Smartwatch Bluetooth Rim Antenna

ELEC-E4740 Antennas Workshop D

Ali Kourani
Sihan Shao

Aalto University
School of Electrical
Engineering

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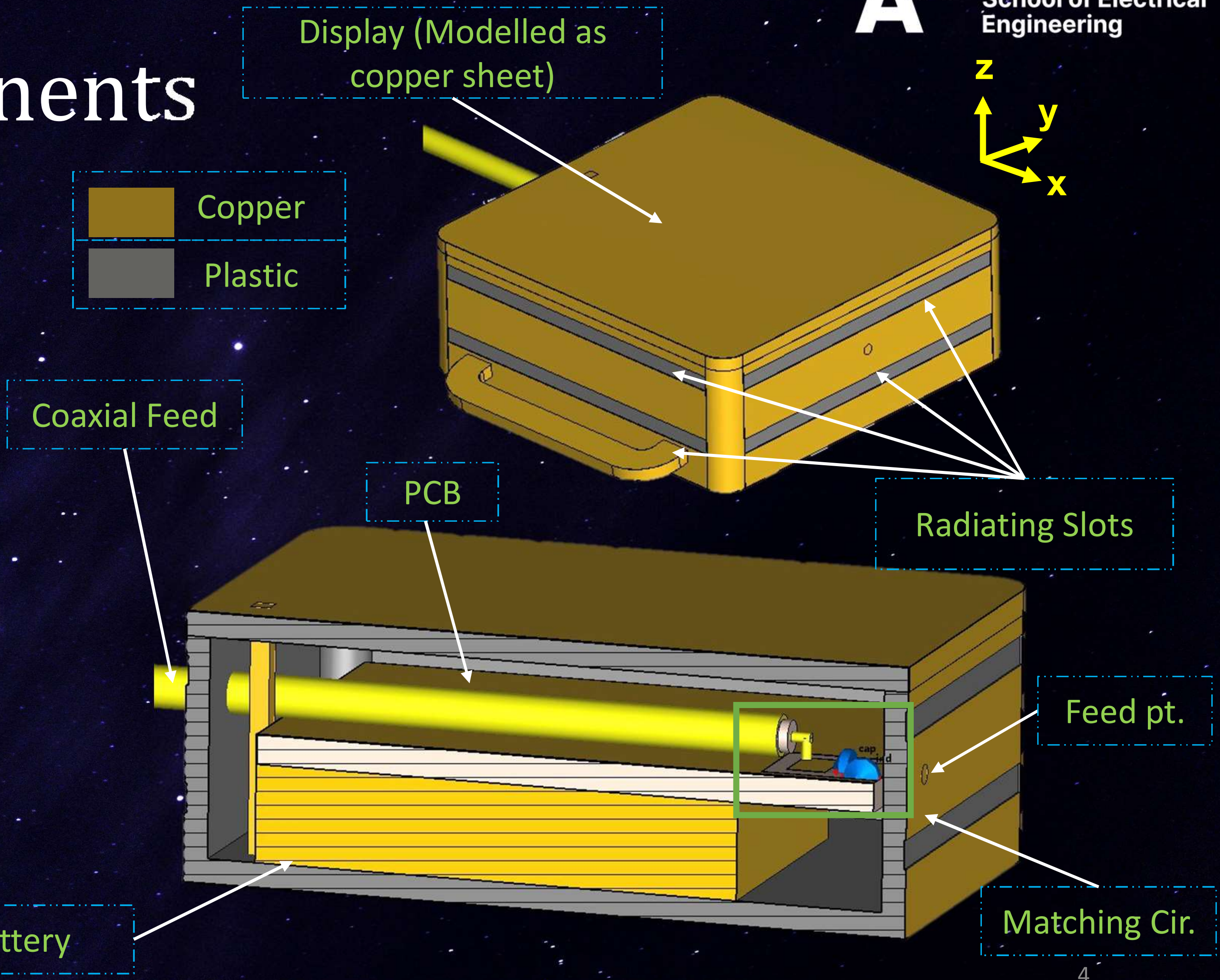
Design Components

- The designs aims at assuring a metallic and stylish look of a smart watch whilst achieving the performance goals.

- The working principle is based on slot antennas embedded in identical lateral faces of the metallic structure.



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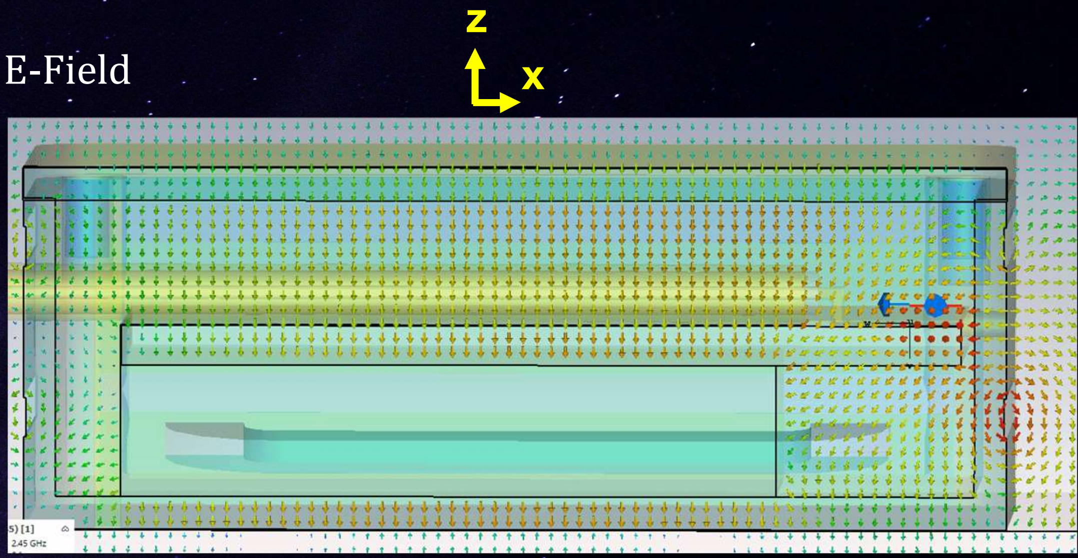
CST Simulation

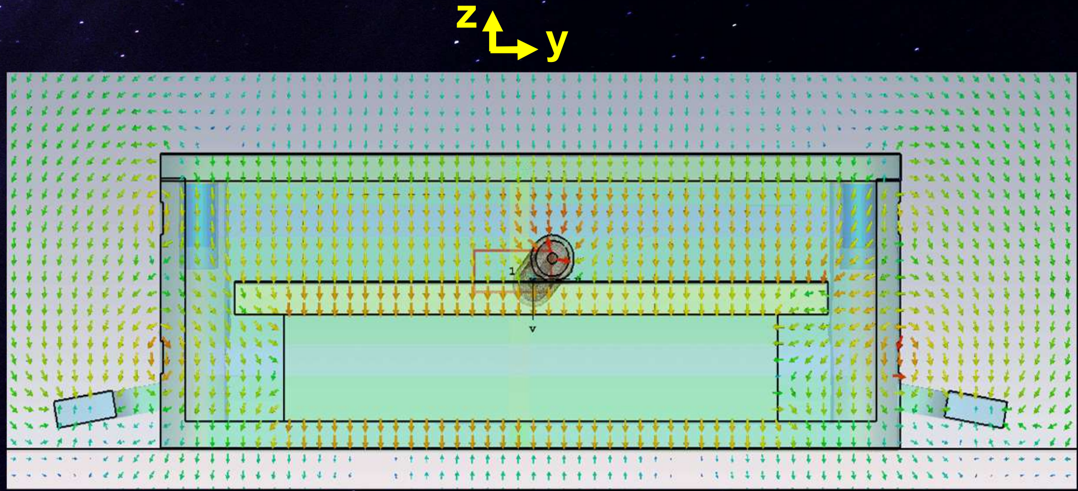
- The adjacent figures exhibit the working principle of rim-embedded slots.

- The results in the table below are based on the final matching circuit decided based on measured input impedance.
(Series 0.6pF capacitor, Shunt 5.6nH Inductor)

	Free Space	Hand Phantom
Rad. Eff.	80%	50%
Tot. Eff.	60%	48%
Directivity	2 dBi	2.63 dBi
Best 2.4->2.5 GHz S11	-5.5dB	-12.8 dB
-10dB Imp. BW	N/A	340 MHz
-6dB Imp. BW	360MHz	560 MHz

E-Field





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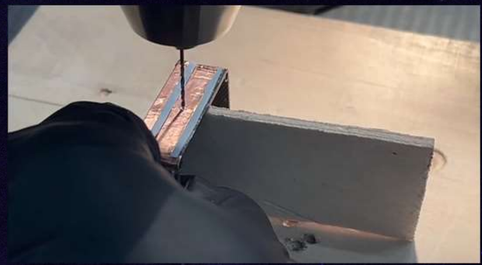
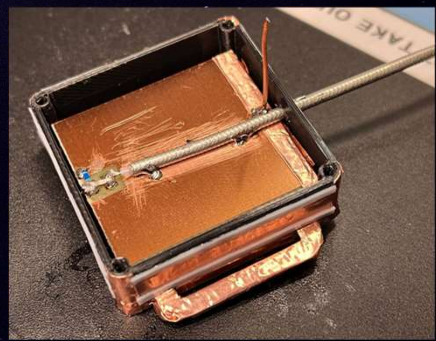
II. Manufacturing

a) Adding slot strips

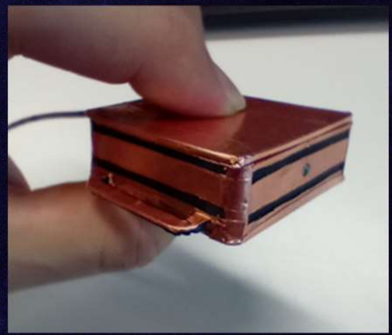


b) Drilling

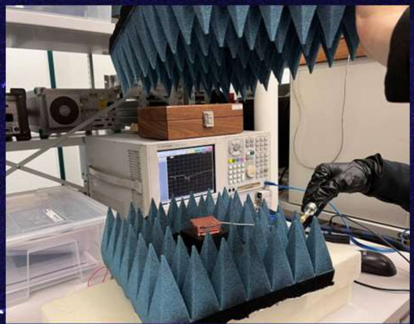
c) Soldering matching circuit



d) Adding feeding structure



e) Final structure



e) Ready to measure

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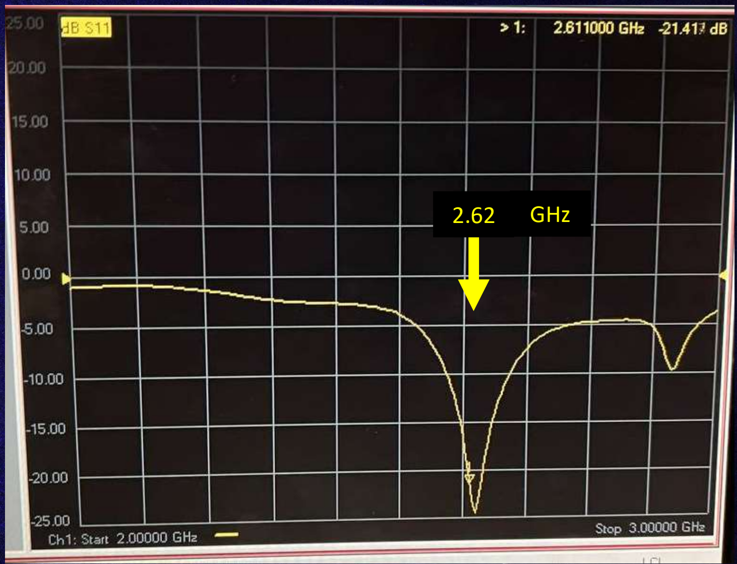
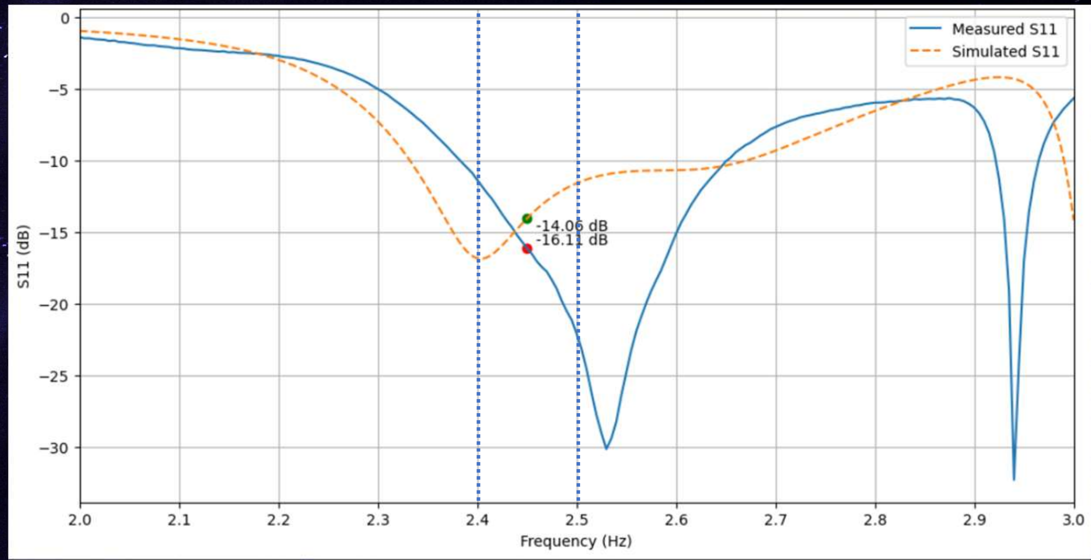
III. VNA Measurements: Sim. Vs. Meas.

As the first S_{11} measurement showed a frequency shift, we proceeded to measure an actual estimate of input impedance by calibrating the VNA including out coax.



Based on the measured input impedance, the new matching components were selected, and the results are shown in the figure below.



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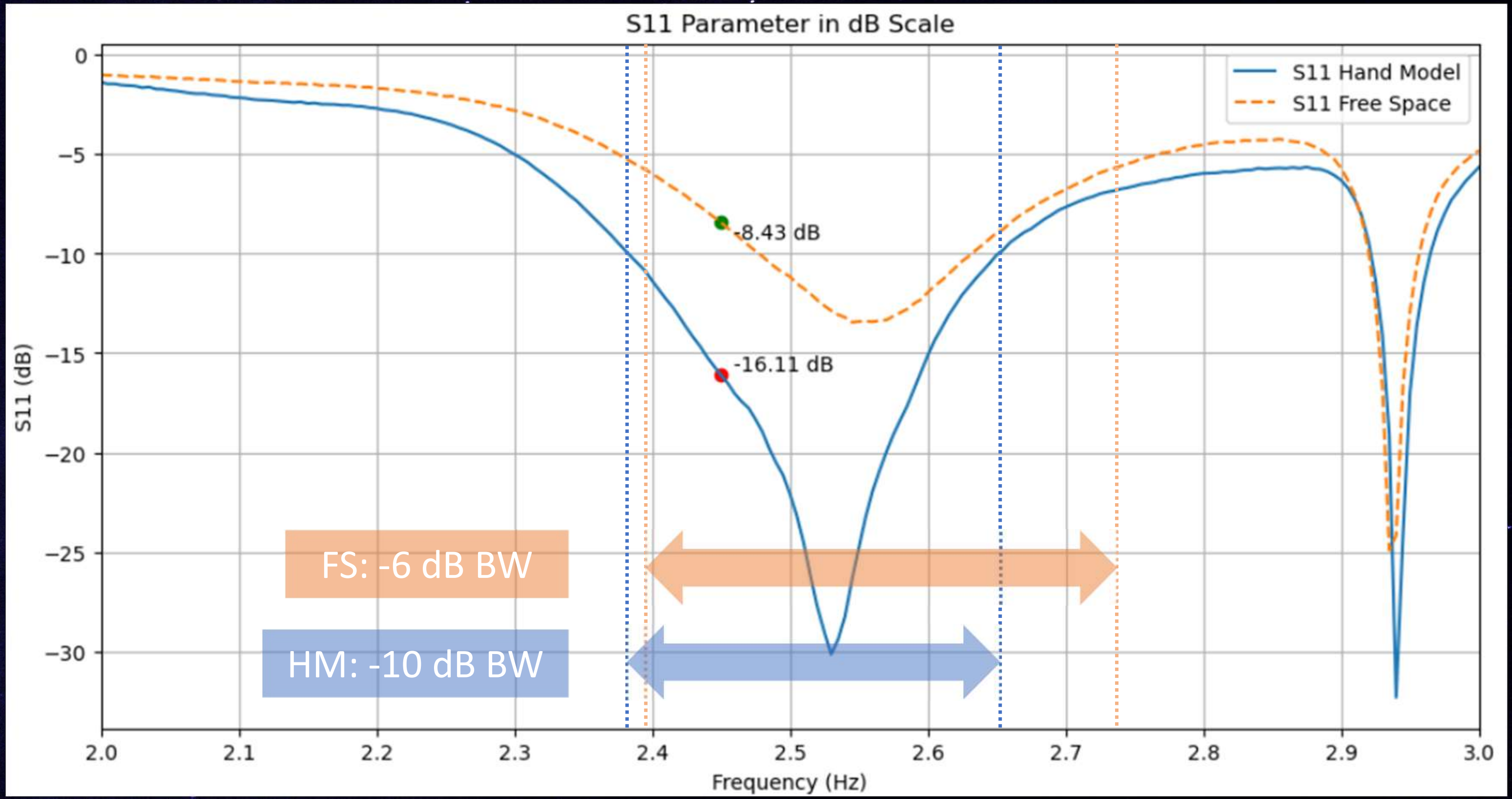
III. VNA Measurements: Hand Vs. FS

	Free Space	Hand Phantom
Best 2.4-2.5 GHz S11	-6.5	-12 dB
-10dB Imp. BW	Out of range	270 MHz
-6dB Imp. BW	340 MHz	685 MHz



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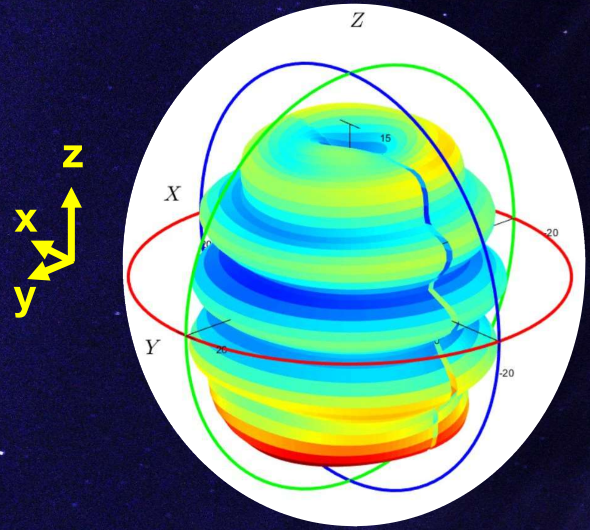
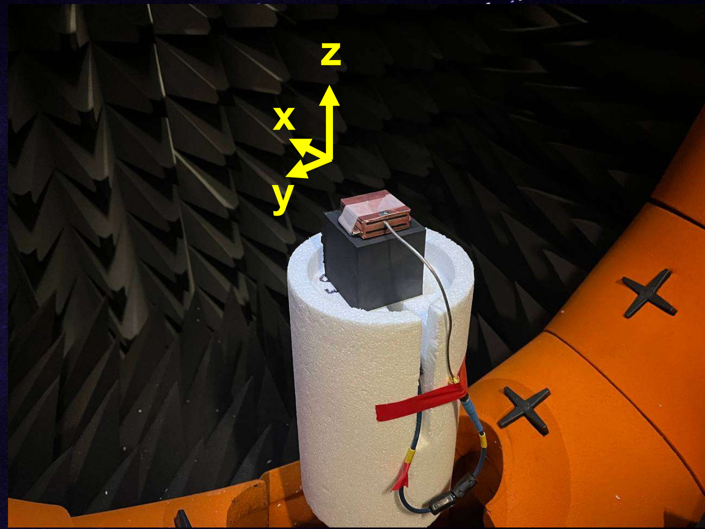
StarLAB Measurements



FF Gain Pattern



	2.4 GHz		2.45 GHz (Meas)	2.45 GHz (Sim)	2.5 GHz	
Total Eff.	-5.2dB (30%)(M)	-3.5 (40%) (S)	-4.7dB (34%)	-3.1dB (49%)	-4.4dB (36%)(M)	-2.9dB (51%)(S)
Realized Gain	--		-1.02 dBi	-0.47 dBi	--	
Directivity	--		3.68 dBi	2.63 dBi	--	

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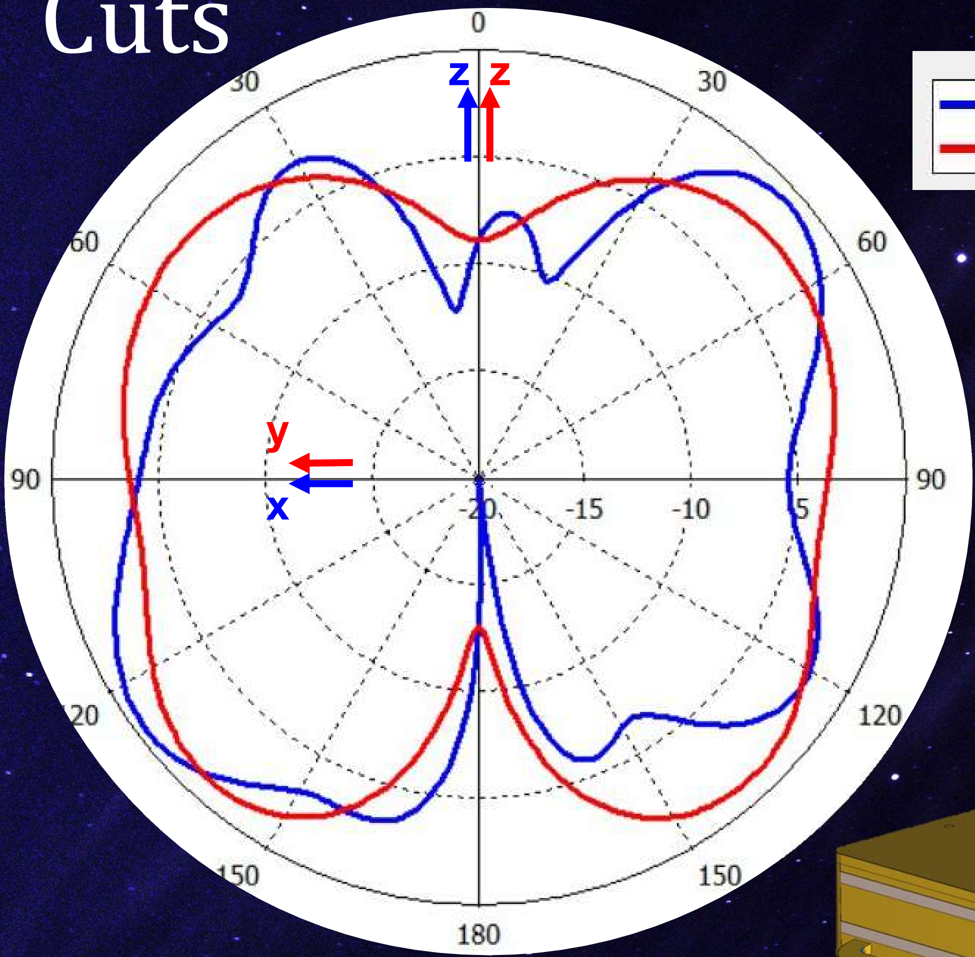
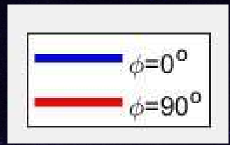
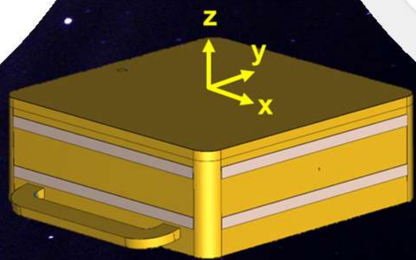
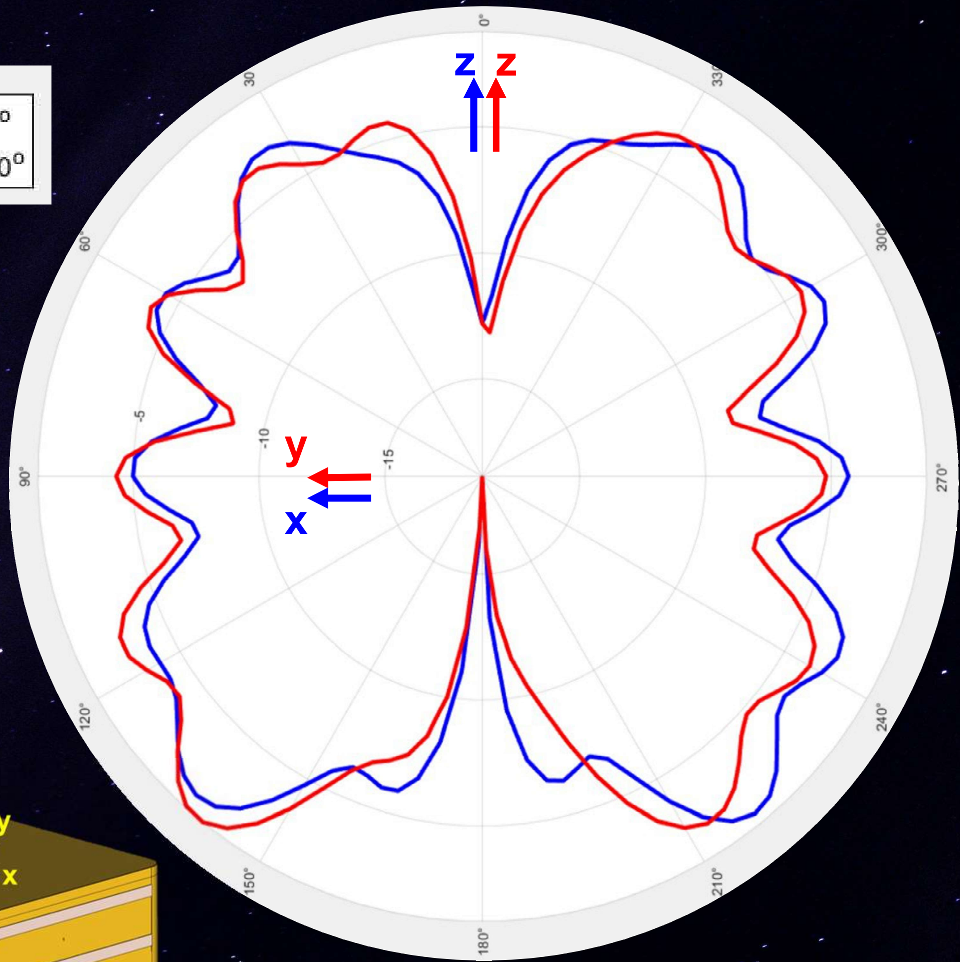
StarLAB Meas.: FF Realized Gain Principal Cuts



Simulation







Measurements

Performance: Coverage

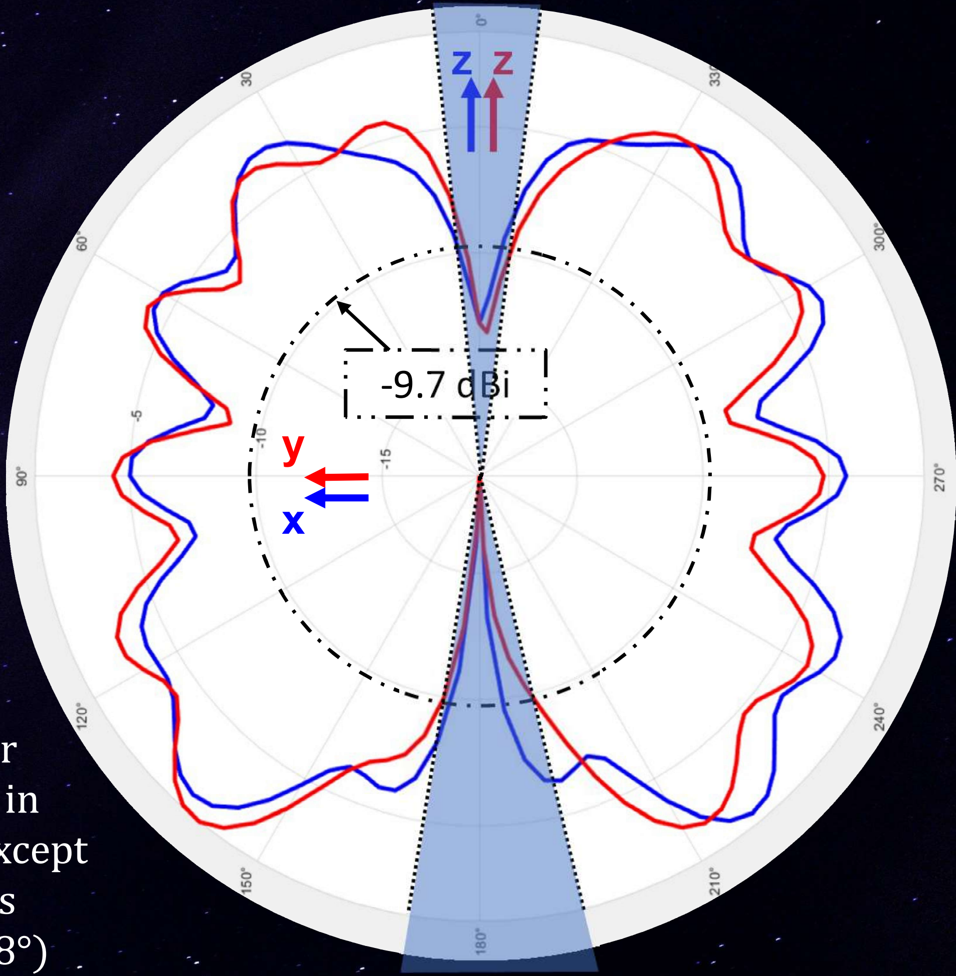
$$P_r = P_t G_t G_r \left(\frac{\lambda}{4\pi r}\right)^2$$

- According to Friis equation, a 10 m coverage of a received power level of -70 dBm requires a TX realized gain above -9.7 dBi.

$G_t = -9.7 dBi = 0.107$
$G_r = 0\ dBi = 1$
$P_t = 0\ dBm = 1\ mw$
$P_r = -70\ dBm = 10^{-7}\ mw$
$\lambda = 0.122\ m$

$$r = \sqrt{\frac{P_t}{P_r} G_t G_r \left(\frac{\lambda}{4\pi}\right)^2} = 10.04\ m$$

The manufactured structure could cover over a 10m distance in the full solid angle except for the shaded angles ($\theta \leq 6°$ and $\theta \geq 168°$)



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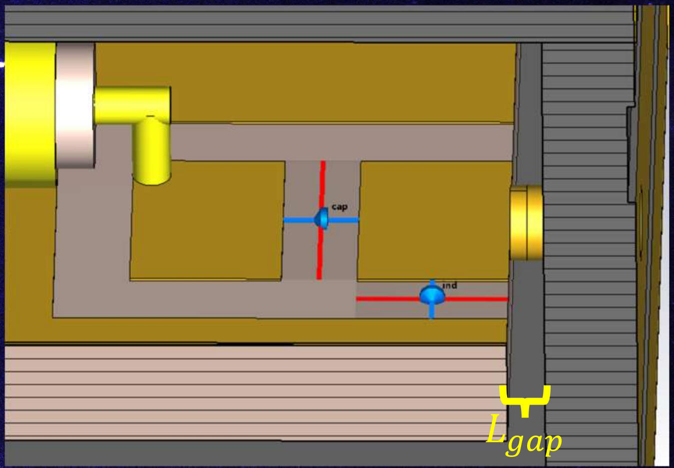
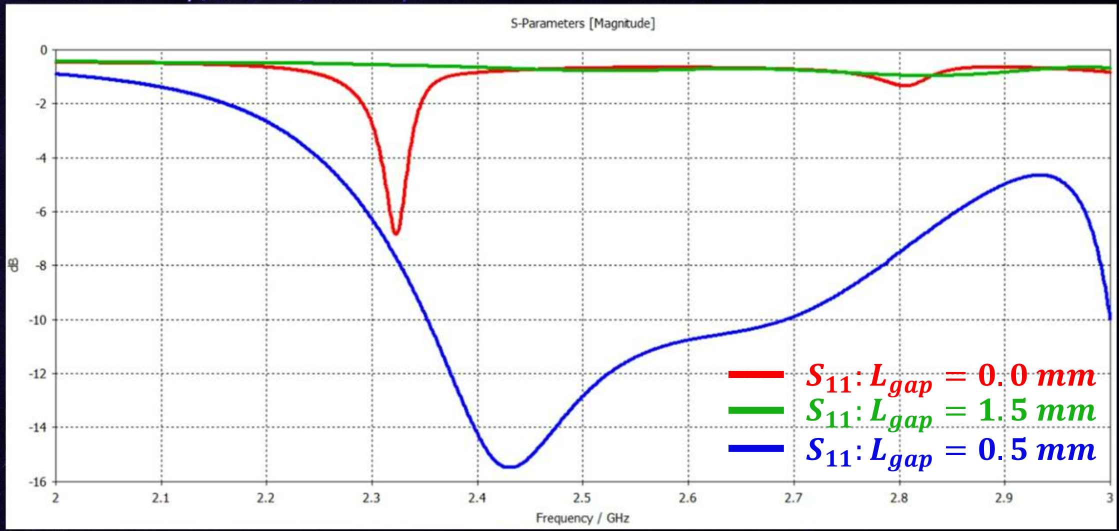
IV. Insights: Sensitive Structure

- ✓ Throughout the design process, it has been crucial to monitor the sensitivity of displacing any component of the structure.
- ✓ The figures below show how a small displacement in the PCB during manufacturing could lead to a drastic impact on matching.





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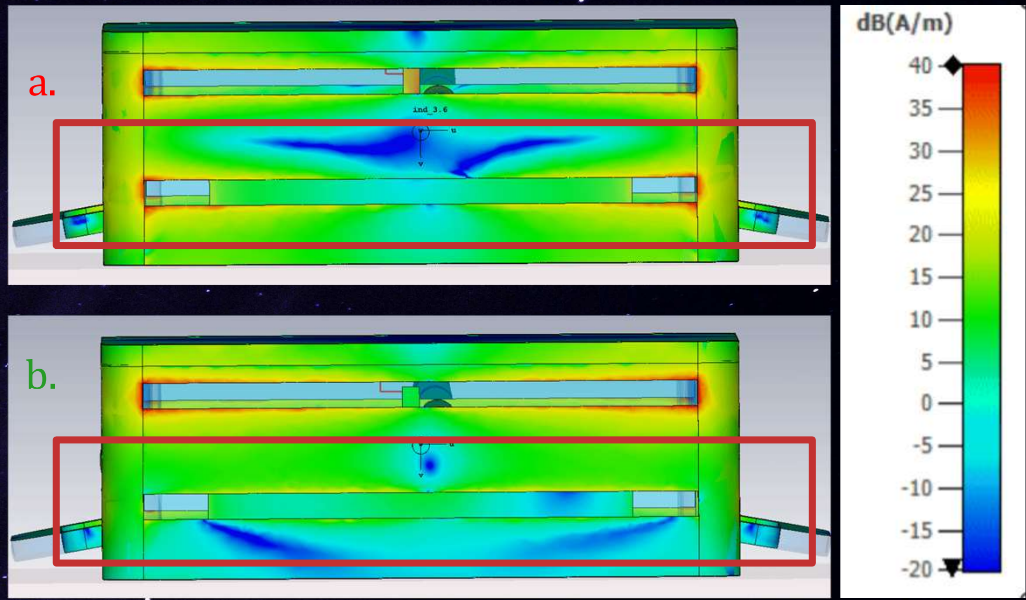
IV. Insights: Ground Location Effect

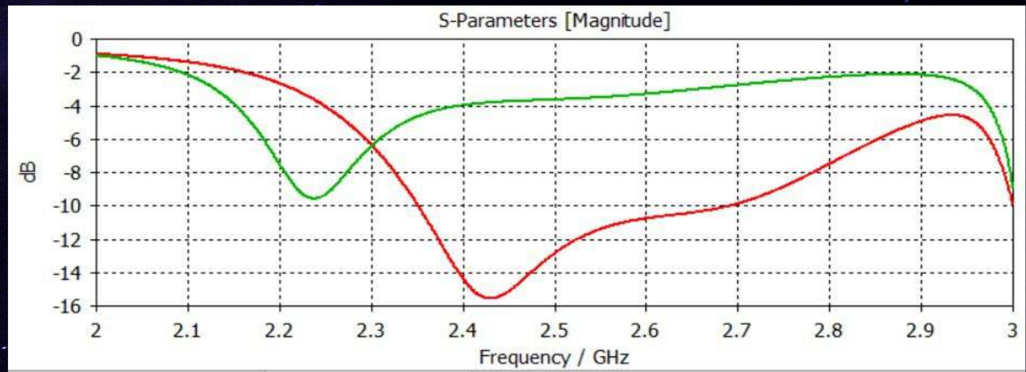
Another pivotal issue to keep an eye on is when it comes to ground the full structure.

Different grounding points leads obviously to different current distributions ending up with great impact on the performance.

a. Structure is grounded with copper wire.

b. Structure is grounded relying on the contact in the outer copper.





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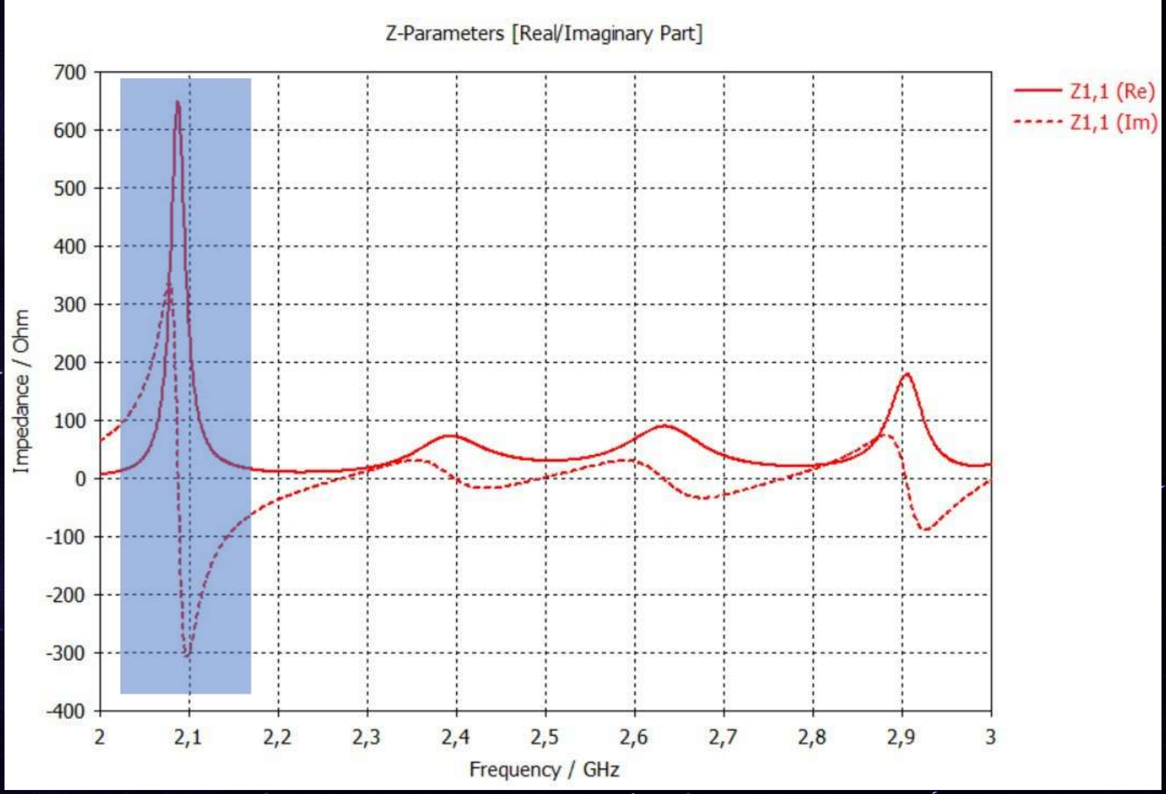
IV. Insights: Anti-Resonant Point

Furthermore, it is important to check for antiresonance points.

It is the point at which the resistance and reactance switches from highly inductive to highly capacitive within a narrow frequency range.

If the target frequency at which the structure is to be matched is near an anti-resonant point, then a slight frequency shift would lead to drastic change in the input impedance making the matching circuit useless.



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IV. Insights: Anti-Resonant Point

The following figures show a similar behaviour to anti resonance case that we encountered once the display part was slightly displaced.

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V. Conclusion

- Based on the comparison between the design and the measured performance parameters, the structure has a good performance complying with design limits set by the course.

- Insights pointed act as important learning outcomes that enhance understanding possible obstacles faced in antenna design field and could give explanation for several question raised about the difference between simulations and measurements.

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Thanks to

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Everyone in this course for the constructive and fruitful discussions

Comments and Questions are welcome