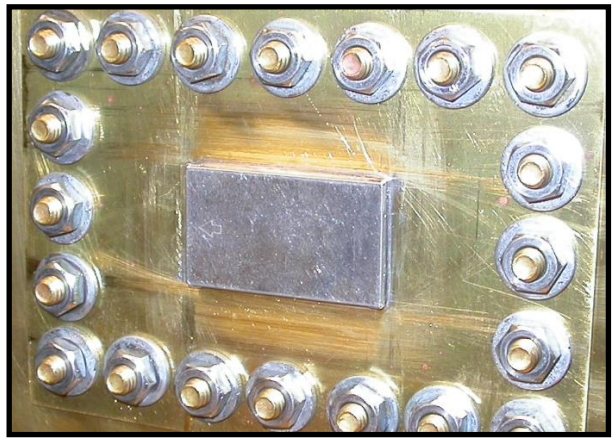
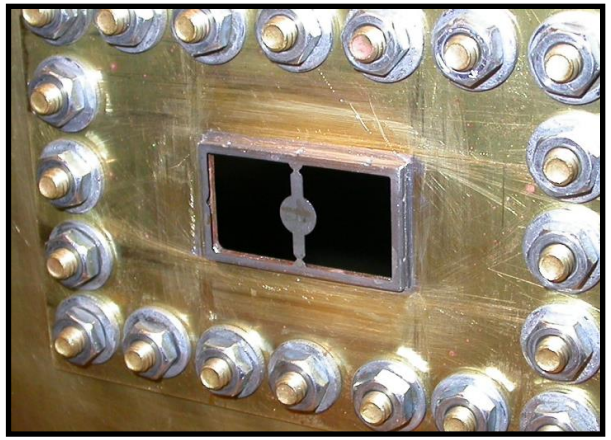
# #4 Shield Cover for PCB Component



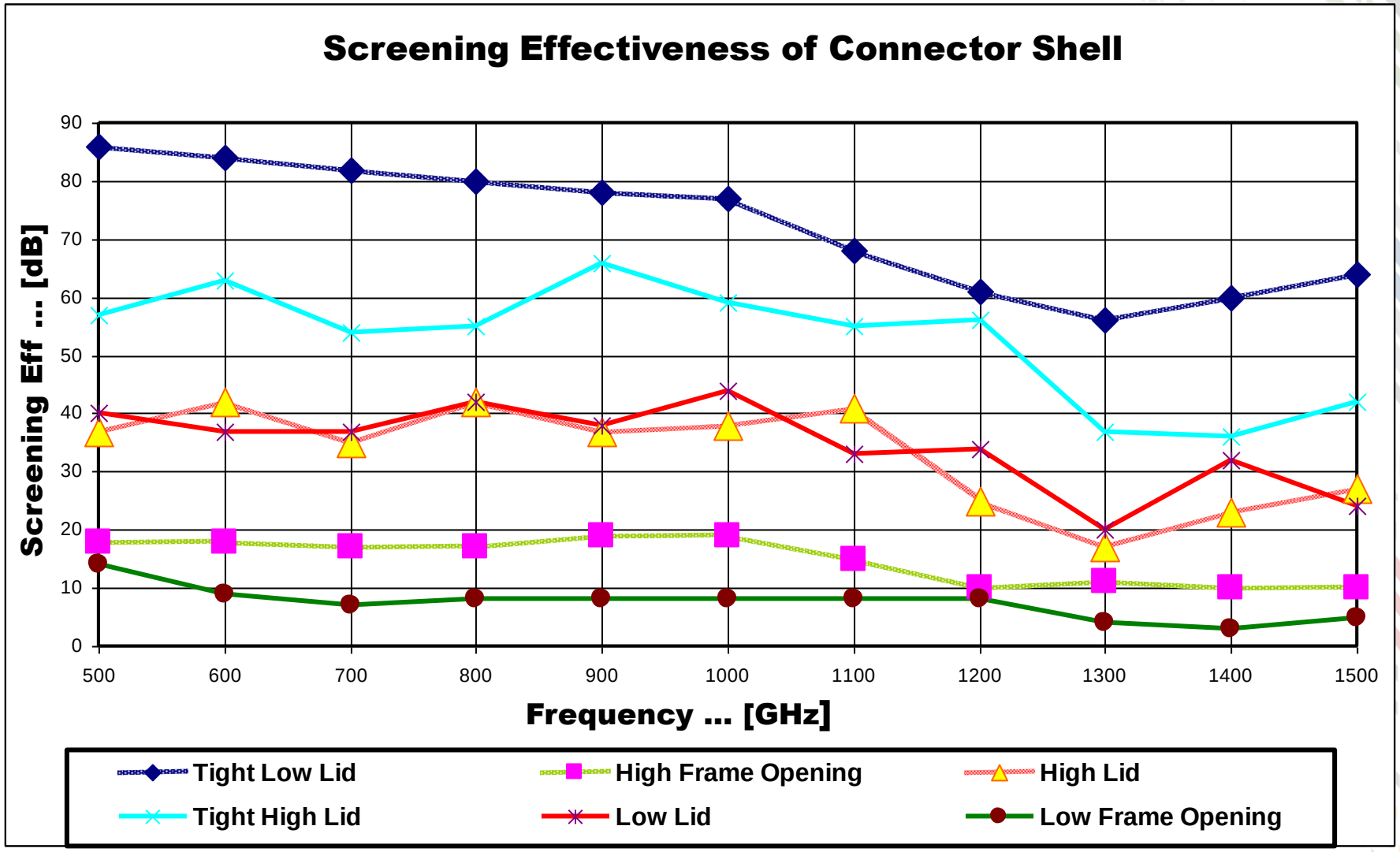
Snap-On-Lid



Prototype Frame Low Height

Prototype Frame High Height

# Screening Effectiveness



# Screening Effectiveness Definition [ScrEff]

**Shielding Effectiveness [SE] definition is widely used across many test specifications:**

$$SE = 10 \log (P1/P2)$$

**Where the Reference Power [P1] is commonly defined in different ways:**

- **Input power a DUT is energized with**
- **TRP from an Unshielded Connector Cable Assembly [CCA]**
- **Power level measured by Chamber Reference Antenna**
- **Coupling Power between Parallel Plates**

**And [P2] is the DUT emissions.**

**For DRC measurements, trying to avoid adding an additional type of Reference Power [P1] into this mix.**

# ScrEff Definition

**Screening Effectiveness [ScrEff] is defined as:**

$$ScrEff = 10 \log (P1/P2)$$

**Where:**

**P1 = Power Transfer thru Test Aperture**

**P2 = Power Transfer thru DUT in the Aperture**

# dB Help ... sidebar

**Screening Effectiveness [ScrEff] provides the relative reduction of power transfer [aka .. power flow] thru a DUT.**

$$\text{ScrEff} = 10 \log (P1/P2)$$

$$\text{ScrEff}/10 = \log (P1/P2)$$

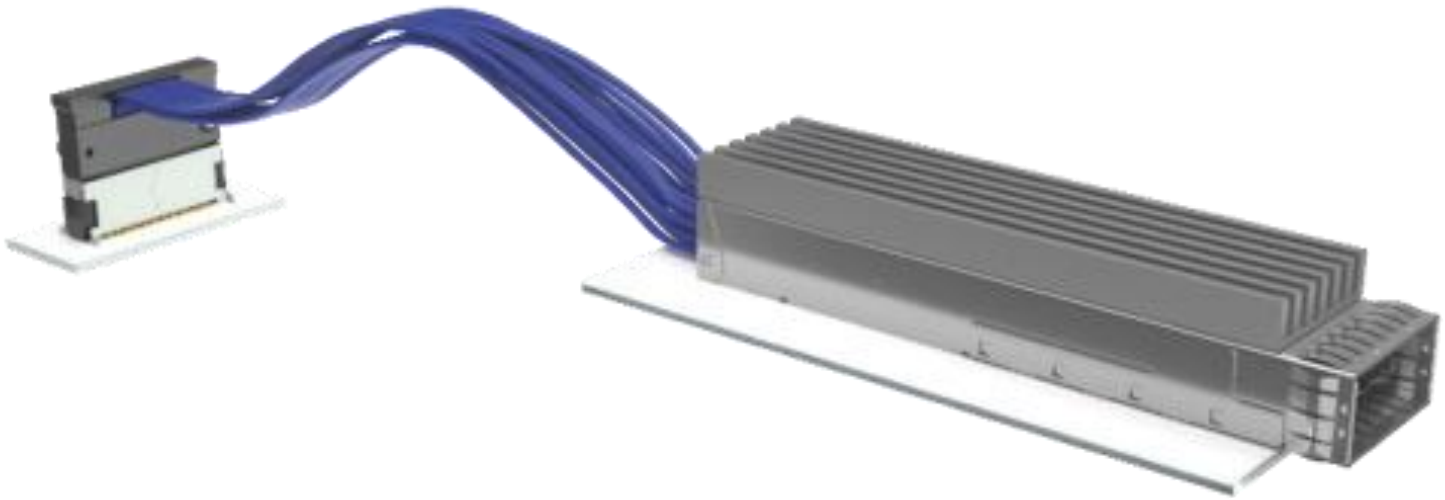
$$\boxed{10^{(\text{ScrEff}/10)}} = (P1/P2) \Rightarrow \boxed{\text{[relative reduction]}}$$

| | | | | |
|---|---|---|---|---|
| ScrEff = 10 dB | equates to | .1 of P1 power transfers thru DUT | -> | 10% |
| ScrEff = 20 dB | equates to | .01 of P1 power transfers thru DUT | -> | 1% |
| ScrEff = 30 dB | equates to | .001 of P1 power transfers thru DUT | -> | .1% |

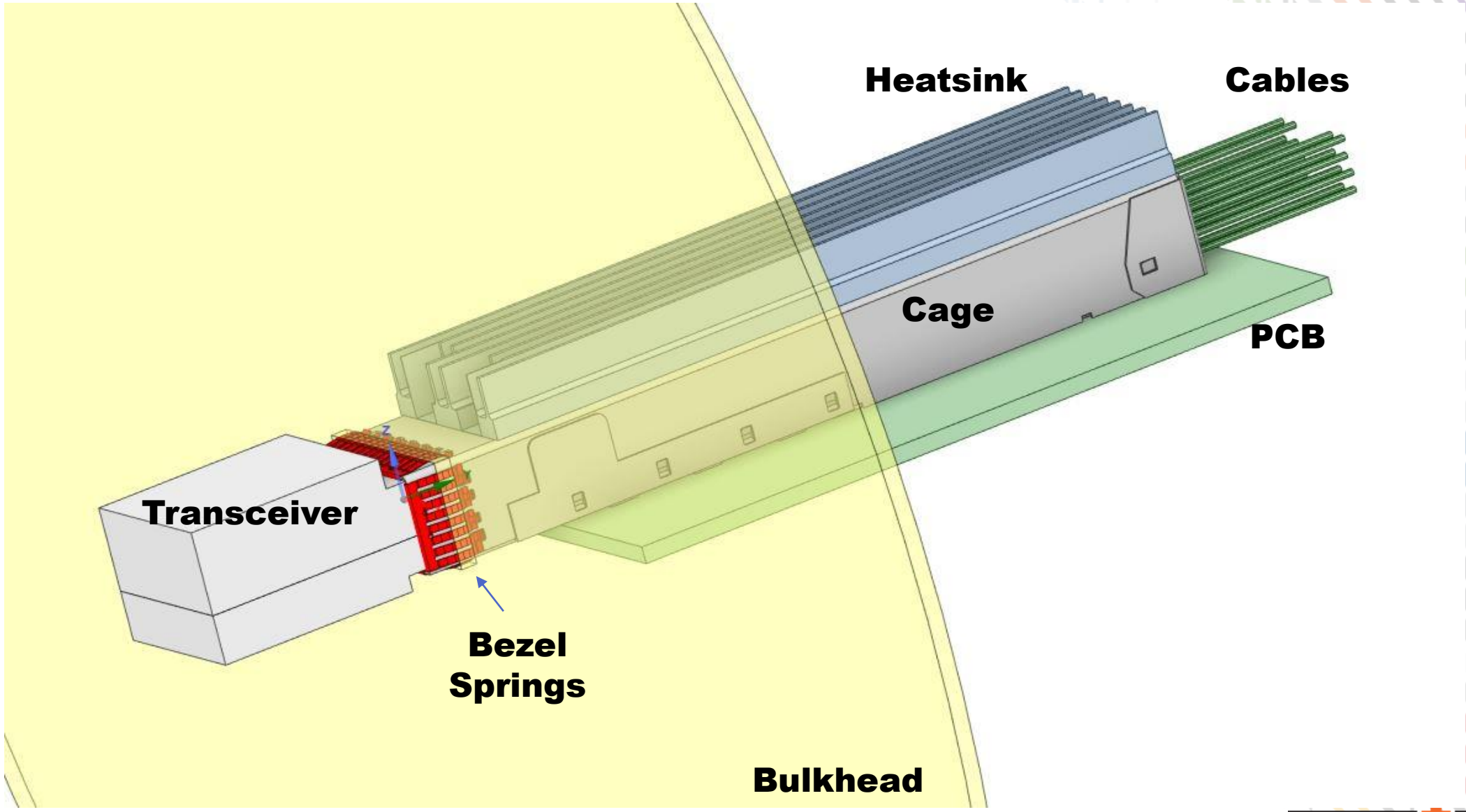
etc....

# IO Connector Port Example

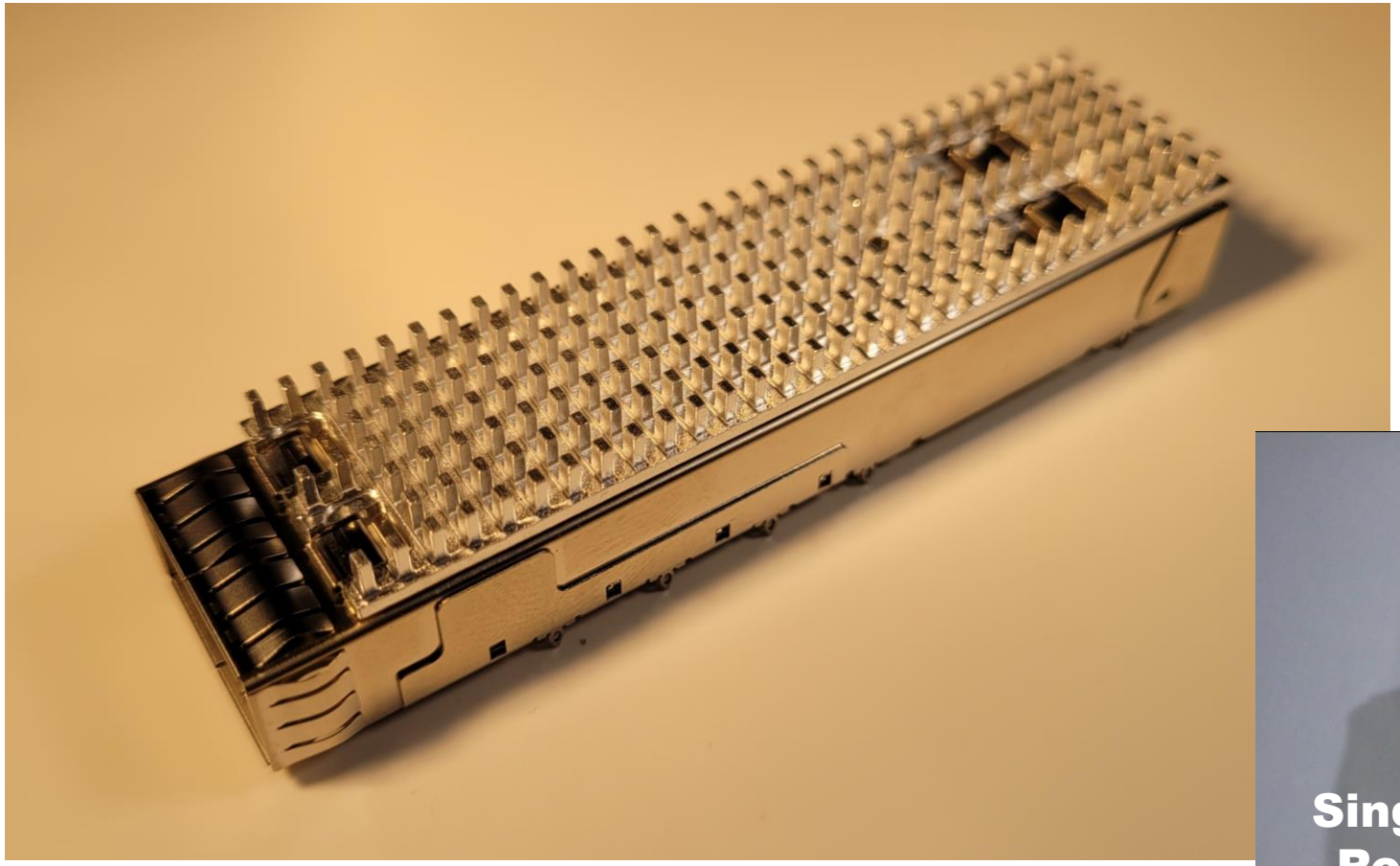
**Double Density Flyover QSFP Cable System Cage**



# Model for Bezel Spring Analysis



# QSFPC-DD Cage



**Cage with single row spring finger design.**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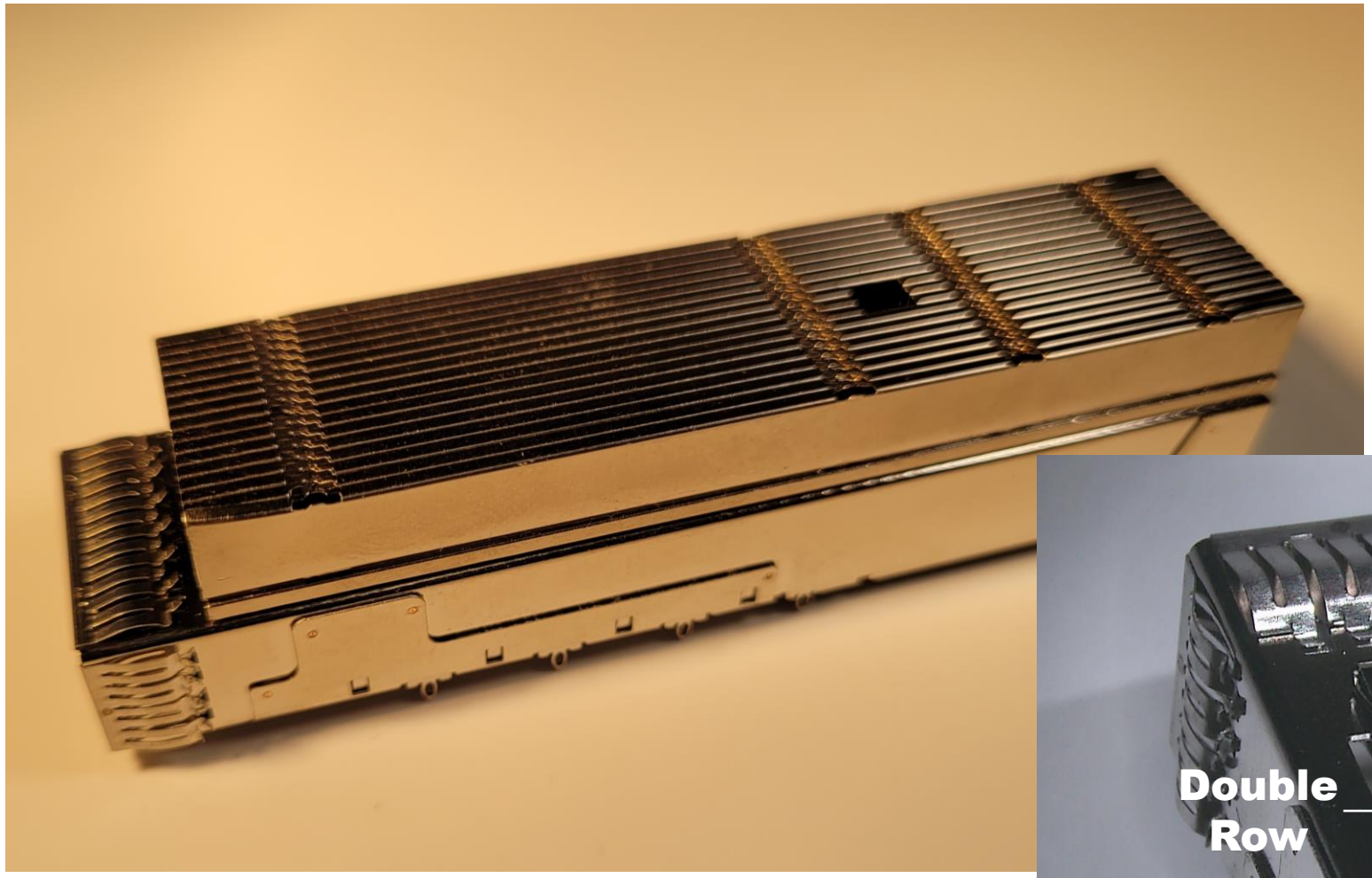
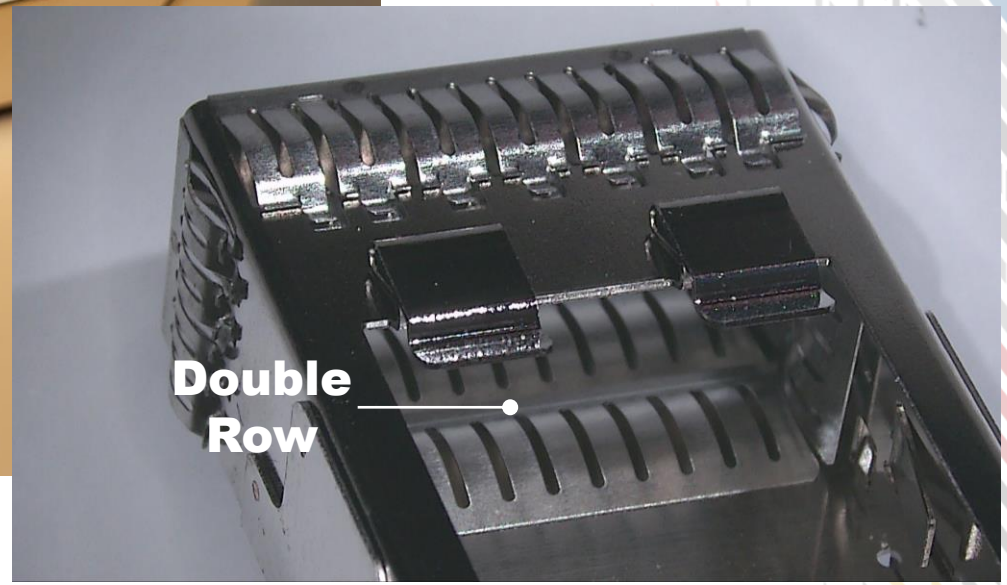
# QSFPC-D8 Cage



Cage with double row spring finger design.

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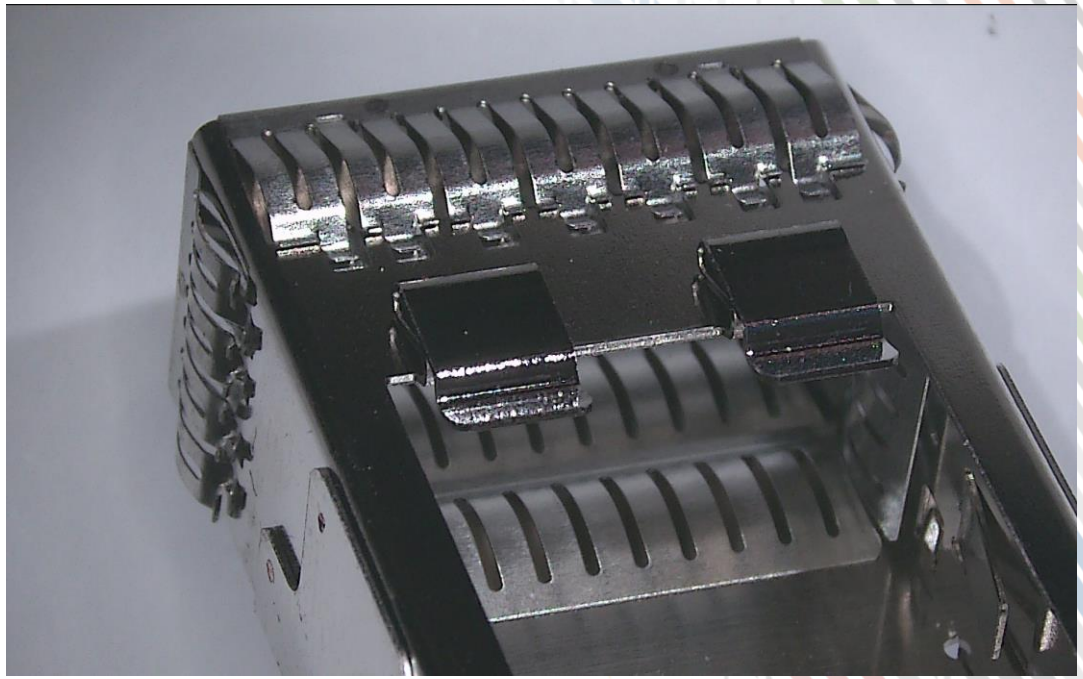
# Spring Finger Comparison

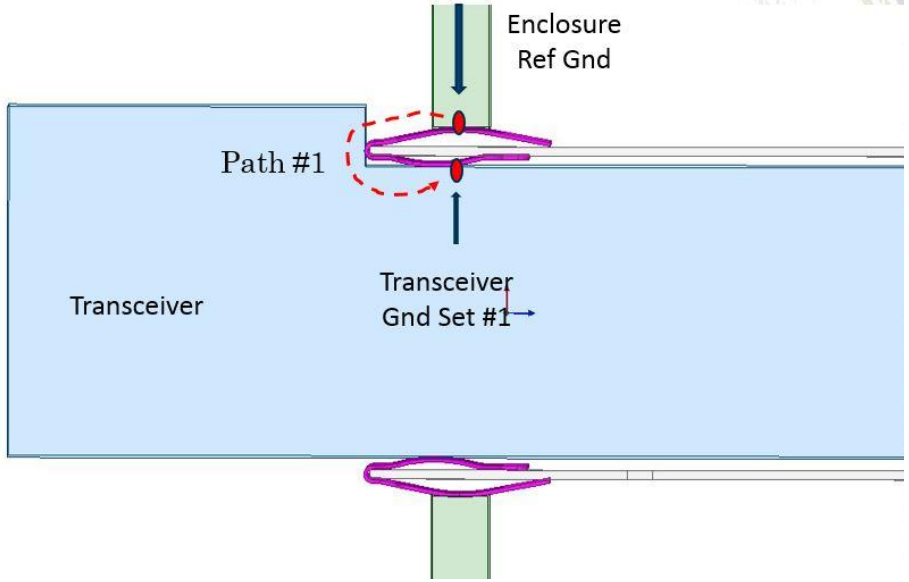
Single Row [DD]



Double Row [D8]

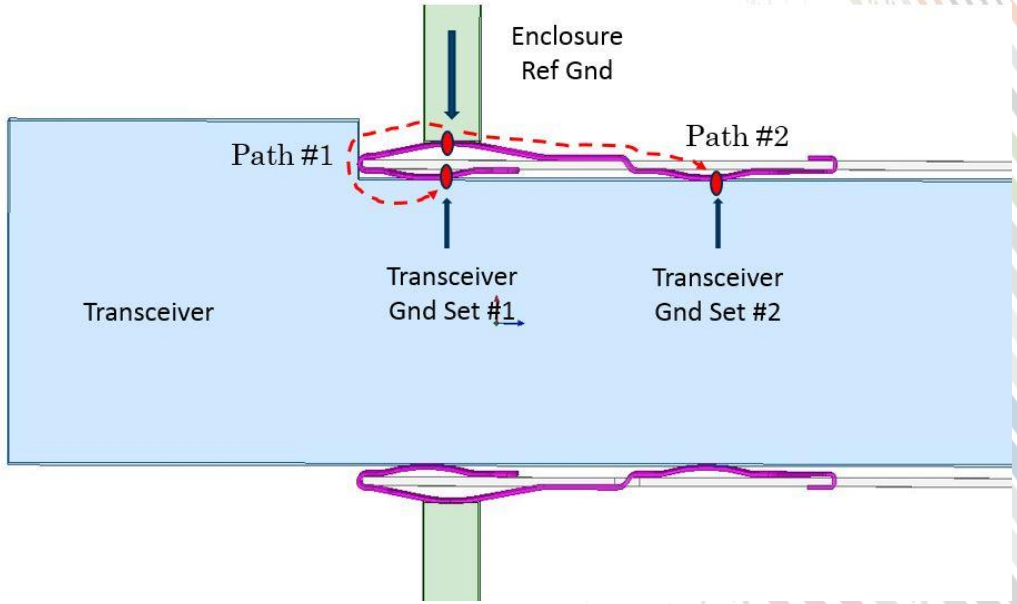
# Single Row vs. Dual Row

## One Ground Path




**Single Row**

## Two Ground Paths

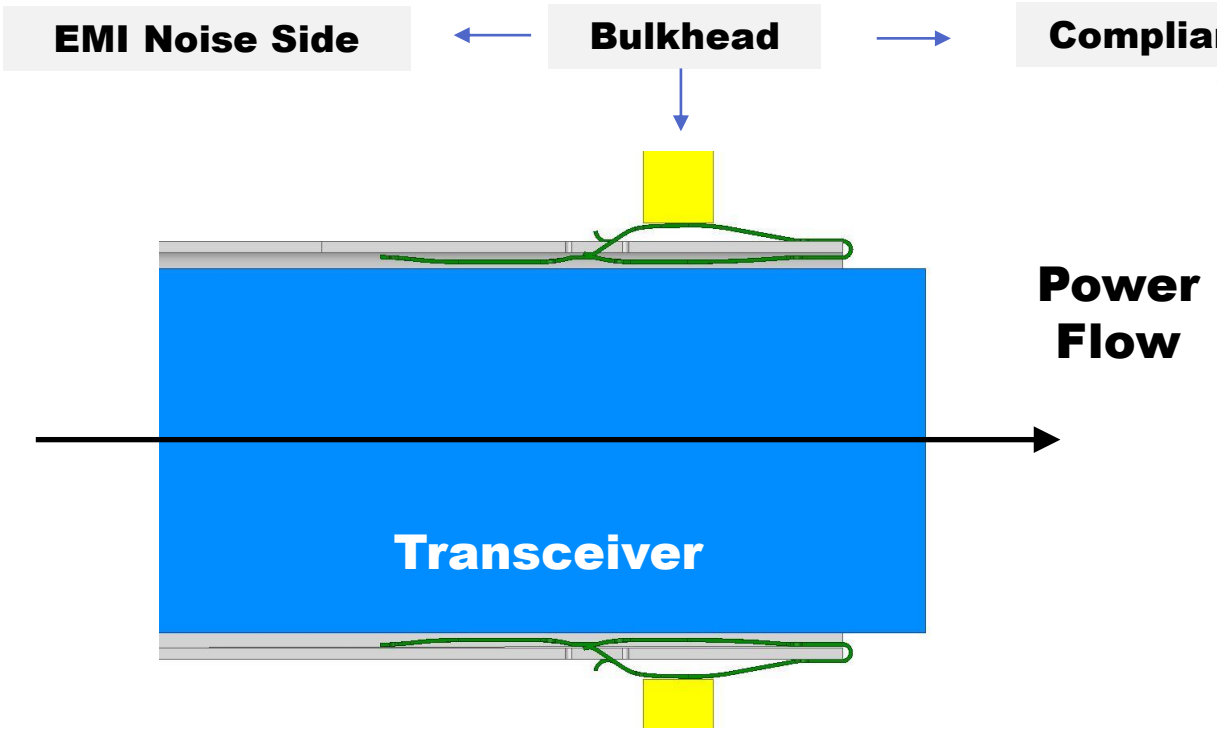



**Double Row**

**Sideview**

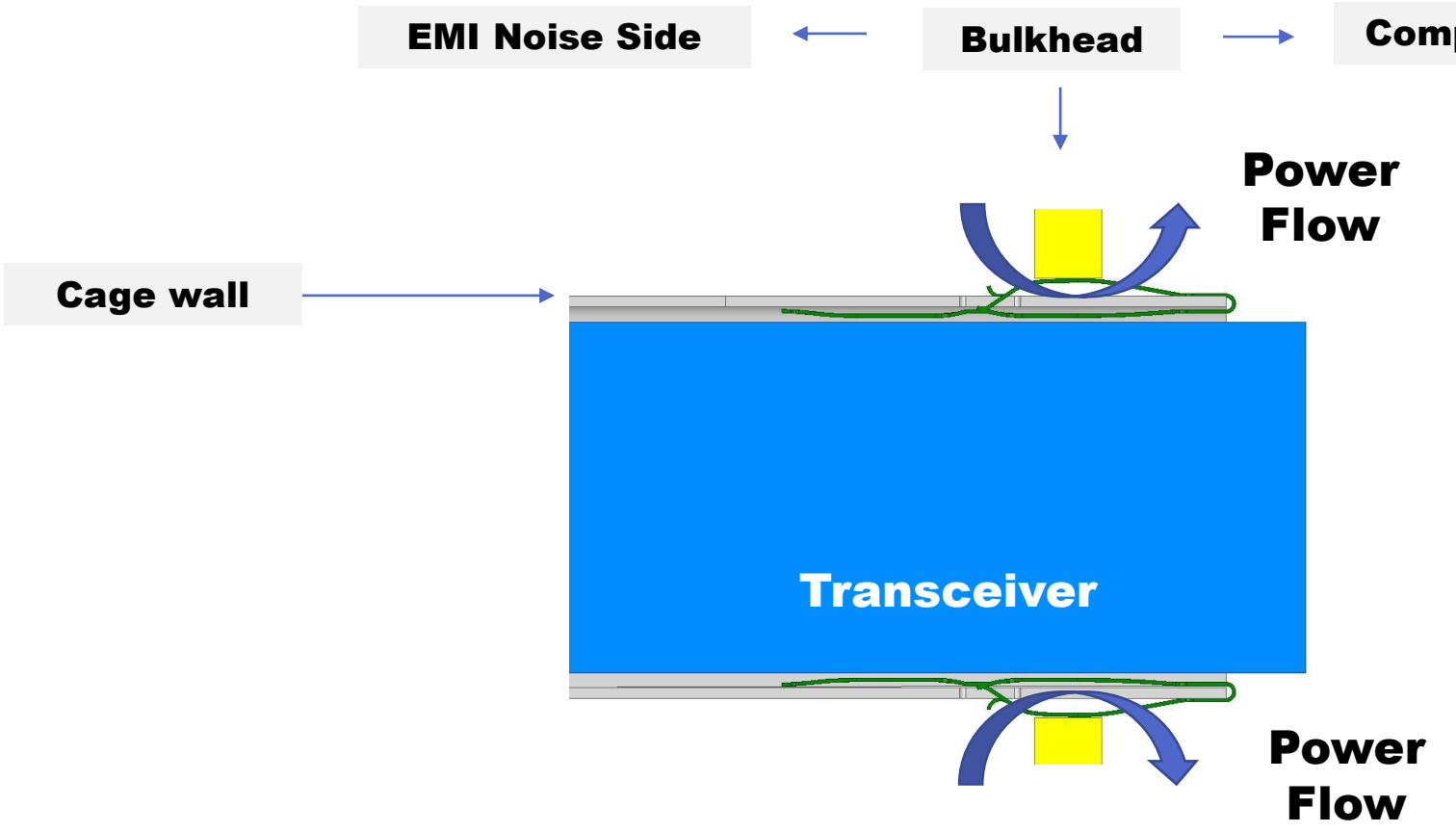
# Pathway #1 for Power Transfer

**Pathway #1 is internal to cage body walls :**



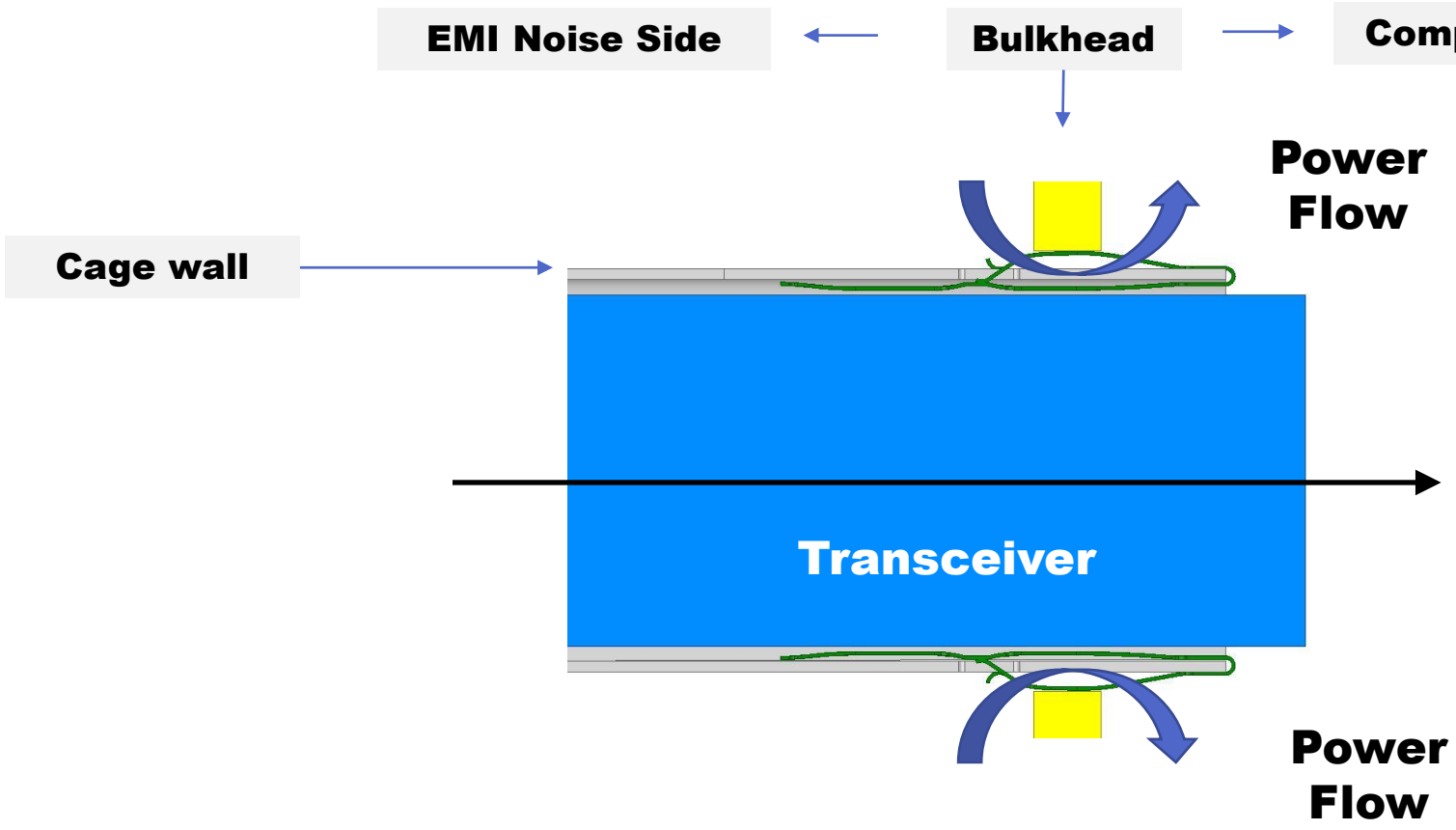
# Pathway #2 for Power Transfer

**Pathway #2 is external to cage body walls:**

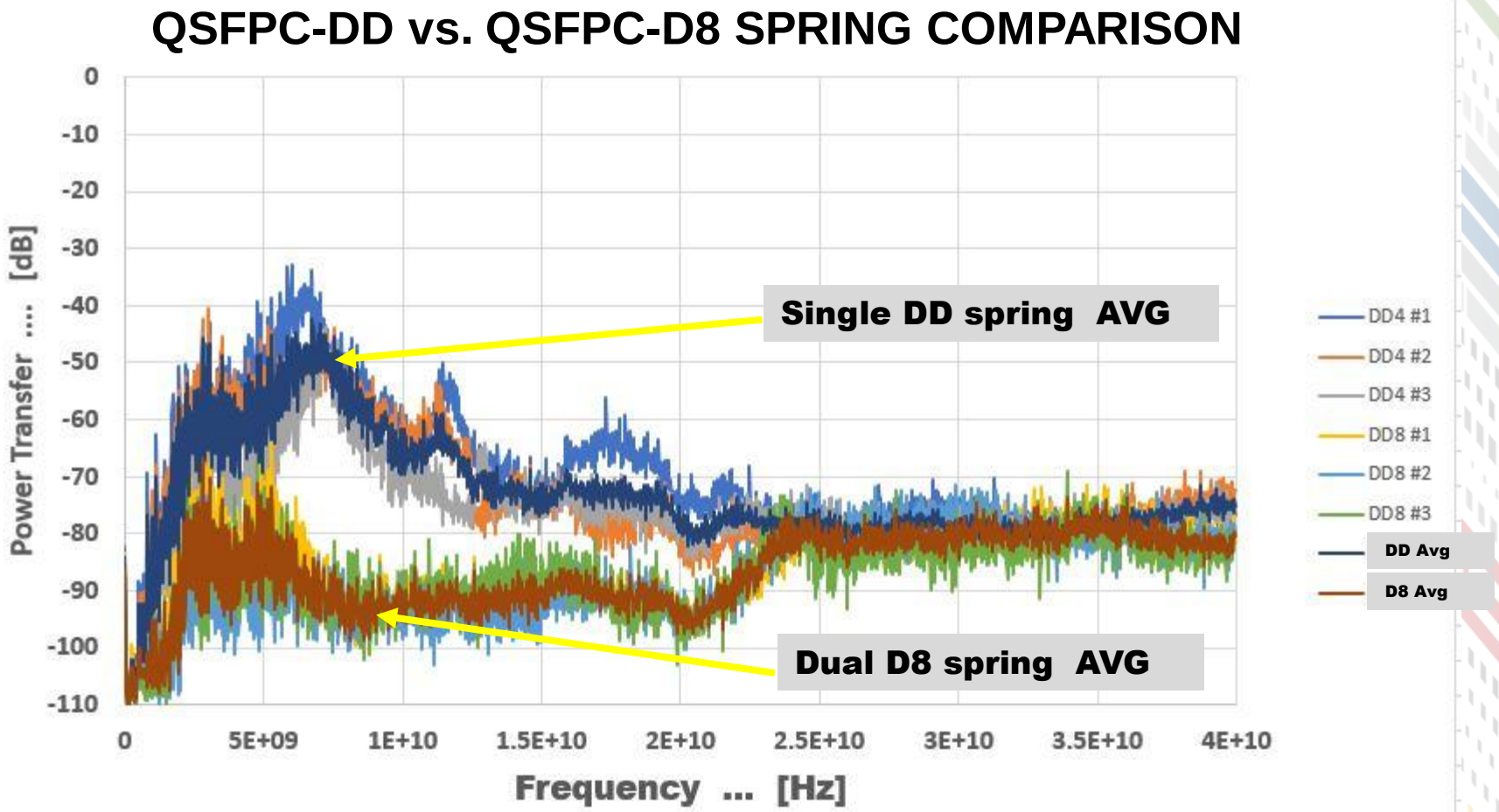


# Final ScrEff Result

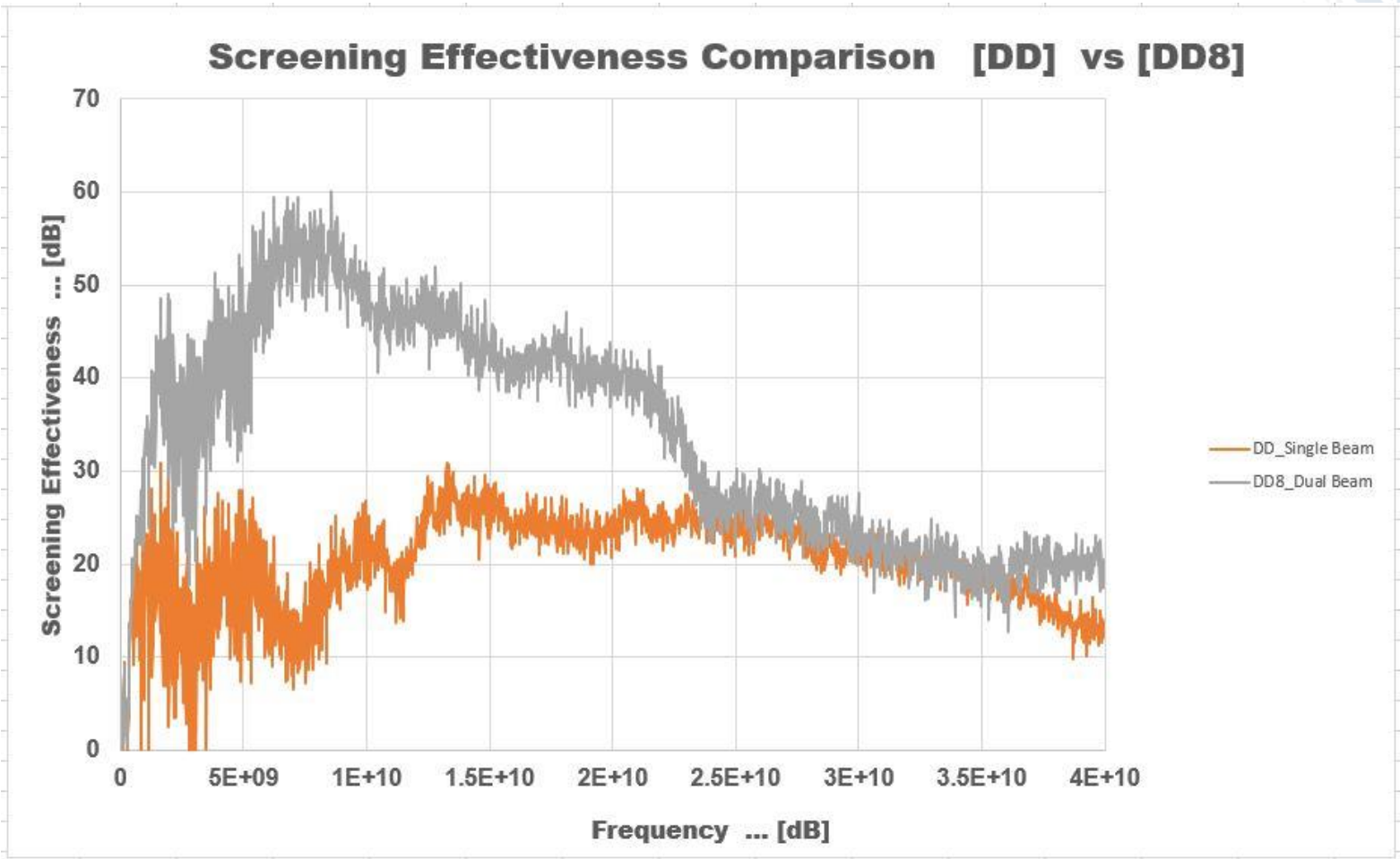
**ScrEff is determined by the sum of Pathway #1 + Pathway #2 power transfers.**



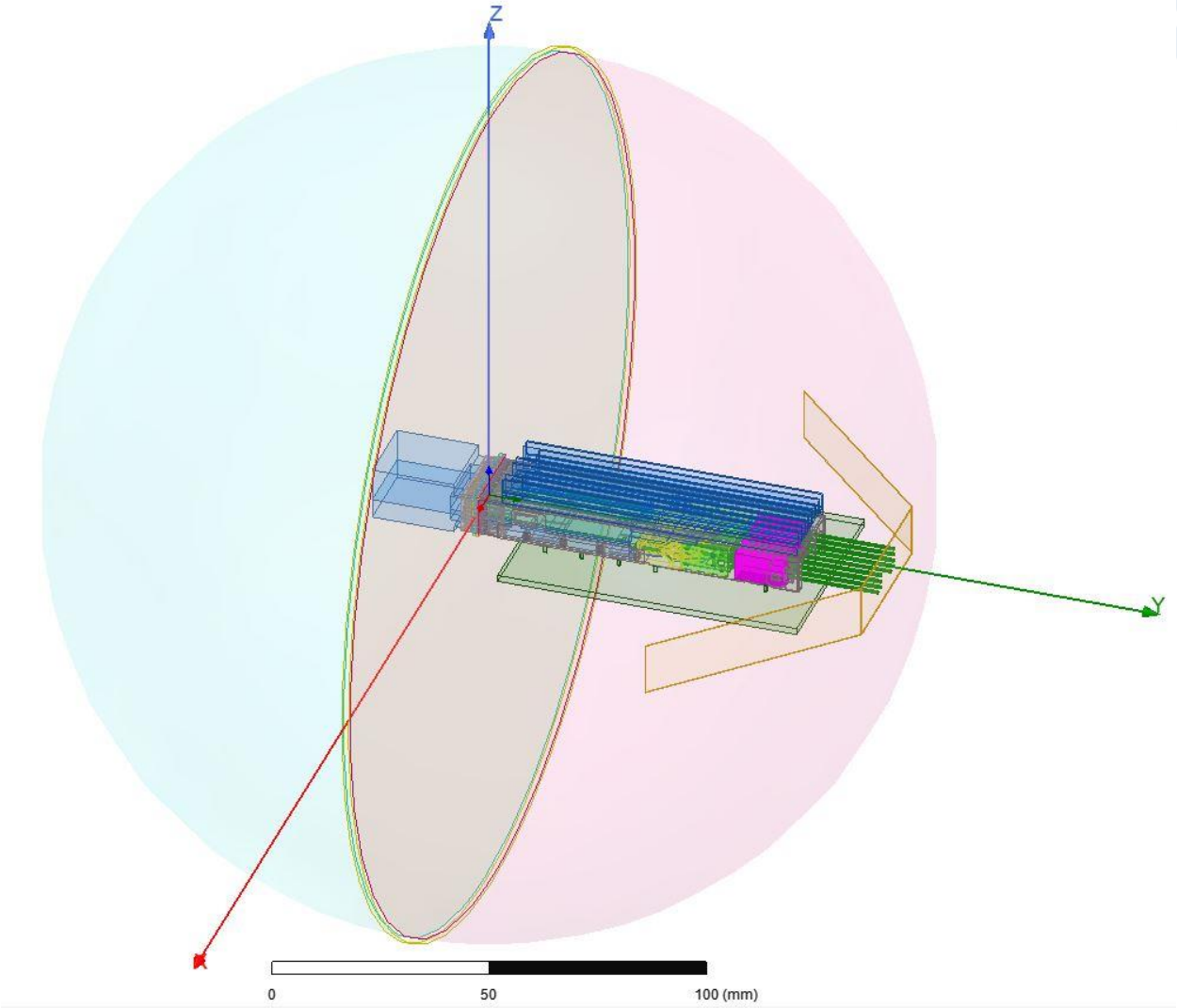
# Power Transfer [Single vs. Dual]



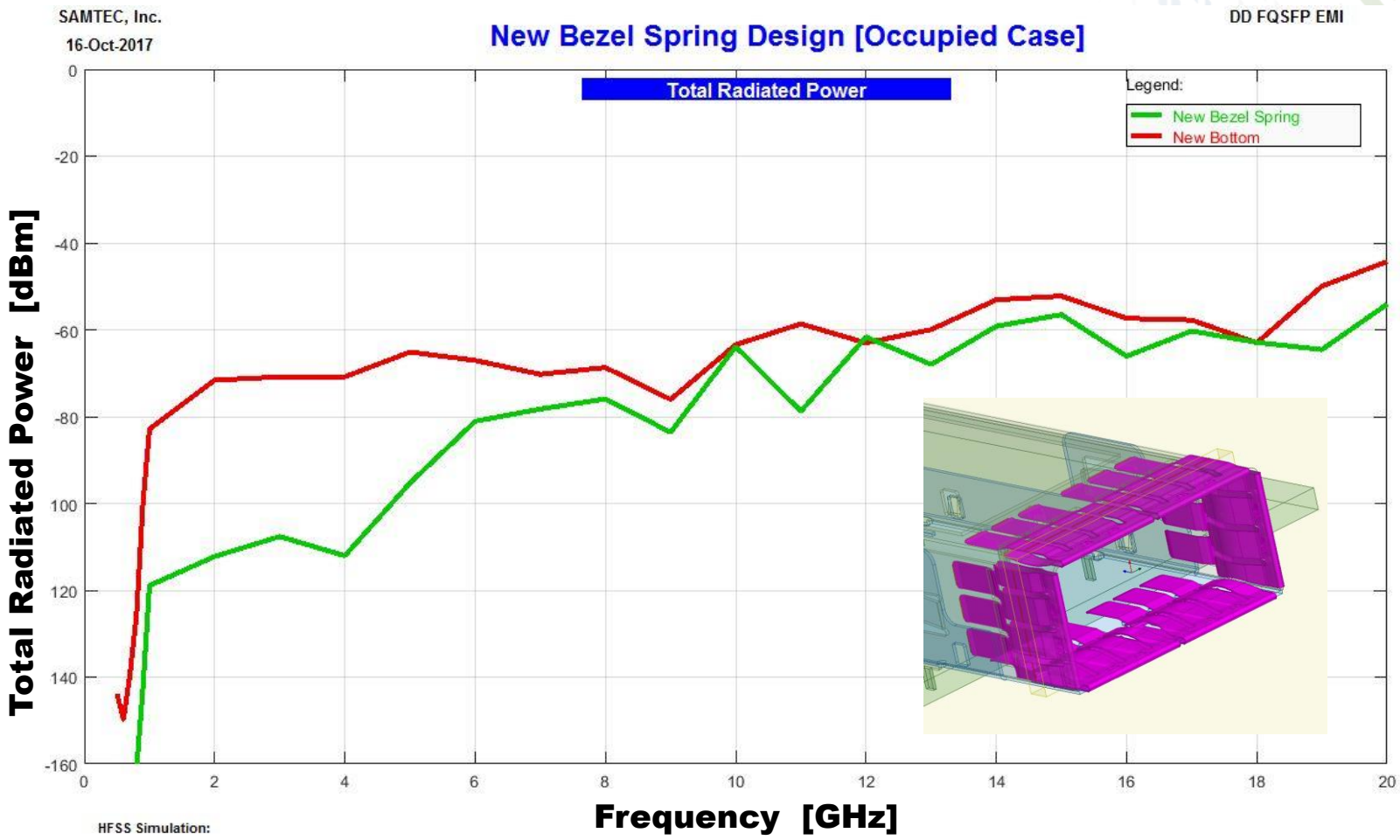
# Screening Effectiveness [Single vs. Dual]



# HFSS Simulation TRP



# Prototype Correlation for TRP



# Summary

- IO product QSFPC has optimized shielding.
- DRC useful for measuring power transfer for I/O panels.
- DRC supports testing / simulation for product development.
- DRC has potential for rigorous calibration.
- Screening Effectiveness is well defined measurement.

# Thank You !!!

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