

On-going work with the cryogenic Eleven antenna at the MIT Haystack Observatory

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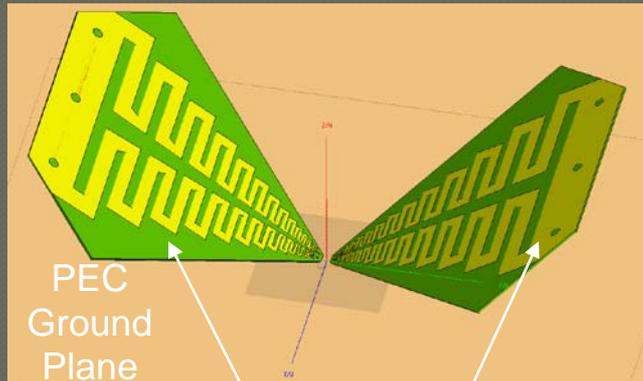
Outline

- Eleven/Cryostat Modeling
 - S parameters compared w/ measurement
 - Far-field patterns
 - Feed Efficiency compared w/ measurement
 - Cryostat Dimensional Constraints
- Rx Front-End Configuration/Sensitivity
 - Two possible configurations
 - Present Experimental Setup
 - Noise temperature for each configuration

Simulation Parameters

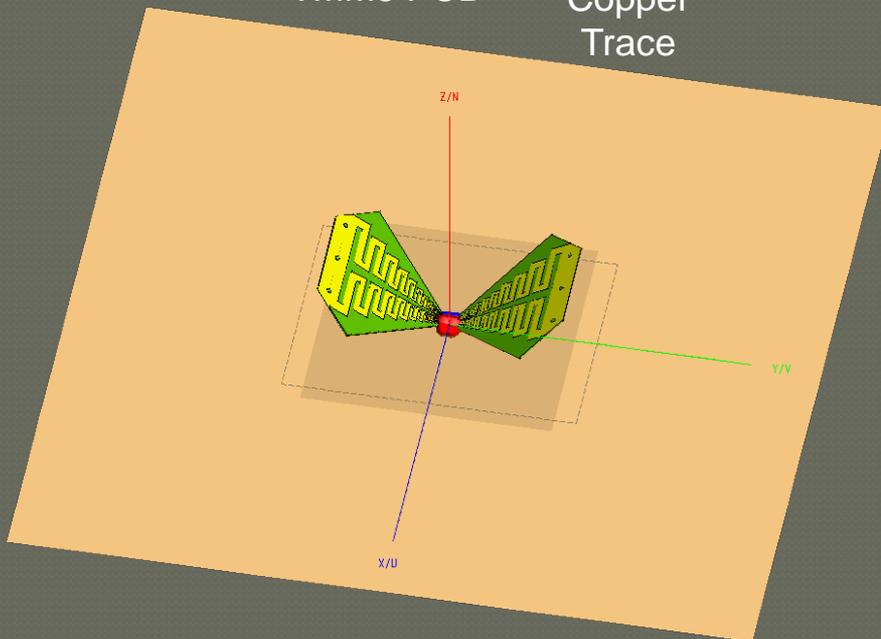
- Simulations of the Eleven were performed with FEKO
- Simulated from 2-10 GHz
 - 100 MHz sample rate for model confirmation
 - 400 MHz for cryostat modeling
- S Parameters and Far-field data generated
- Far-field sampling
 - θ : 0-90° every 1°
 - ϕ : 0-345° every 15°

Geometric Model



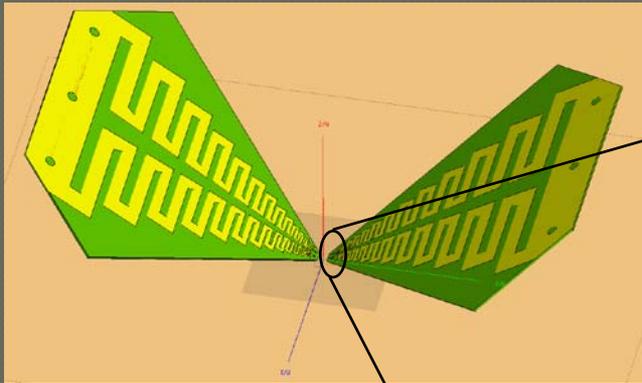
TMM3 PCB

Copper Trace



- The full geometric description of the E-plane antenna requires too many unknowns
- The geometric description was reduced to those components thought to be critical to model the antenna's electrical behavior.

Geometric Model



Petal Composed of
TMM3

Feed Pin

Z

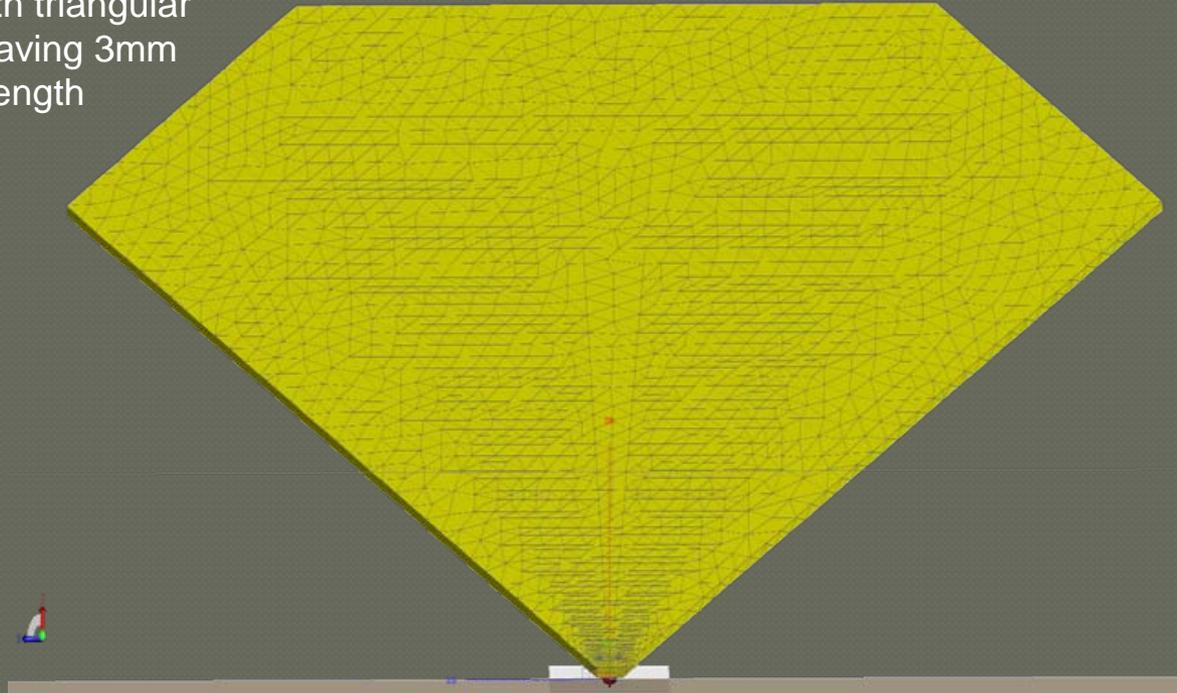
X

Y

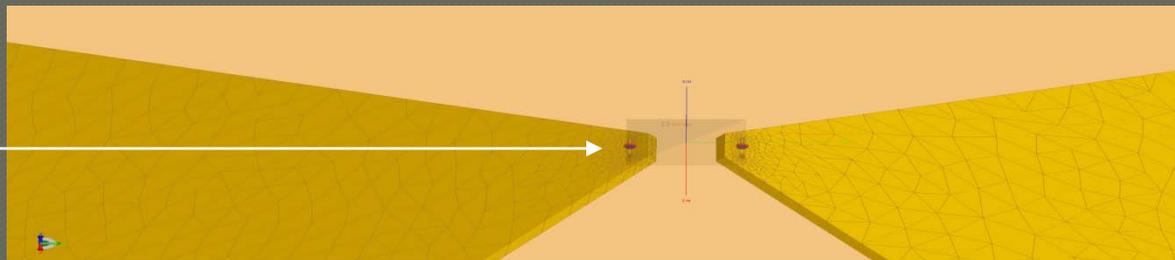


Geometric Model

Model meshed with triangular basis functions having 3mm max edge length

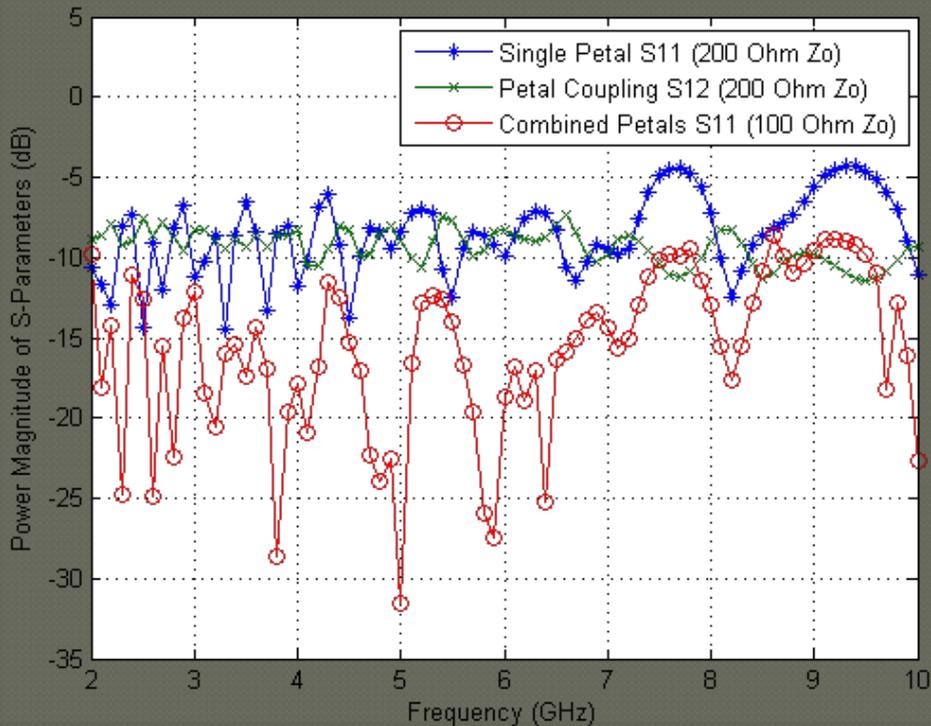


Zoom-in of mesh around two-wires feeding the petals

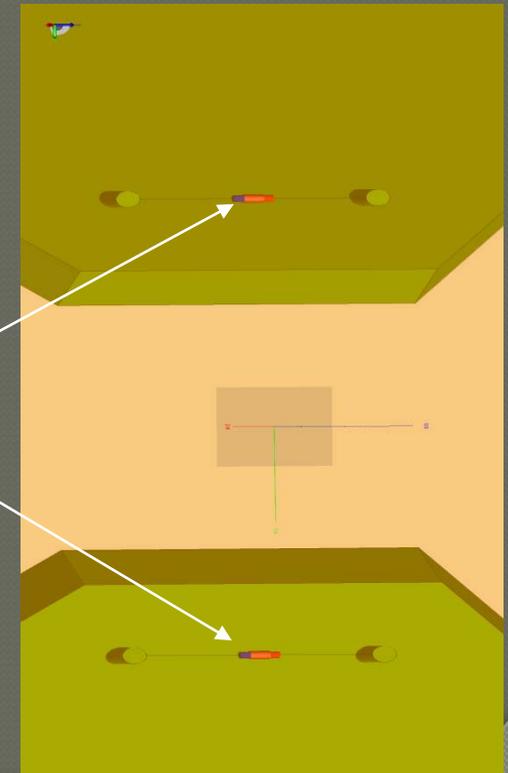


S Parameters

- S-Parameters of 200 Ohm Ports on each Petal are direct products of the simulator
- S11 of combined petals derived as follows
 1. 200 Ohm S-Parameters transformed to unnormalized Z-parameters
 2. Using Z-parameters and 2-port equivalent circuit, impedance looking into the combined ports is calculated
 3. S11 looking into this port is calculated assuming $Z_0 = 100$ ohms

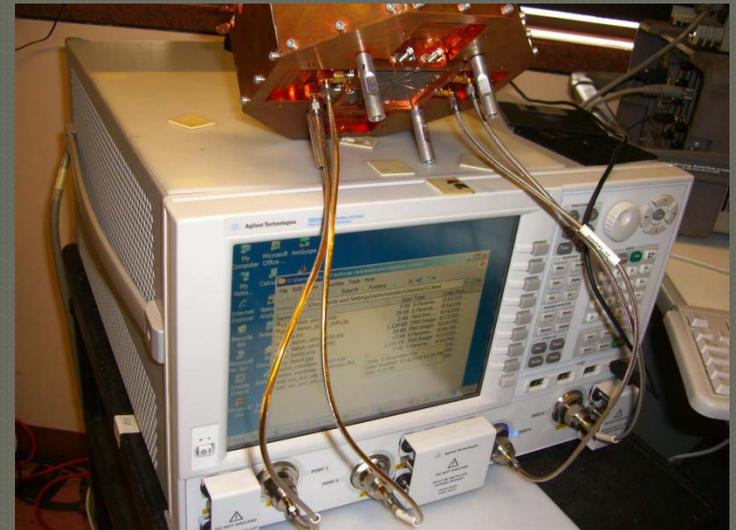
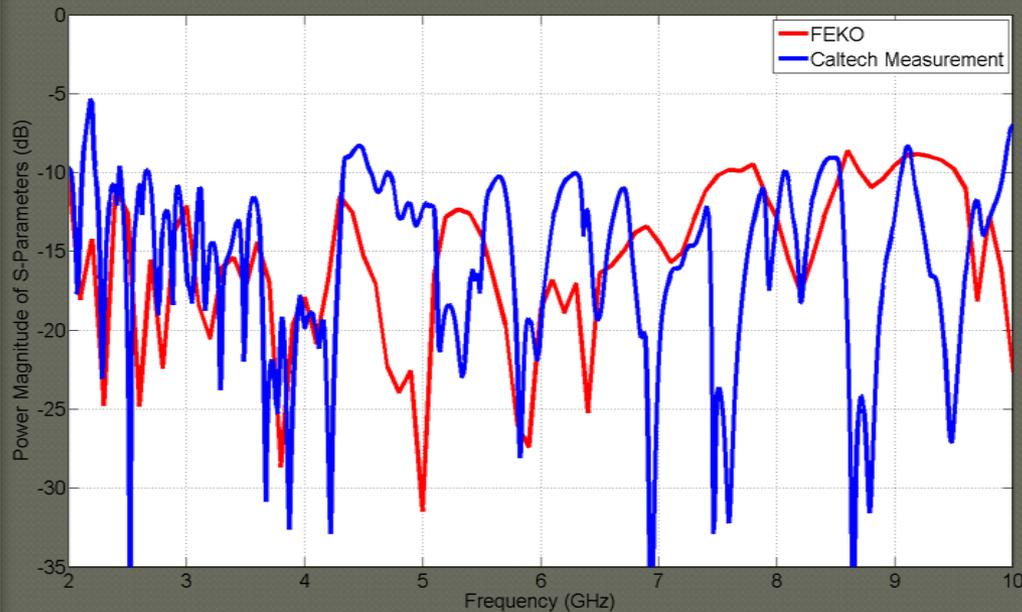


200 Ohm wire ports
feeding the petals
in-phase



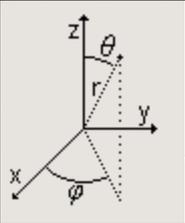
S Parameters

- Same FEKO 100 ohm return loss plot from previous slide
- Full 16 S parameters measured at Caltech

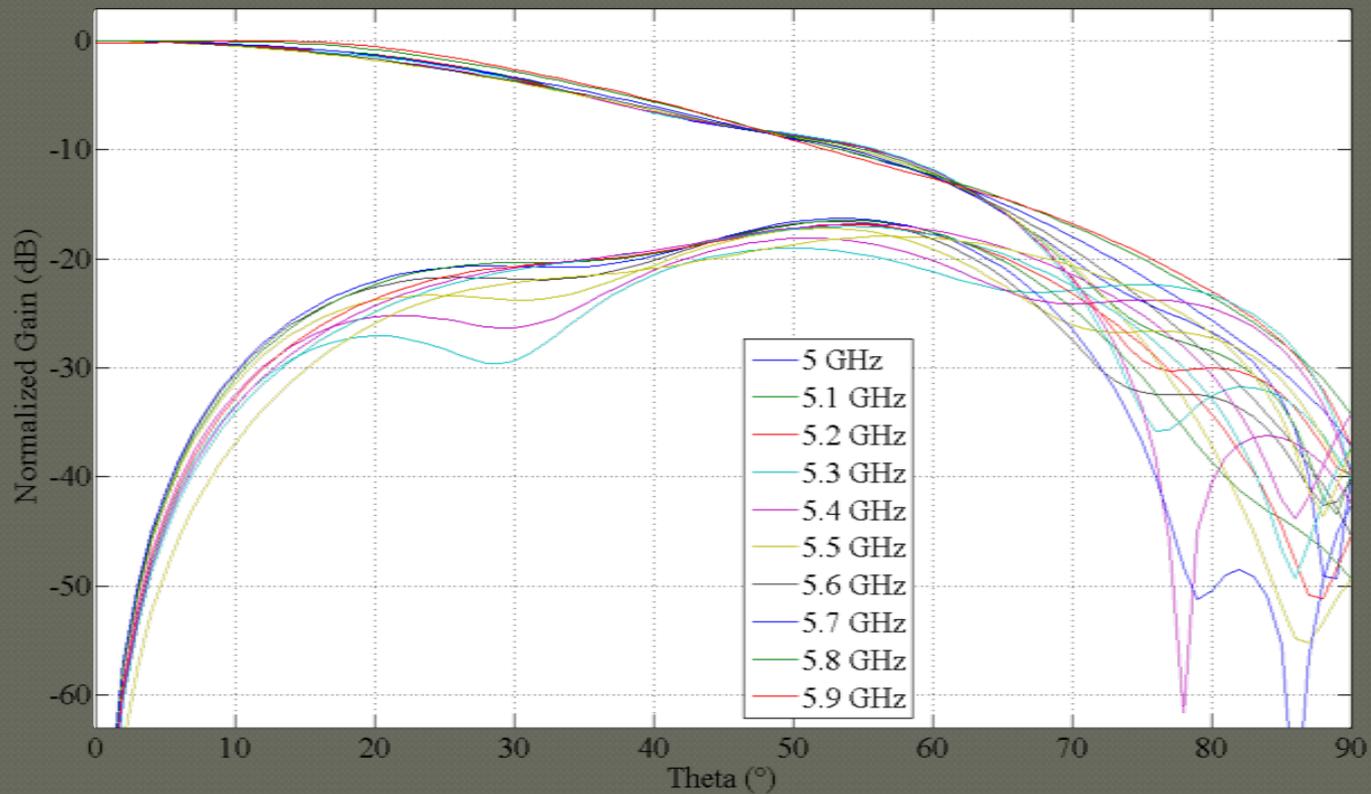


CO-XP Patterns

$$\phi = 45^\circ$$

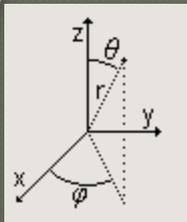


Co and cross-polar antenna patterns

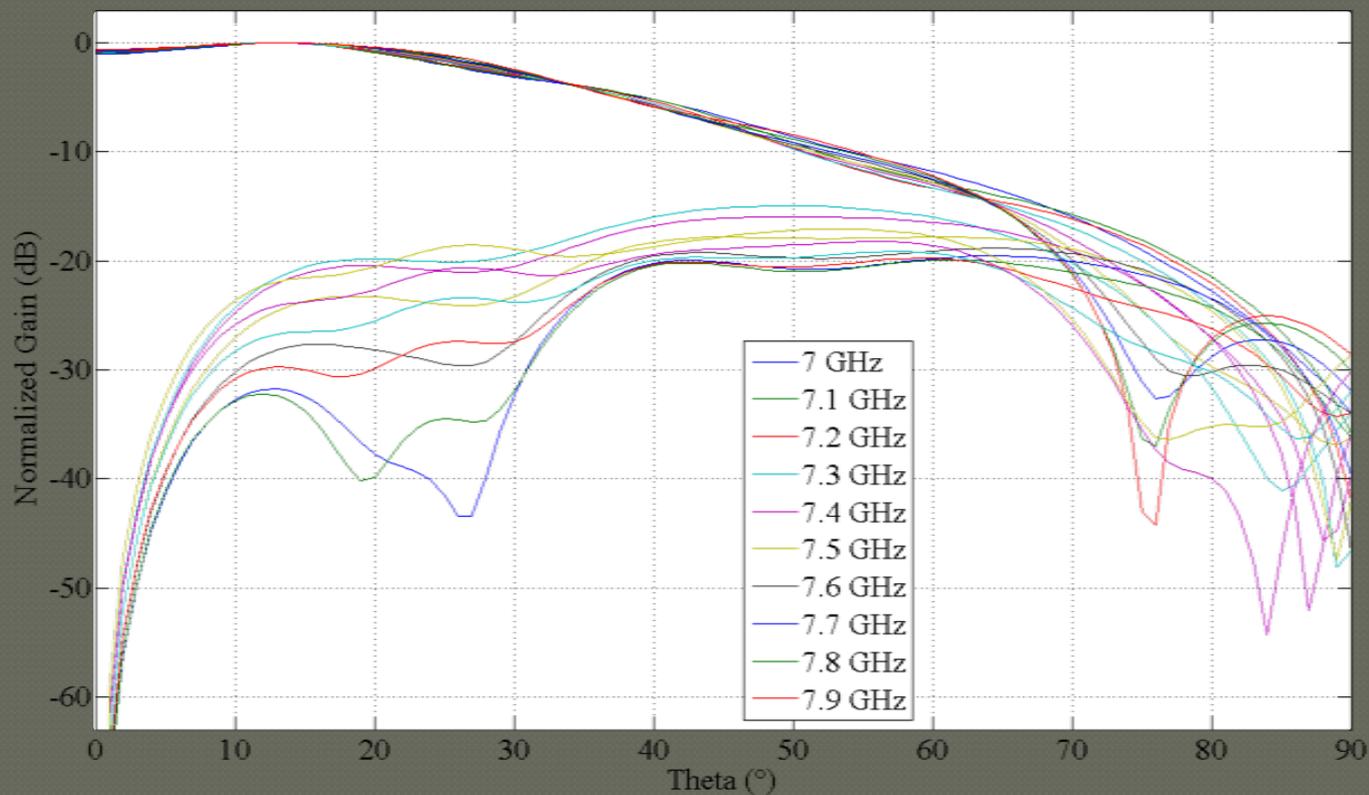


CO-XP Patterns

$$\phi = 45^\circ$$

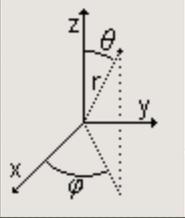


Co and cross-polar antenna patterns

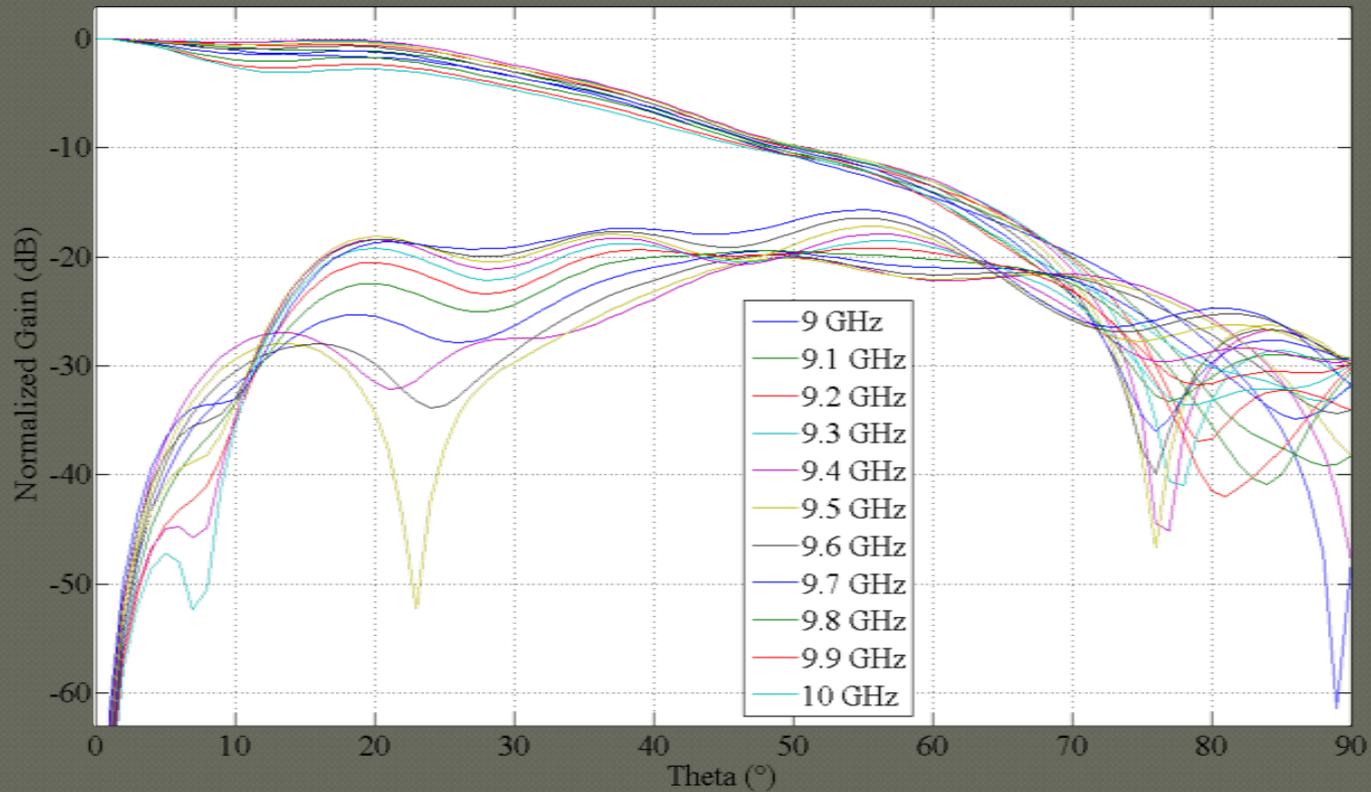


CO-XP Patterns

$$\phi = 45^\circ$$

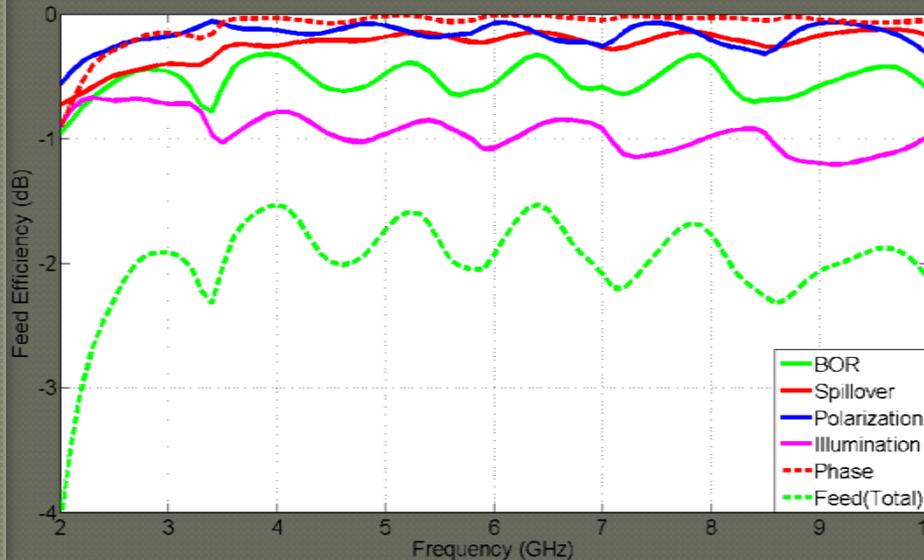


Co and cross-polar antenna patterns

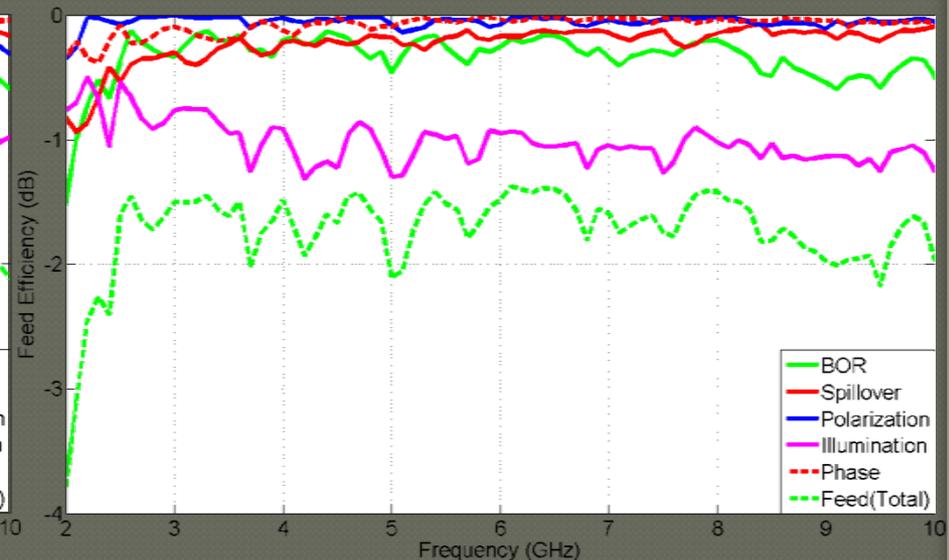


Feed Efficiencies

Calculation based on $\theta_0 = 60^\circ$; $F/D = 0.43$



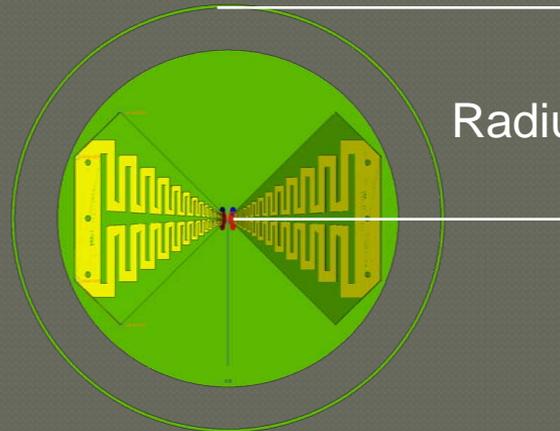
From FEKO Simulations



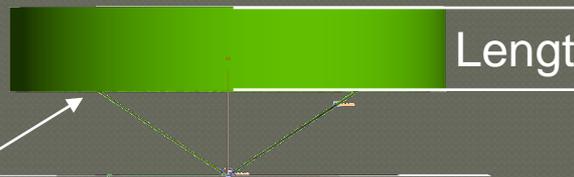
From measurements at
Technical University of Denmark

Preliminary Cryostat Modeling

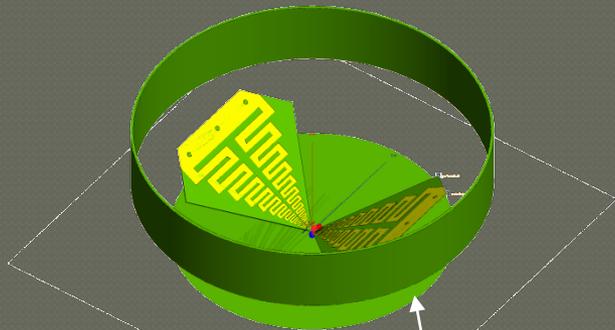
Feed Efficiencies Studied for Various Cylindrical Geometries



Radius = 100, 125, 150 mm



Length = 10, 30, 50, 70 mm



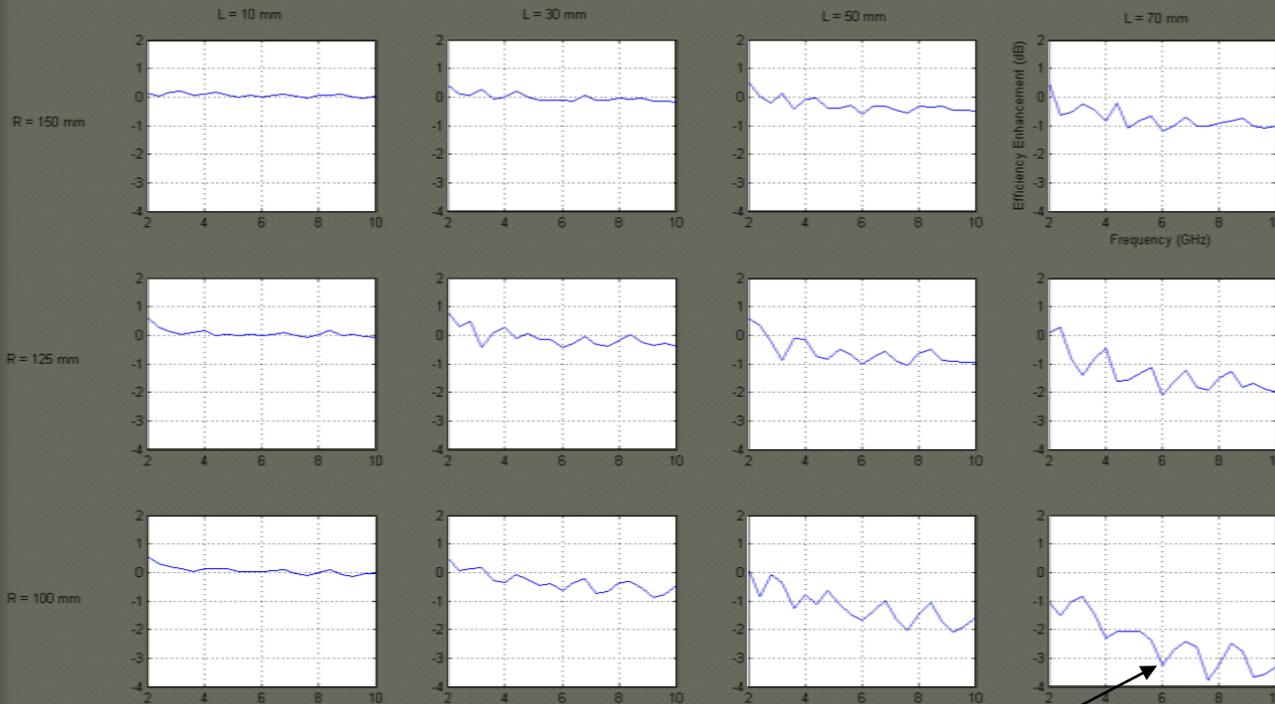
Bottom of Cylinder Overlaps Top of Eleven by 10 mm in all cases

Preliminary Cryostat Modeling

Efficiency Degradation Plots

Degradation is normalized to freespace total feed efficiency

“Negative quantities represent efficiency degradation”

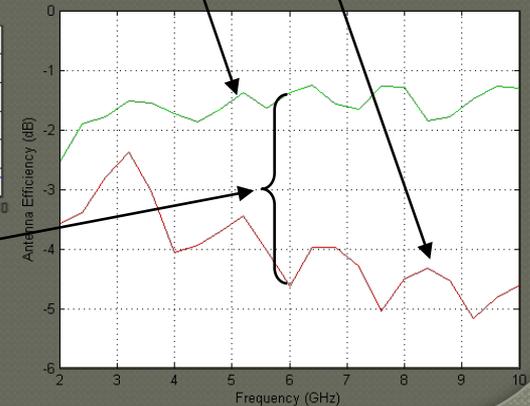


Green Curve is Total Feed Efficiency in Freespace

Red Curve is Total Feed Efficiency when Eleven is inside R = 100 mm L = 70 mm Cylinder

Downsampled 2-10 GHz to facilitate computations in reasonable time

Efficiency Degradation is Red Curve minus Green Curve



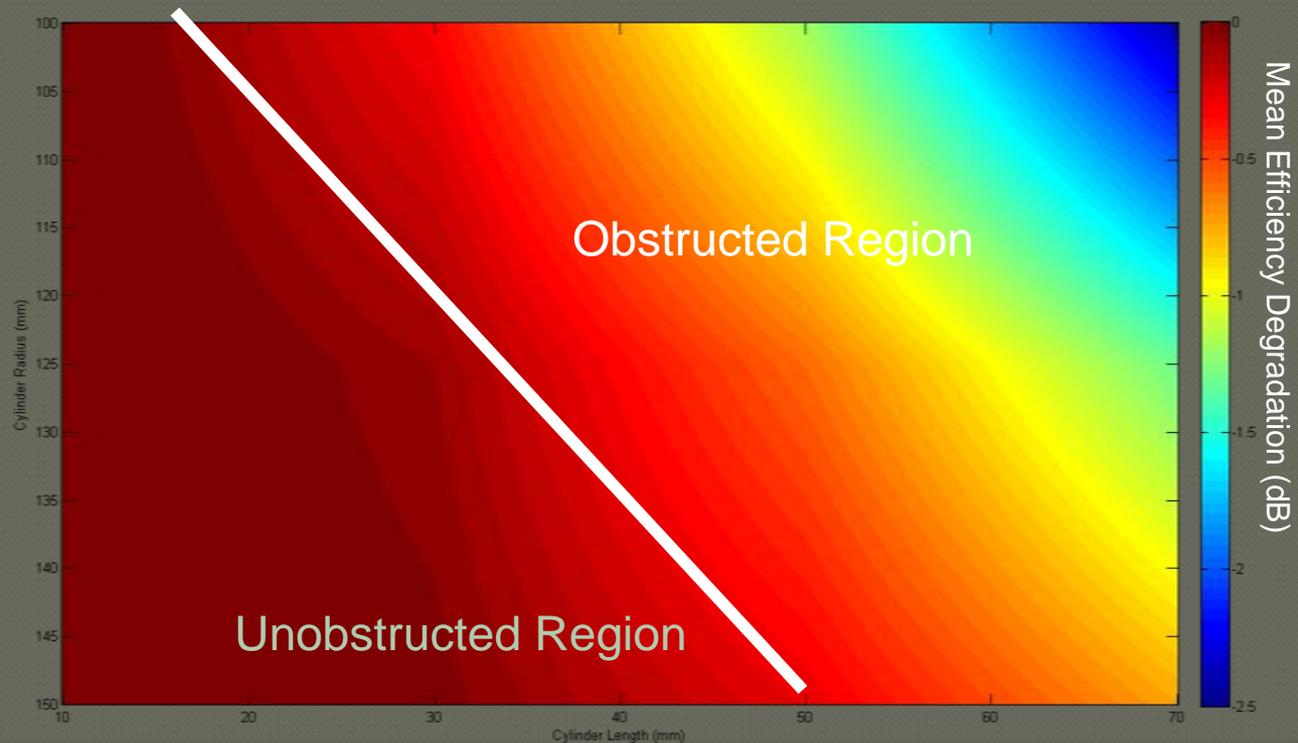
Preliminary Cryostat Modeling

Mean Efficiency Degradation

The mean efficiency degradation (over all frequencies) is calculated for each cylinder size

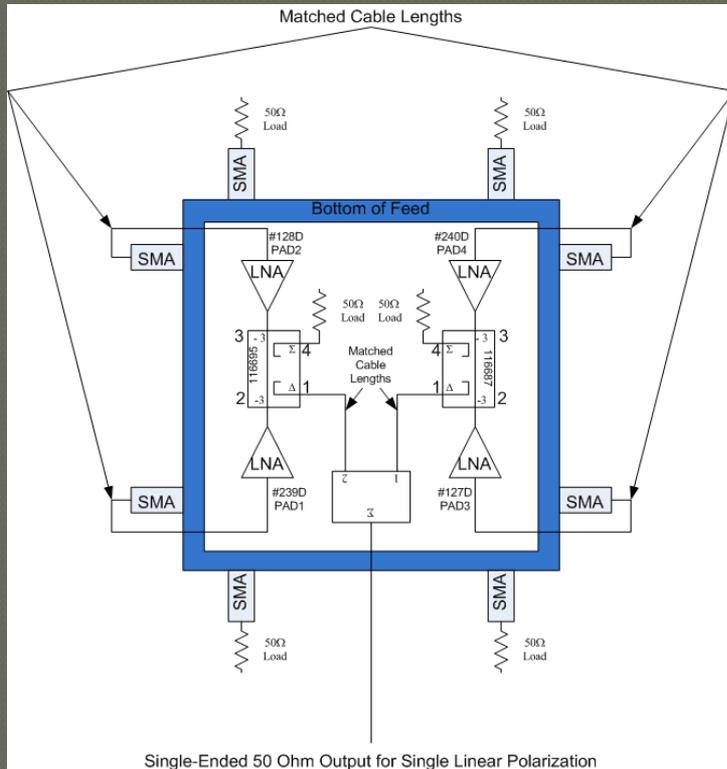
Bilinear interpolation of these mean values were used to generate the plot below

Obstructed region is that in which the cylinder radius and length are such that the opening angle of the feed is obstructed by the cylinder in the geometrical optics sense

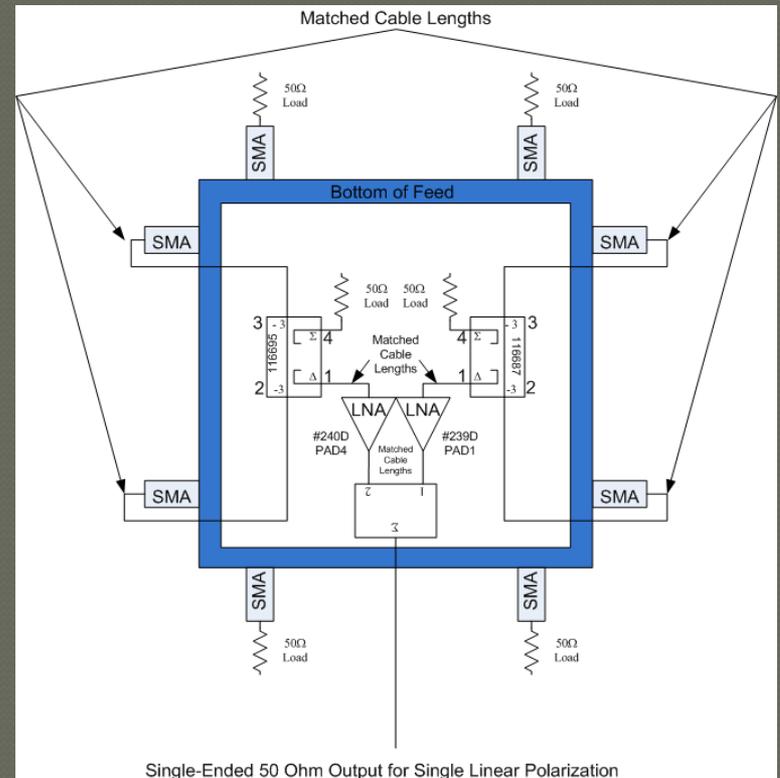


No blockage of the opening angle
in the geometrical optics sense

Receiver Front-end Configuration

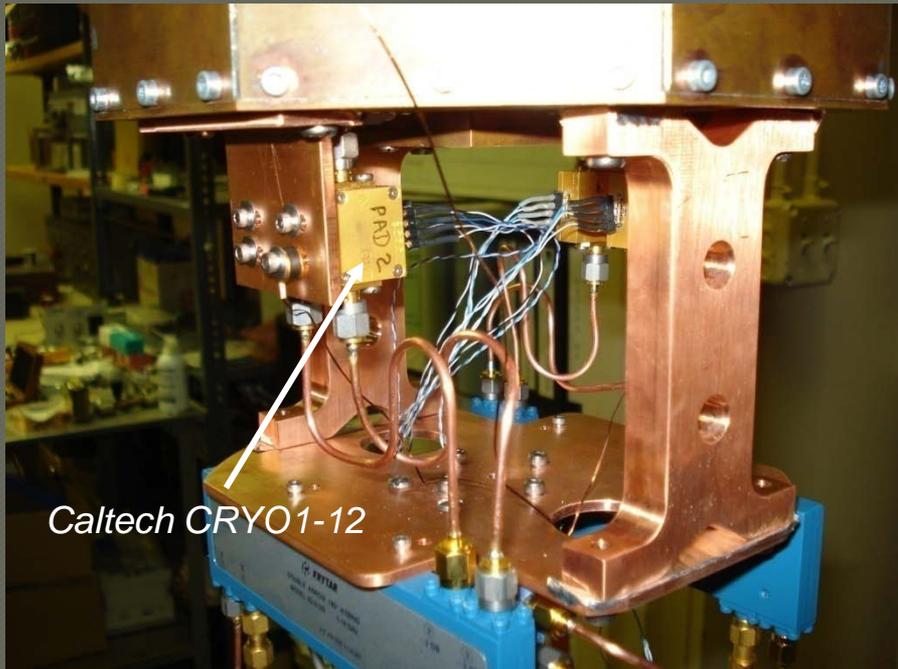


8 LNA configuration (4 per pol.)
Best Noise Figure – more costly



4 LNA configuration (2 per pol.)
Reduced Noise Figure – less costly

Receiver Front-end Configuration



8 LNA Configuration



4 LNA Configuration

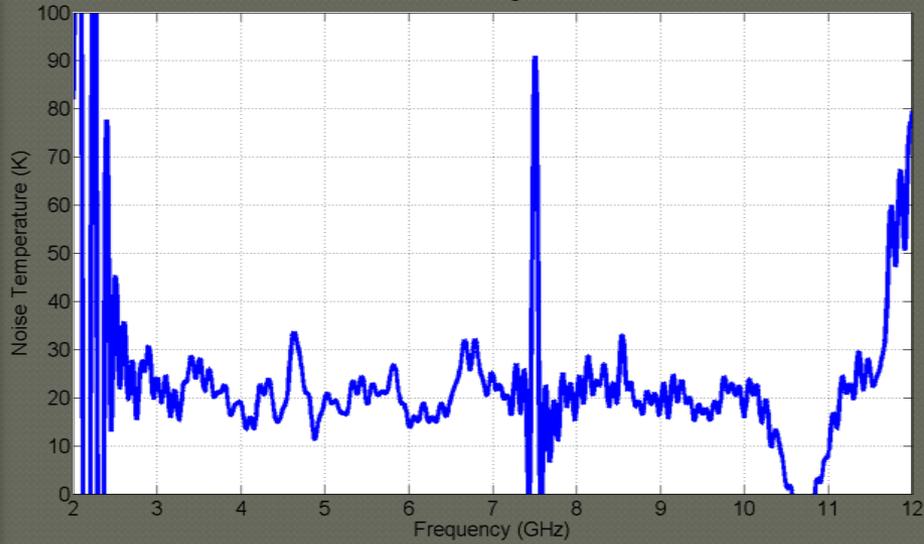
Y Factor Test Setup



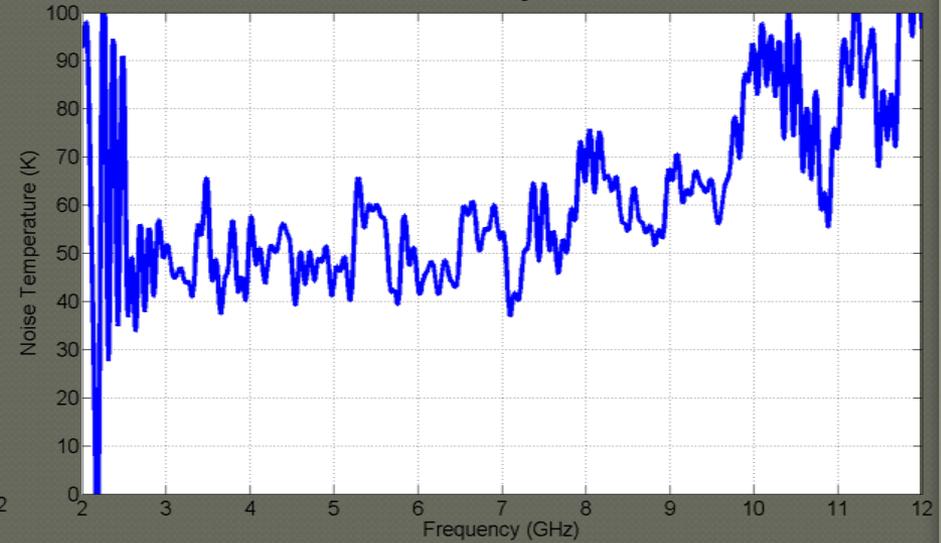
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Receiver Noise Temperature

8 LNA Configuration



4 LNA Configuration



Conclusions and Next Steps

- Developed a metric to quantify Cryostat's influence on feed efficiencies
- Demonstrated $\sim 20\text{K}$ noise temperature with 2-14 GHz Eleven using Caltech CRYO1-12 LNAs
- Build our new cryostat and have the patterns characterized at cryogenic temperatures
- Further investigation of hybrid losses