Do we need ground plane for SKA-low Radio Telescope?

International Centre for Radio Astronomy Research

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Outlines:

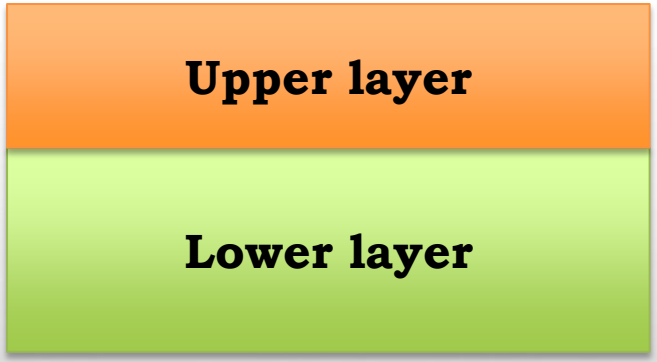
- Introduction
- Soil characterization
  - Measurements:
- Ground plane option:
  - Sensitivity with ground plane
  - Antenna noise calculation with mesh ground
  - Antenna noise on dispersive soil
- Antenna Measurements:
  - Antenna performance
- Conclusions

Introduction:

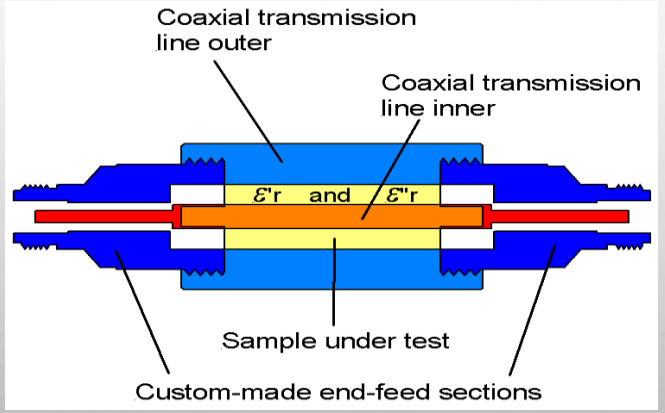
- Soil modelling
  - Very important to understand the environmental influence on antenna performance.
  - Accurate characterization sensitivity of antenna (array)
  - Helpful in calculation of power budget
- Ground plane choice
  - Cost
  - System level performances
  - Mesh-grid design (for improved performance)
  - Sensitivity of antenna
- Antenna metrology
  - Challenges in fabrication of Spiral antenna fabrication.
  - measurements

Soil Characterization

- We classify the morphology of soil as two layers structure.
- Upper layer: mixture of gravels, sands, silt and clay.
- Lower layer is granite base
- Thickness of upper layer: 30 cm to 80 cm.
- 5 samples were collected during sunny day
- 4 samples were taken from each corner of 200 m length square area.
- The 5^{th} one collected from the centre of square.
- The samples were sieved and oven dried before measurements.

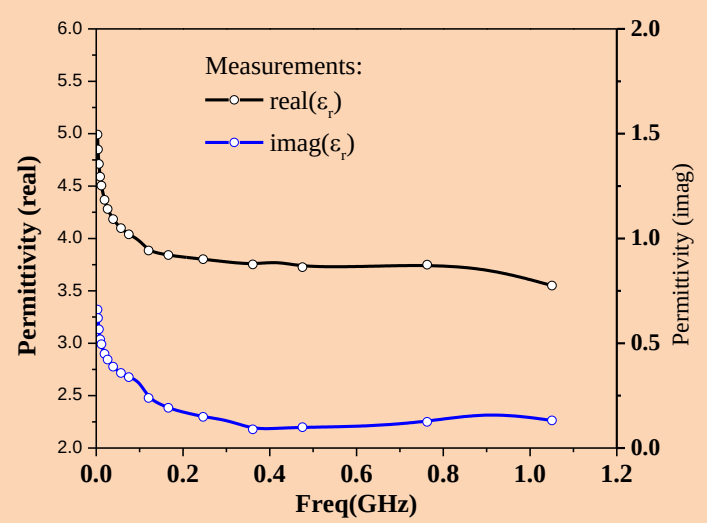


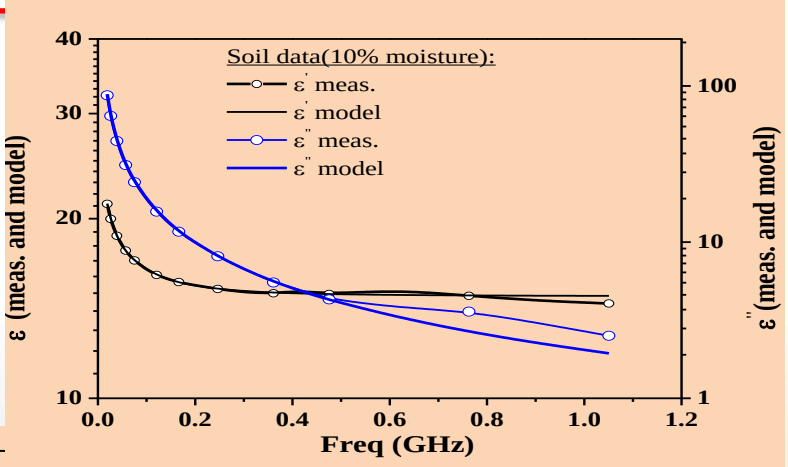
Soil Measurements:

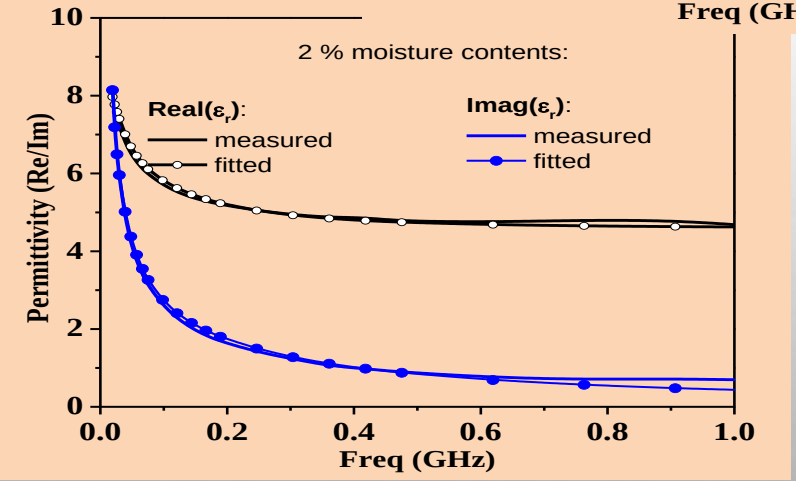


- Chemical analysis + mineral composition
- Measured relative permittivity of the soil samples, in CSIRO facility.
- Permittivity measurements with different moisture contents.
- Nicholson-Ross-Weir algorithm is used in the calculation of permittivity.
- Debye 2 parameter model is used for fitting data (model).

Soil: measurements:



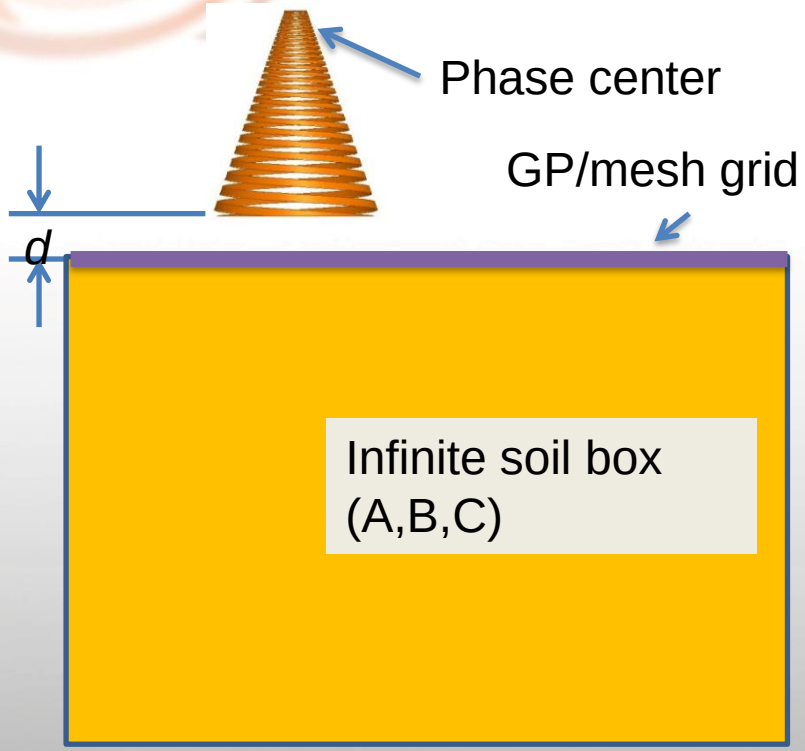


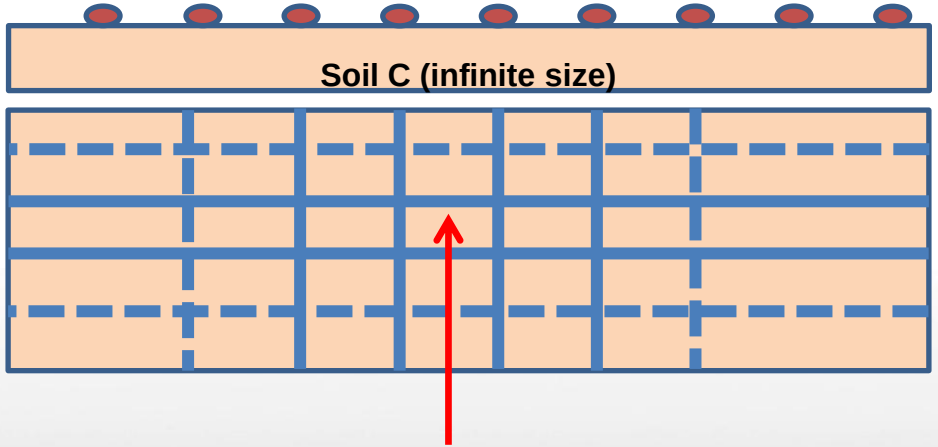


Do we need a ground plane??

- Ground planes are critical components of antenna.
- GP influence (depends on various types of antenna)
  - Impedance match
  - Gain/sensitivity of antenna
- GP needed for mechanical support or robust placement/fixing antenna
- Proper grounding of circuits etc..
- Cost is important for GP size ??
- Alternate option:
  - Mesh grid (reducing cost (and improve performance))

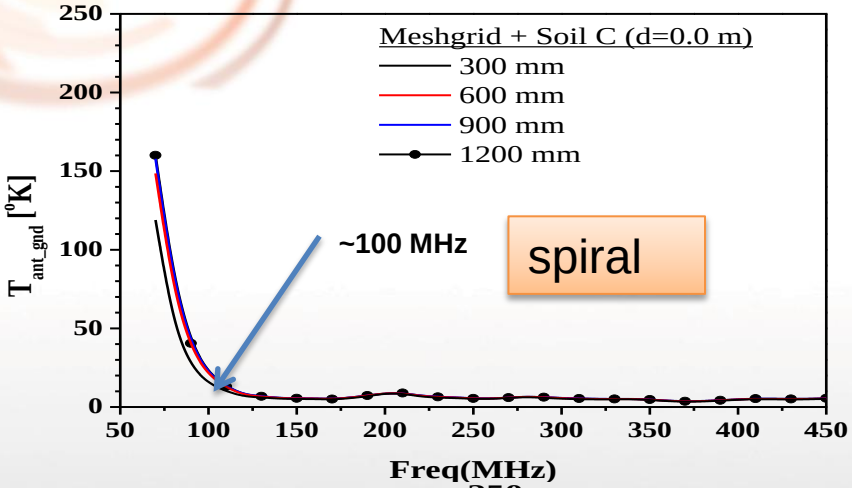
Mesh grid model:

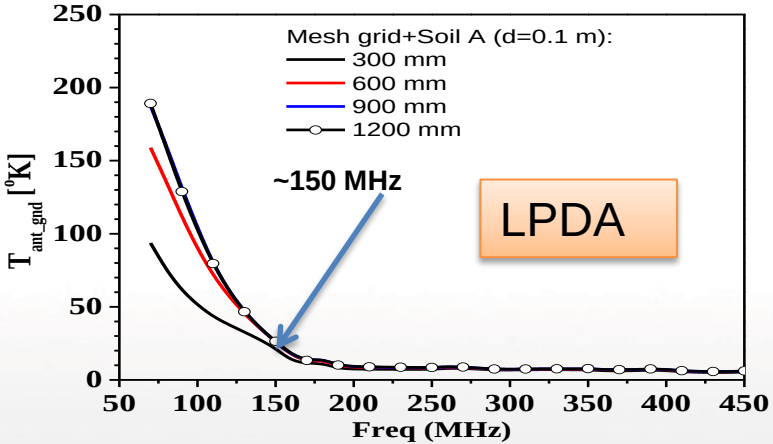


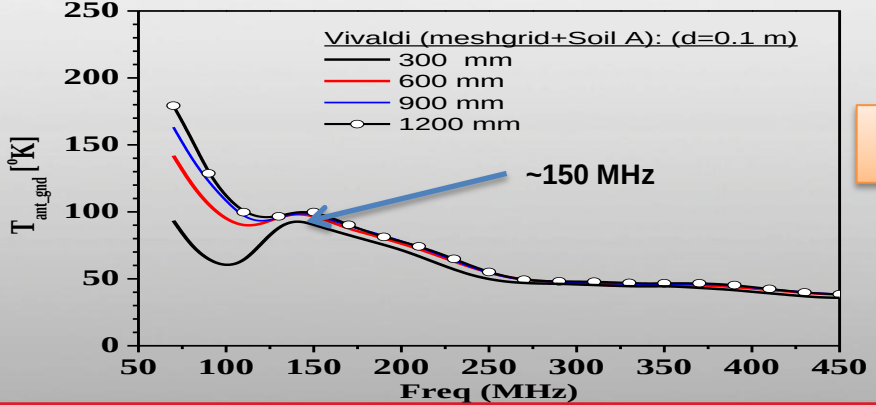


Mesh size:
Pitch: 300 mm
Dia: 2.5 mm
Size of grid: 10m x 10m
Media: copper

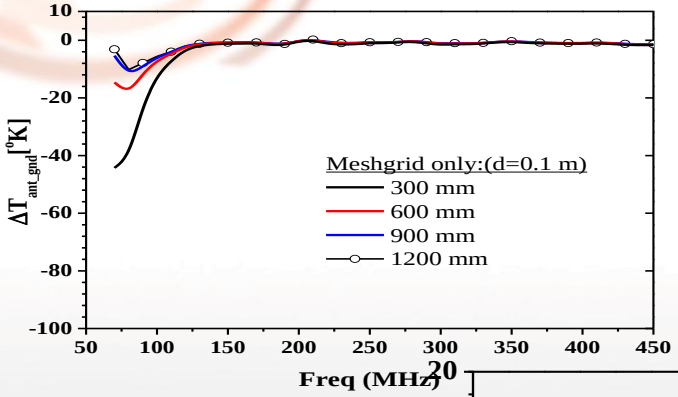
Noise Temperature ($T_{mg+soil}$) VS pitch size:



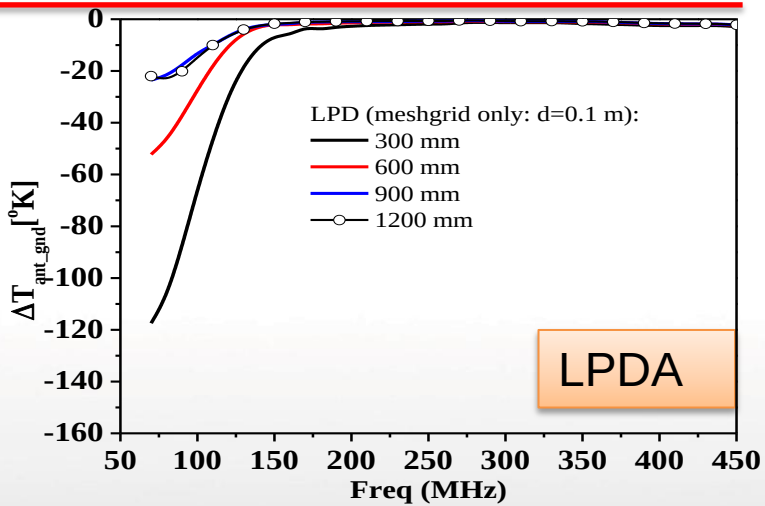




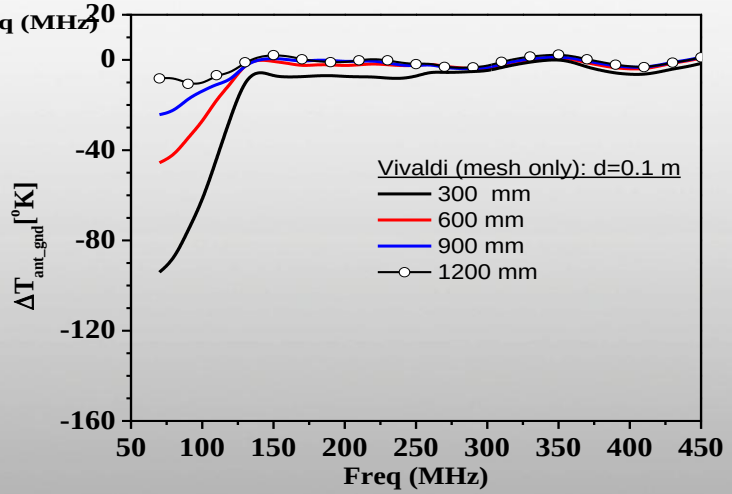
Sensitivity with/without mesh grid



spiral



LPDA



vivaldi

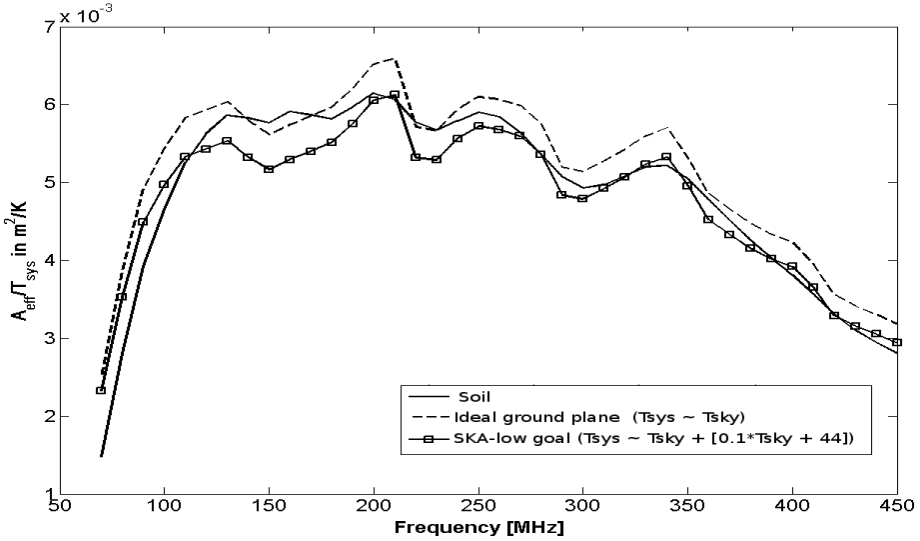
Comparison of T_{ant_gnd} (Soil-A)

Freq.	Spiral Antenna		Vivaldi Antenna		LPD Antenna**	
	ASR-V1.4	FEKO	ASR-V1.4	FEKO	ASR-V1.4	FEKO
70 MHz	134.0	153.1	209.8	223.5	127.5	198.7
150 MHz	2.12	8.53	65.2	85.0	12.7	27.0
300 MHz	4.00	8.92	40.6	54.5	na	8.1
450 MHz	1.2	7.5	29.2	42.3	0.8	8.25

**: compared with d=0.16 cm data

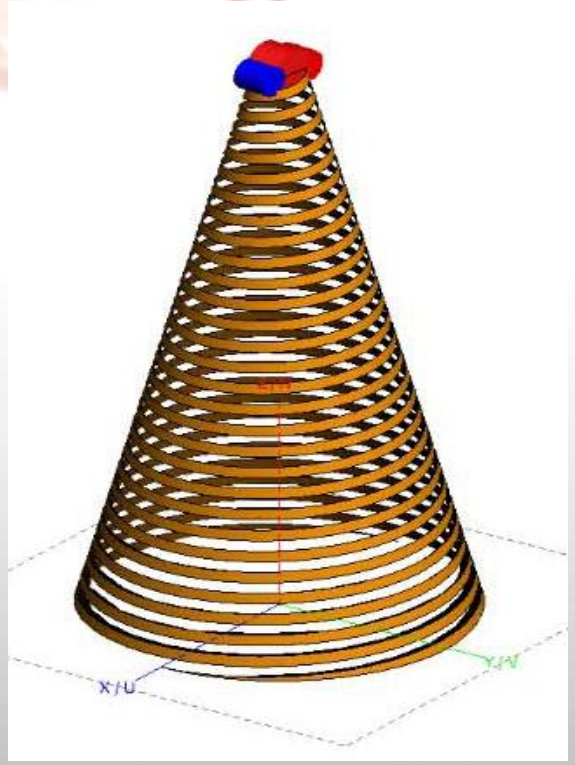
Do we need a ground plane?

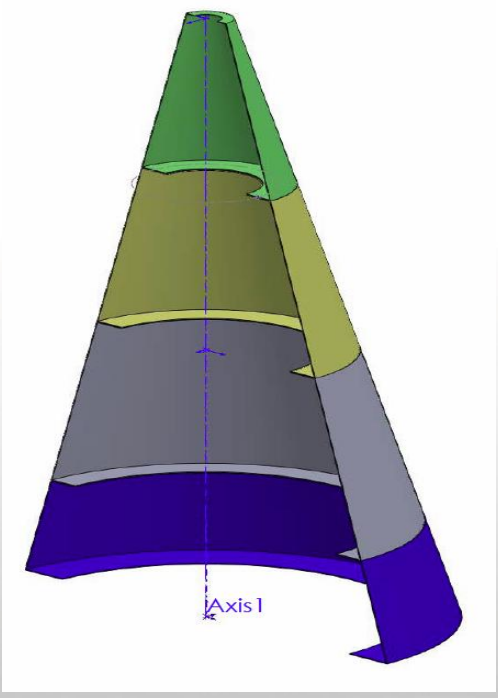
Sensitivity of isolated sheet spiral at SKA site – infinite extent back surfaces



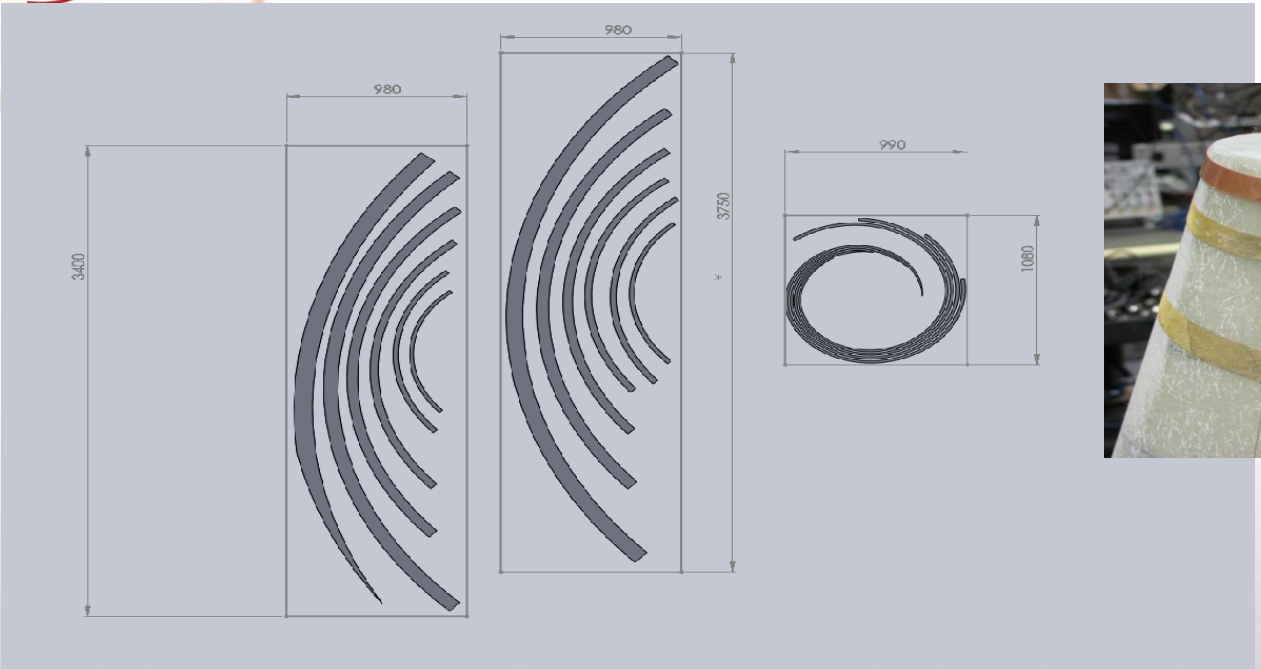
- Spiral with a metallic ground plane has higher sensitivity than SKA-low goal
- Spiral over the soil does not meet goal below 110 MHz, but is close enough to warrant detailed performance and cost trade-off
- Highly-directive SKA-low antennas (like the conical spiral) may not need a metallic ground plane
- Or use only very wide mesh

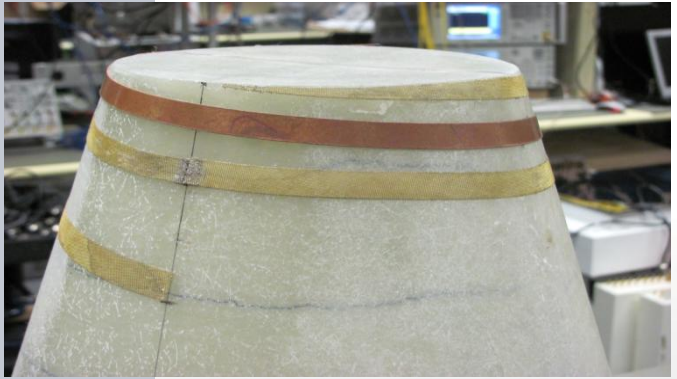
Antenna metrology:





Conductor patterns:





- 2 identical spiral racks made from 13 sections
- Water-jet cut from brass mesh (or copper foil)
- low-temperature solder joints, epoxy to cone

Conclusions

- Electrical and chemical parameters of Soil are characterized in details.

- Debye model is used to fit the measured data. The comparison between the two are reasonable close.

- Ground plane effects are characterized for 3 antennas using MoM solver.
- Mesh grid might be a better option and cost effective compared to metallic ground plane. Tant is sensitive to lower end only .
- And for high requency end (> 150MHz) Tant is insensitive to mesh grid/GP.
- With Meshgrid Tant is reduced to ~100 K (@70 MHz) for all three antennas.