International Centre for Radio Astronomy Research

Conical log spiral antennas for SKA-low?

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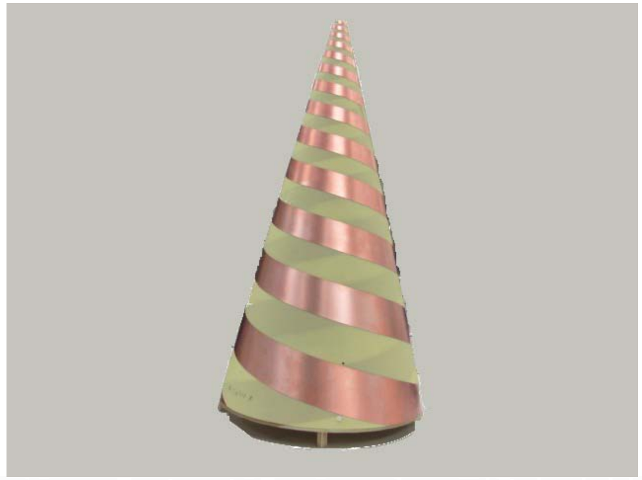
Curtin University

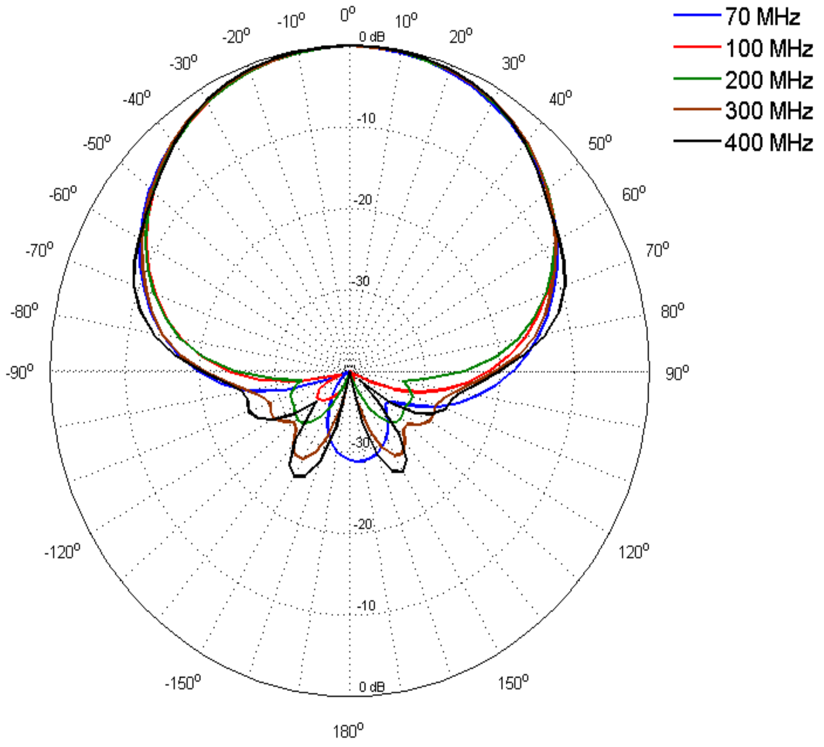
The University of Western Australia

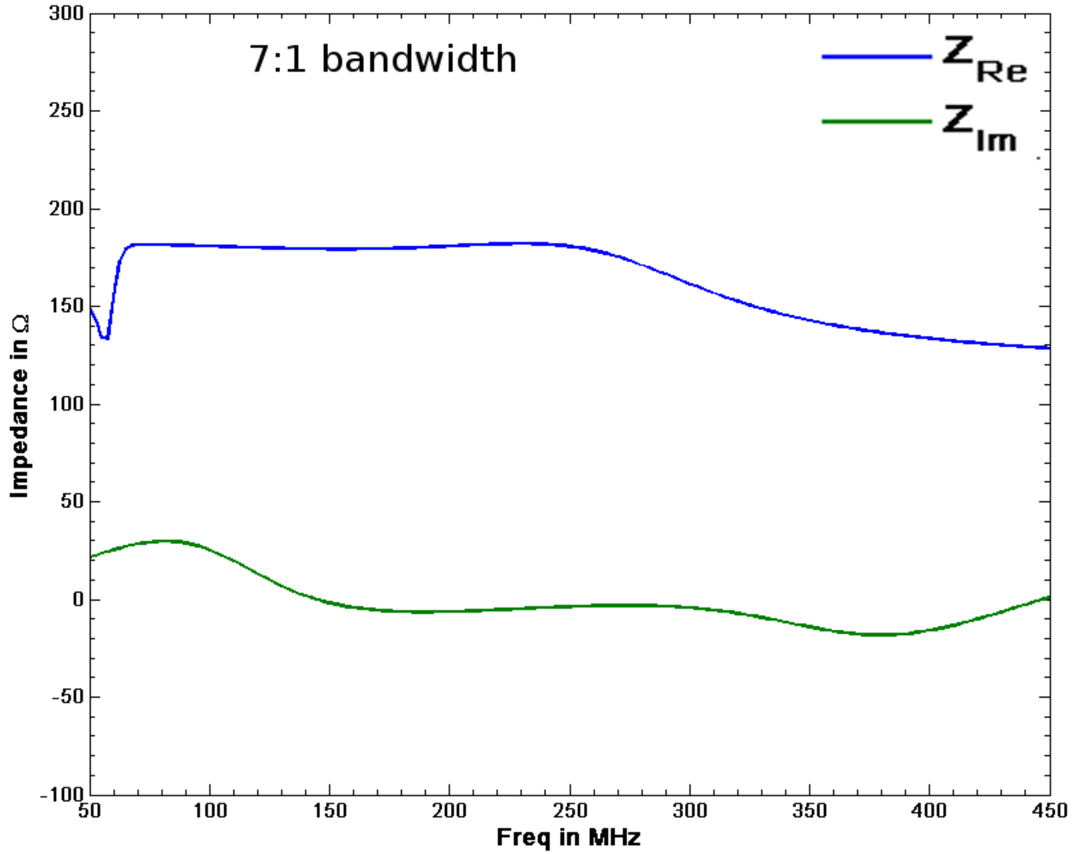


Motivation

- Most antennas are not able to maintain characteristics across >2:1 bandwidth.
- Conical spirals are frequency independent travelling wave antennas having many favourable characteristics for the SKA-low;
  - Smooth impedance across the bandwidth
  - Constant beamwidth
  - Low cross polarisation
  - Low mutual coupling
- The conical spiral, however, is a single polarised antenna.
- Presented are the results of investigation into dual polarised designs of the conical spiral antenna.

Spiral features

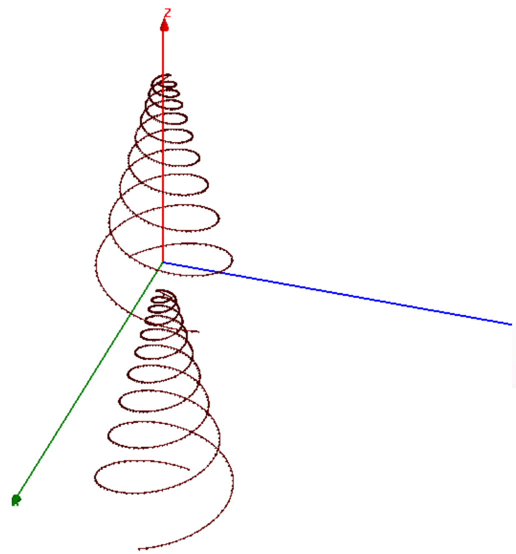




Calculated conical spiral radiation pattern

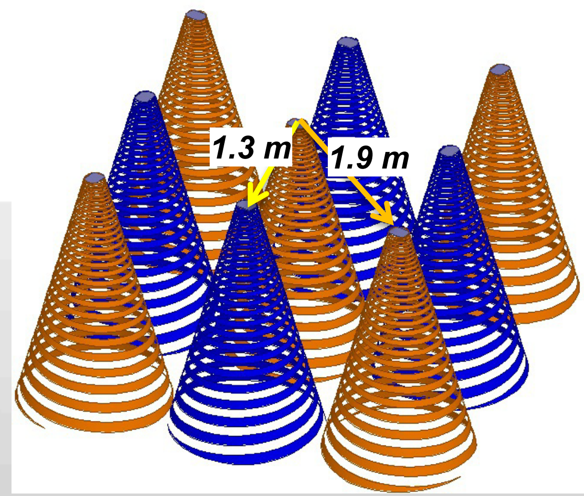
Calculated real and imaginary component of impedance

Different spiral models

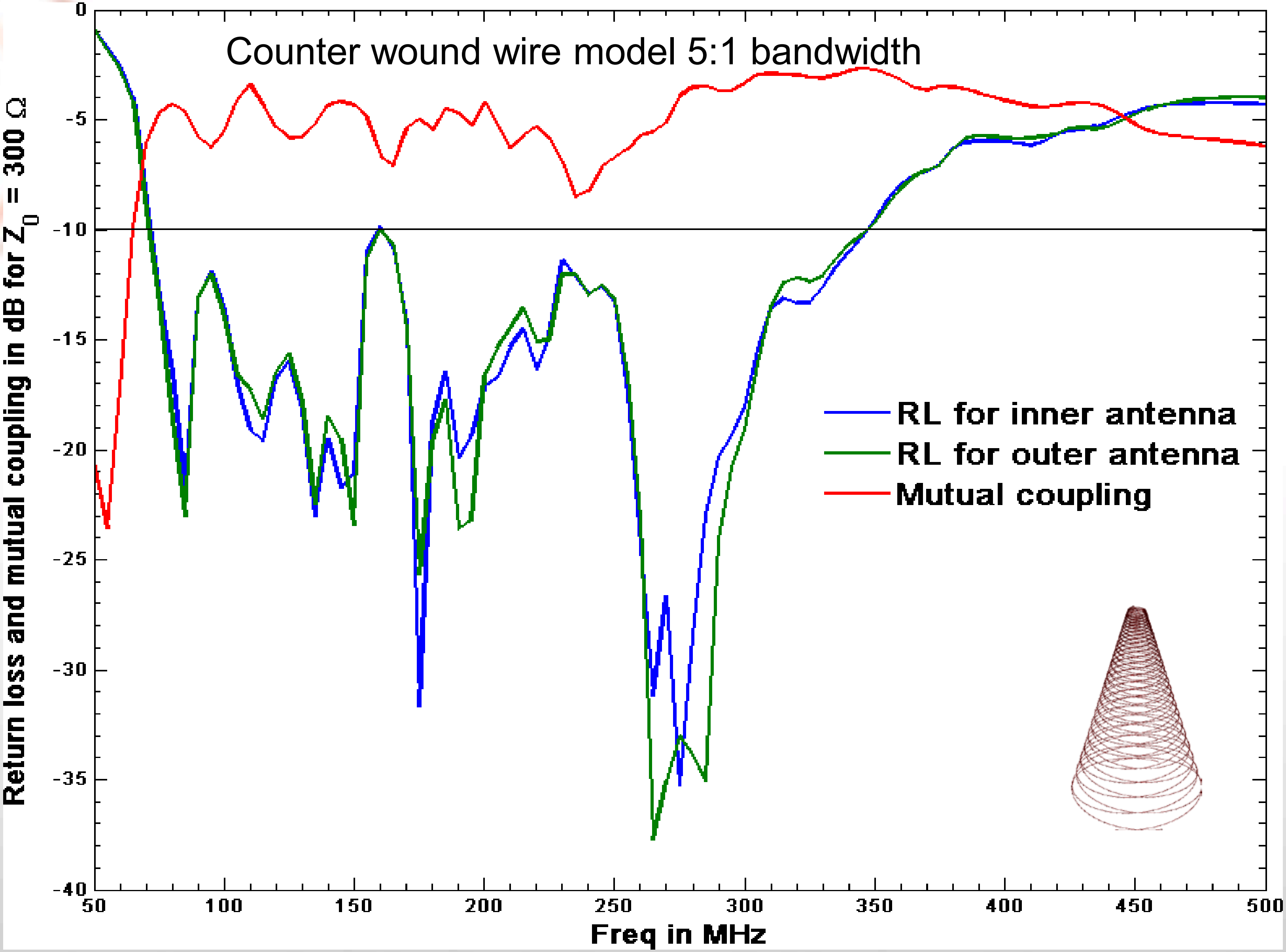


Co-linear counter wound spiral

Counter-wound Co-axial conical log spiral

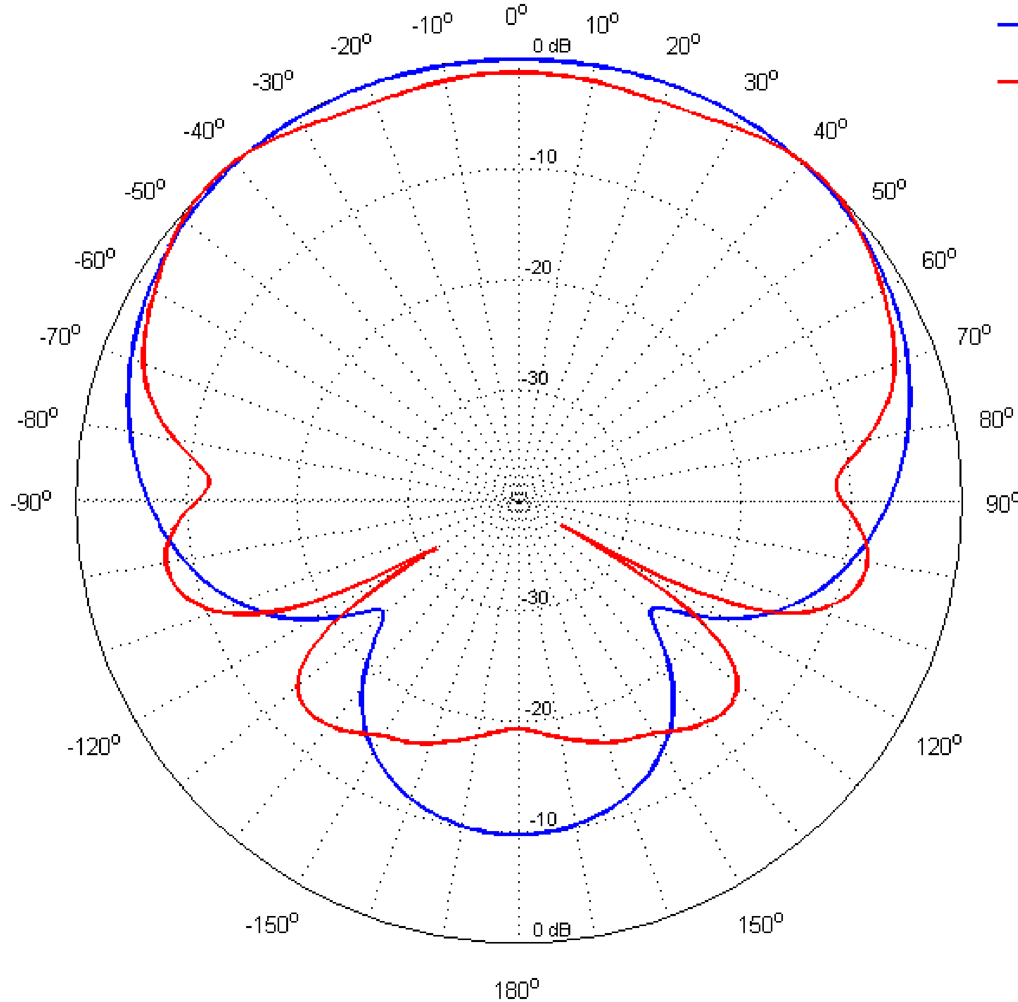


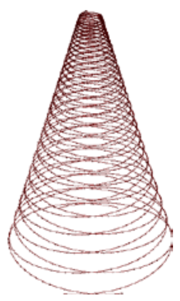
Dual-sense spiral array



Counter wound spiral calculated return loss and mutual coupling

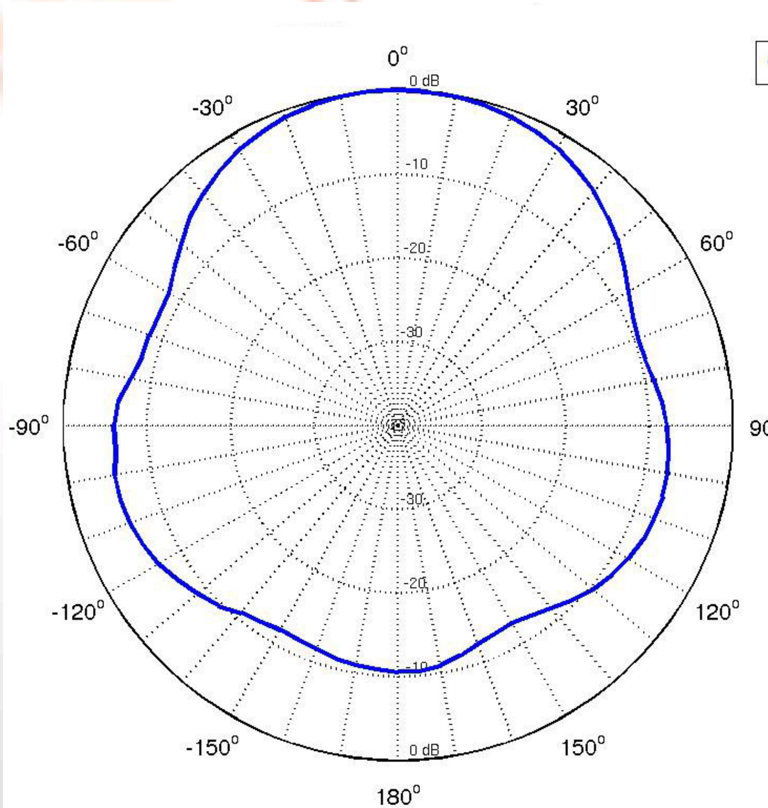
Counter wound wire model 5:1 bandwidth

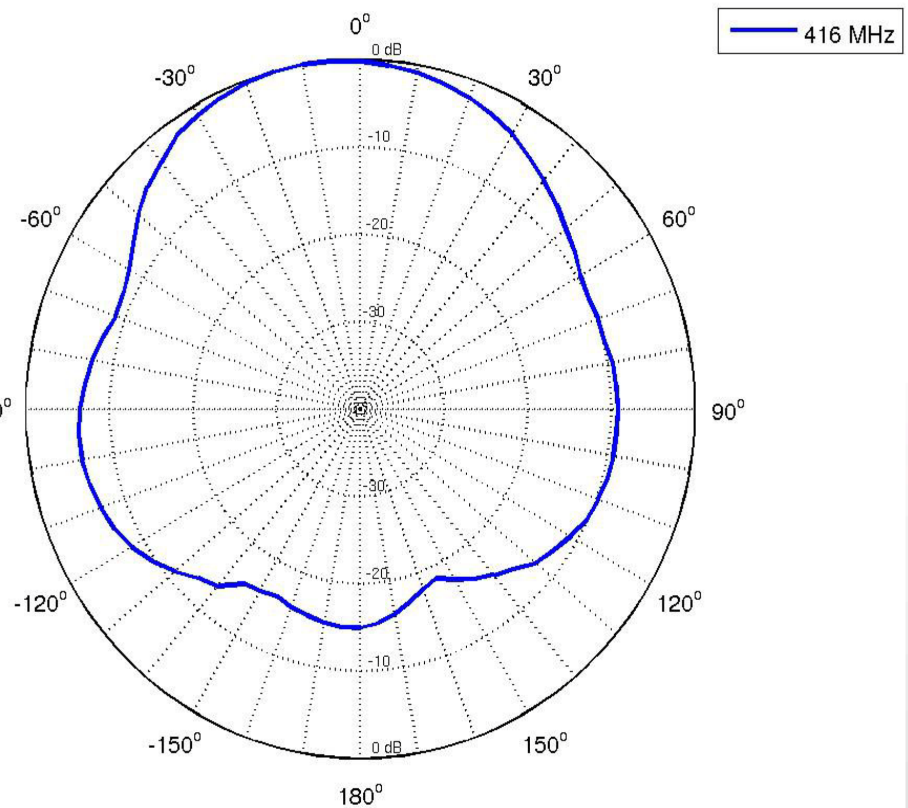




Counter wound spiral calculated radiation pattern

MEASURED RADIATION PATTERN



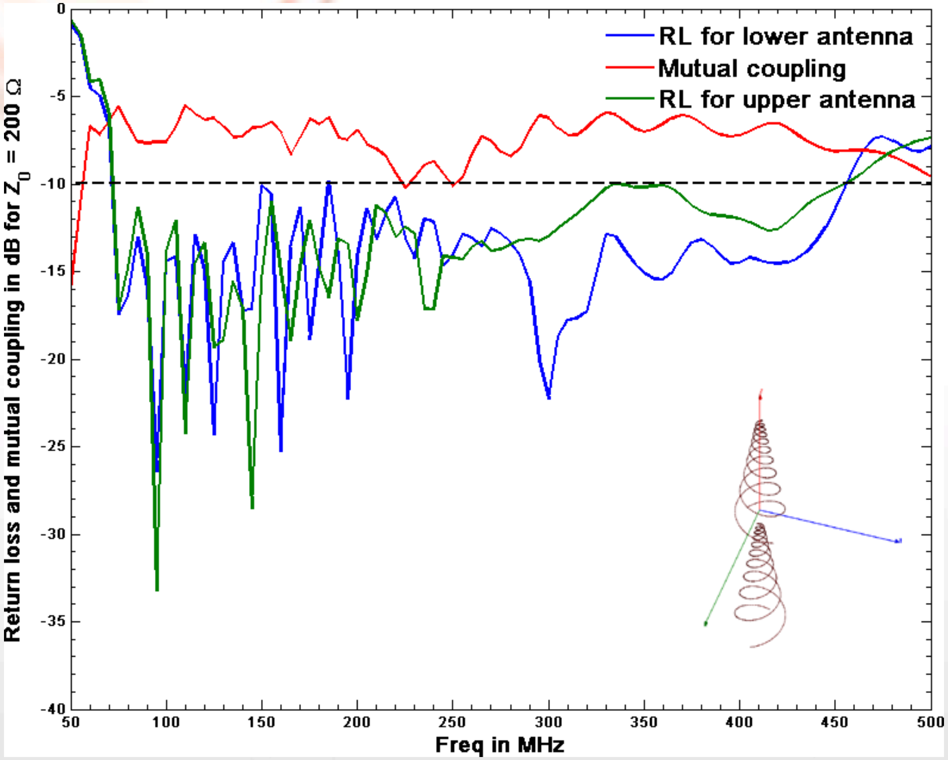


Inner arm radiation pattern

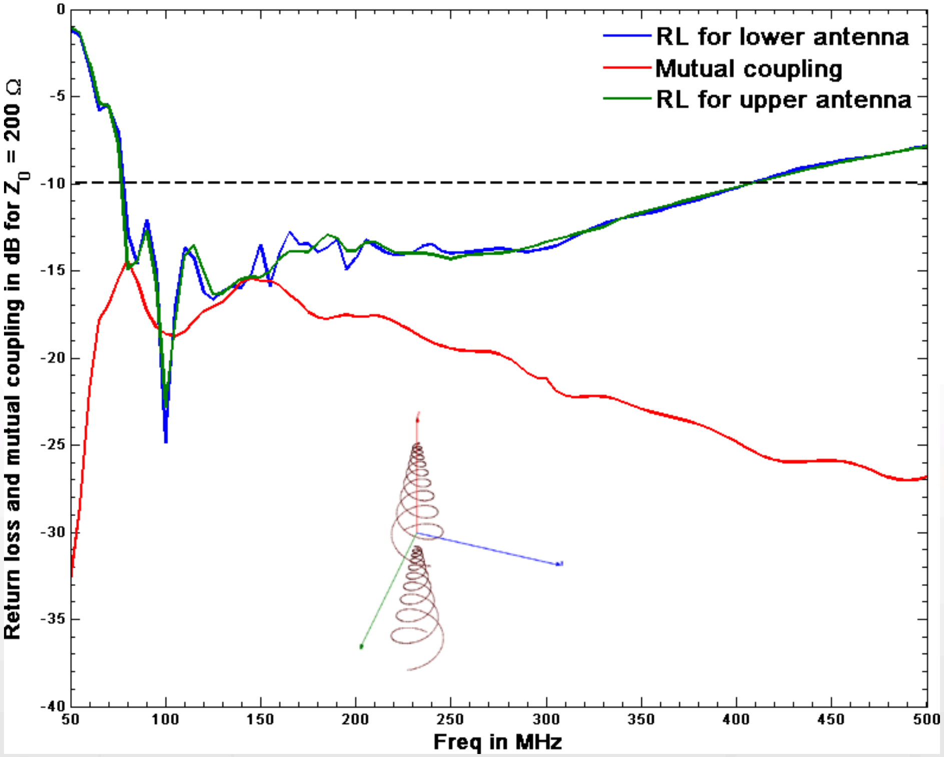
Outer arm radiation pattern

- Scaled prototype operating from 350 – 2250 MHz.
- Low back lobe.
- Pointing error is due to asymmetry in the feed.

Co-linear spiral model 6:1 bandwidth



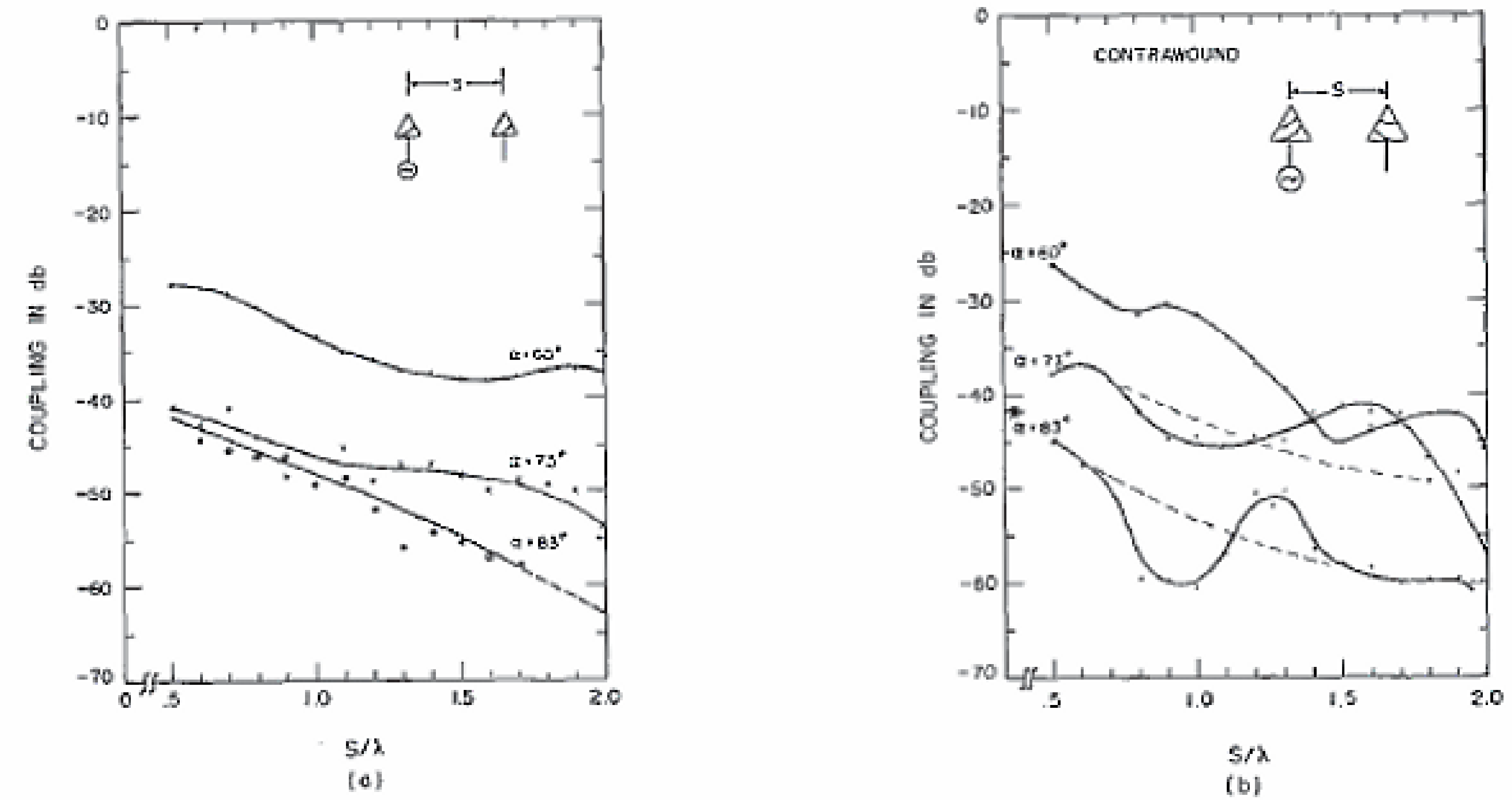
Separation = 200 mm



Separation = 2000 mm

Calculated return loss and mutual coupling of co-linear spiral

- Isolation increases and ripples in the return loss decreases as the separation between the antennas increase.
- Strong coupling of the magnetic and electric near fields.
- Indicates that counter wound antennas will only work in a small frequency bands and are unsuitable for the SKA-low.

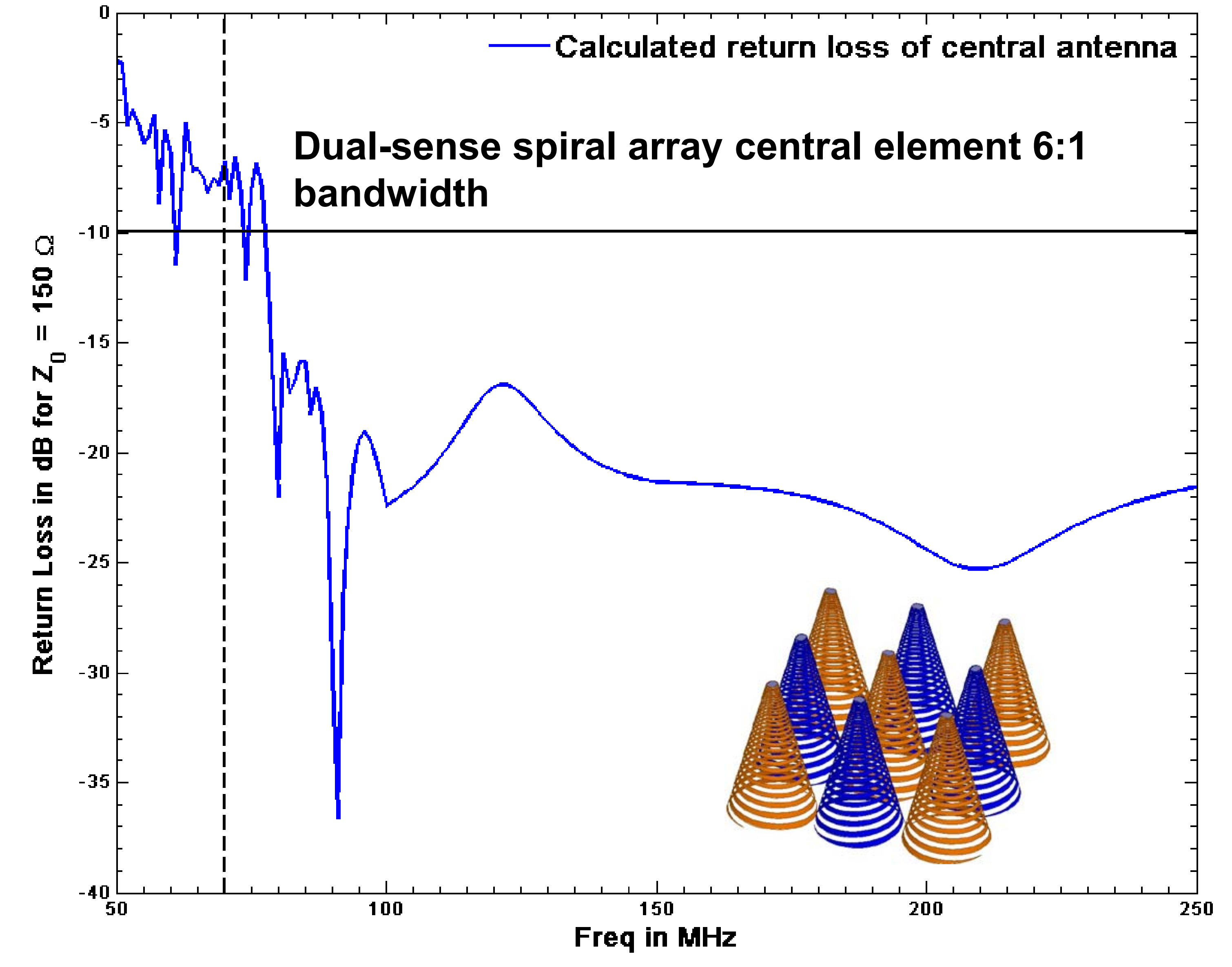


Ref: Dyson, J.; , "The characteristics and design of the conical log-spiral antenna," *Antennas and Propagation, IEEE Transactions on* , vol.13,, Jul 1965

- Early Dyson work (see figures) shows that spiral have very low mutual coupling between antennas of same and opposite wounds.
- This leads to investigation of dual sense spiral arrays.

Justification

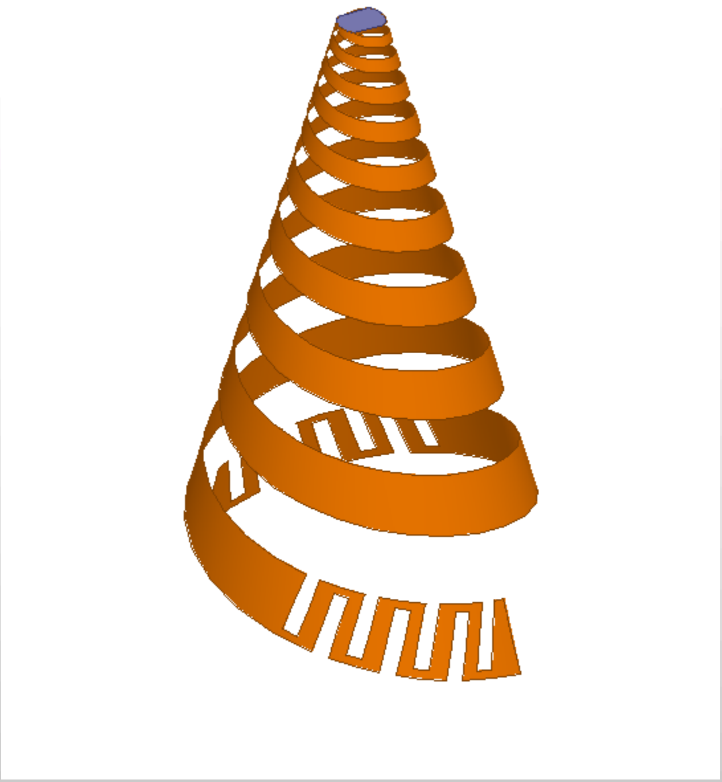
- Assuming average spacing of λ at 115 MHz (due to the sparse nature of the SKA-low array)
- There is space to put two spiral antennas (footprint of < λ/2 at 115 MHz)
- This is achieved only if the opposite wound spirals have little affect on the antenna radiation and terminal characteristics.
- Extra cost will be antenna formers.
- Benign features of spiral will give you a single antenna fulfilling all the requirements of the SKA-low



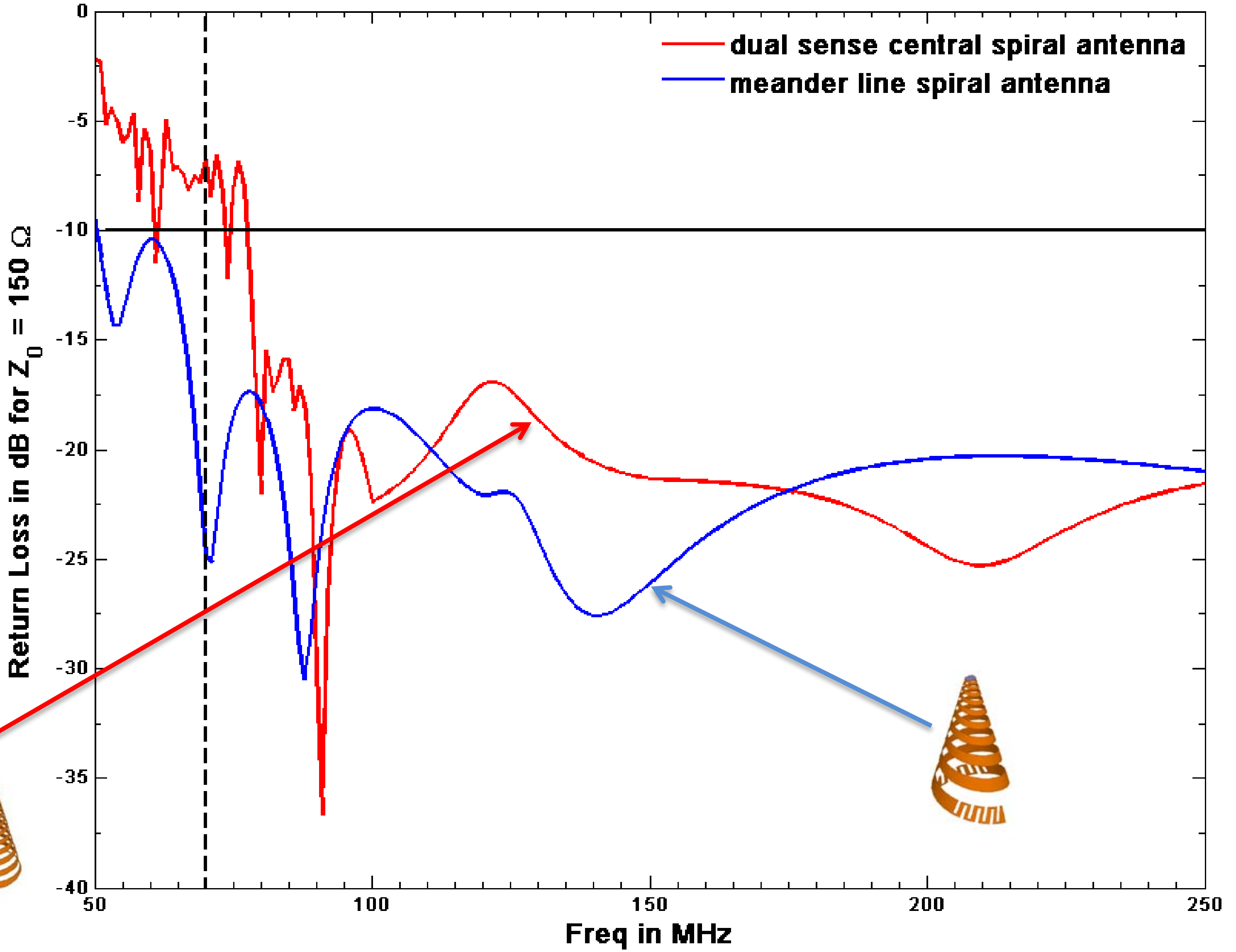
Dual-sense spiral calculated return loss

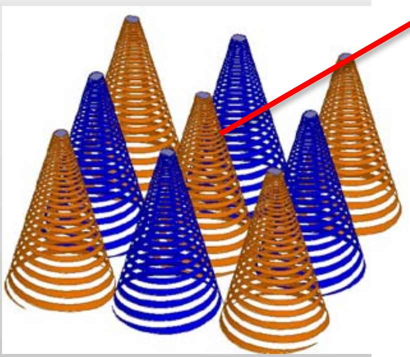
Meander line spiral

- The reflection loss (impedance) misbehaviour at lower frequencies is a result of the reflections due to the travelling wave meeting the end of the spiral arm.
- This reflections also cause the larger back-lobes in spiral radiation pattern at lower frequencies.
- One way to mitigate this is to increase the electrical length of the spiral arm at lower frequencies.
- This is accomplished by cutting meander lines into the spiral arm (shown in figure).

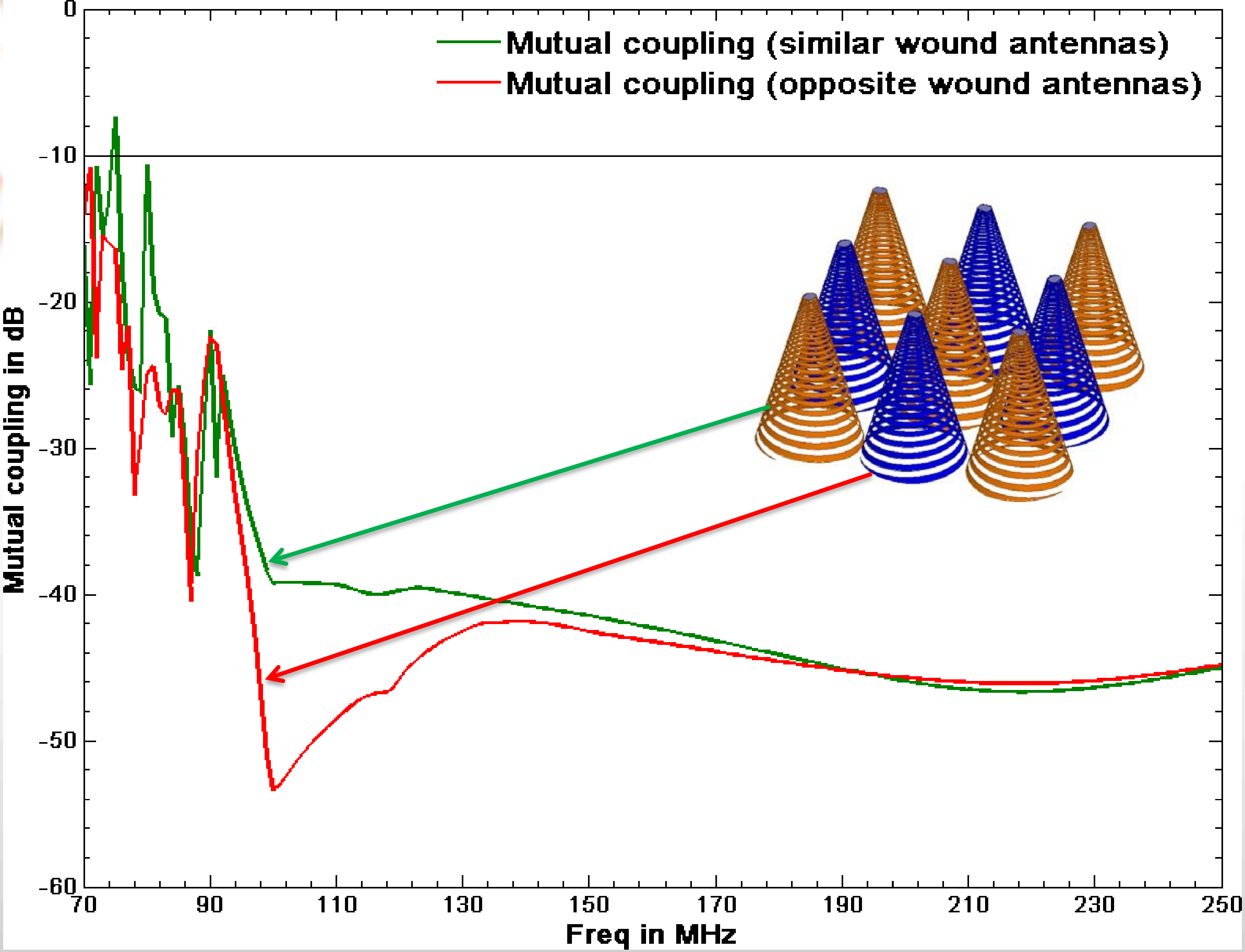


Meander Line spiral model

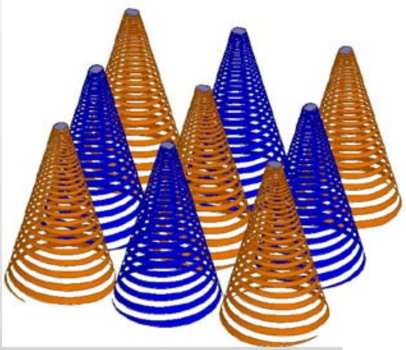


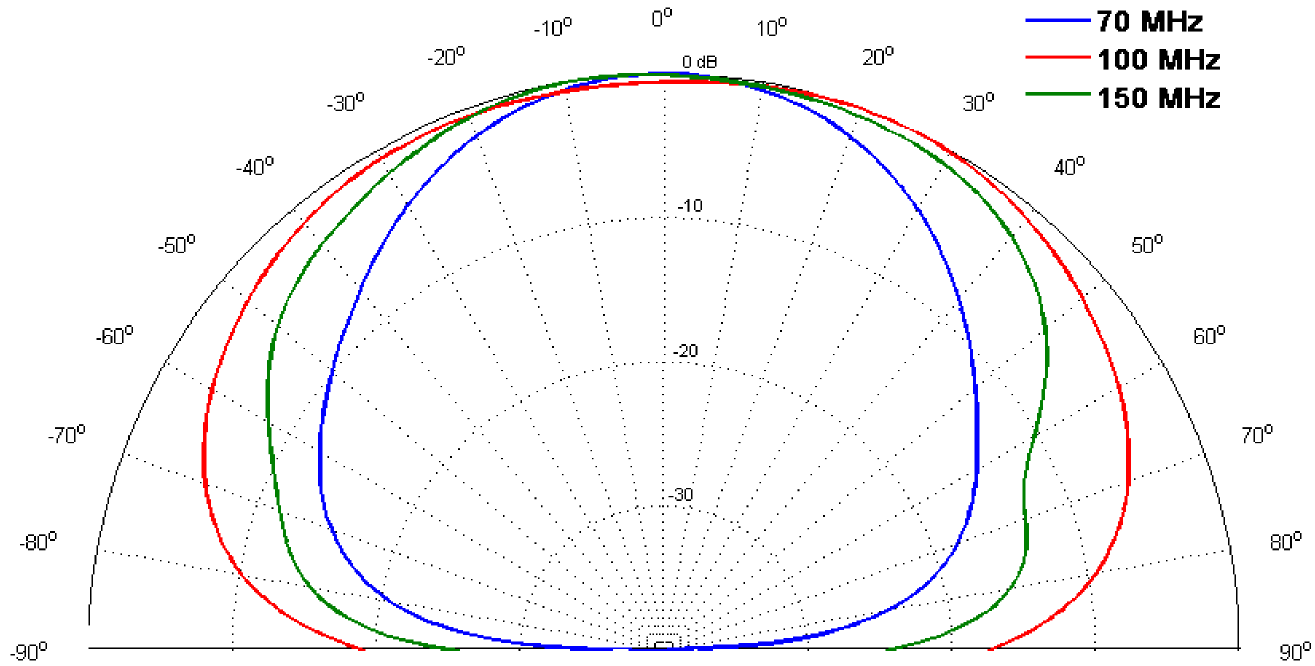


Calculated return loss plot of simple and meander line spiral



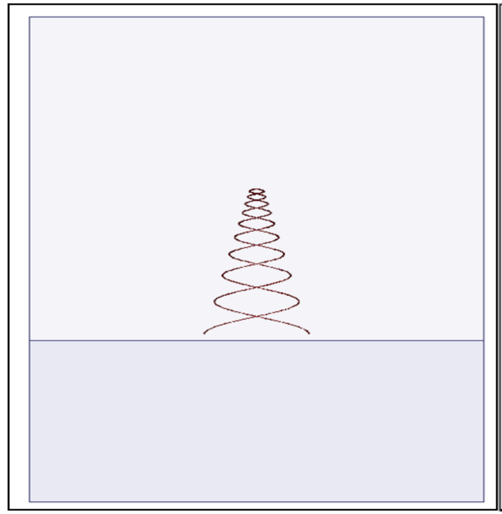
Dual-sense spiral calculated mutual coupling

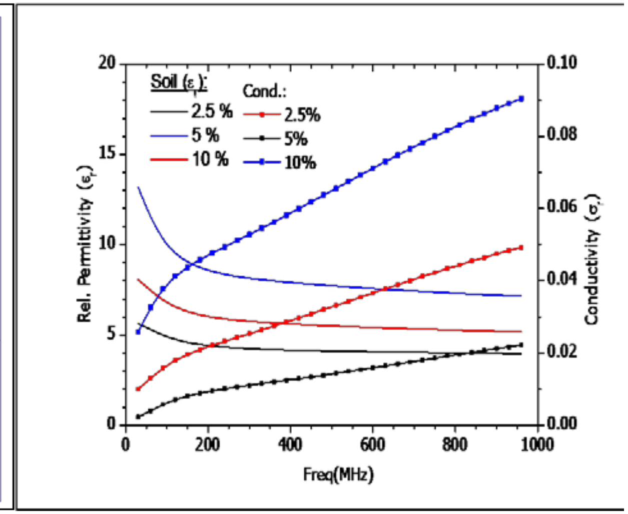




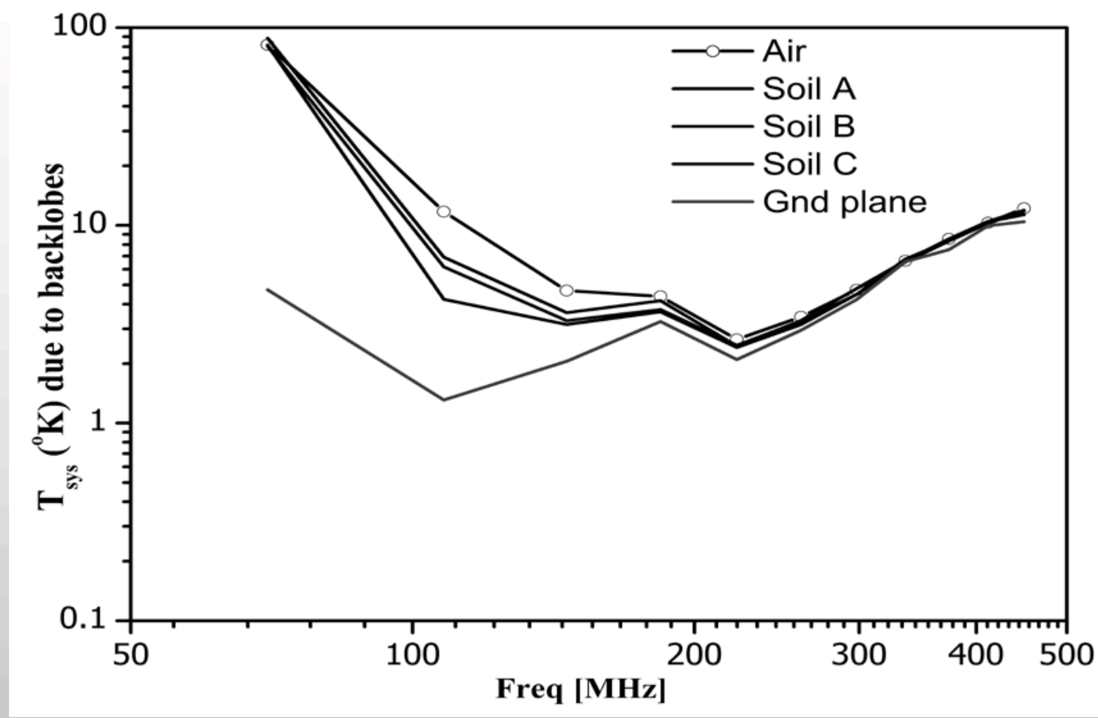
Main Beam elevation response of central element

Do we require ground plane?

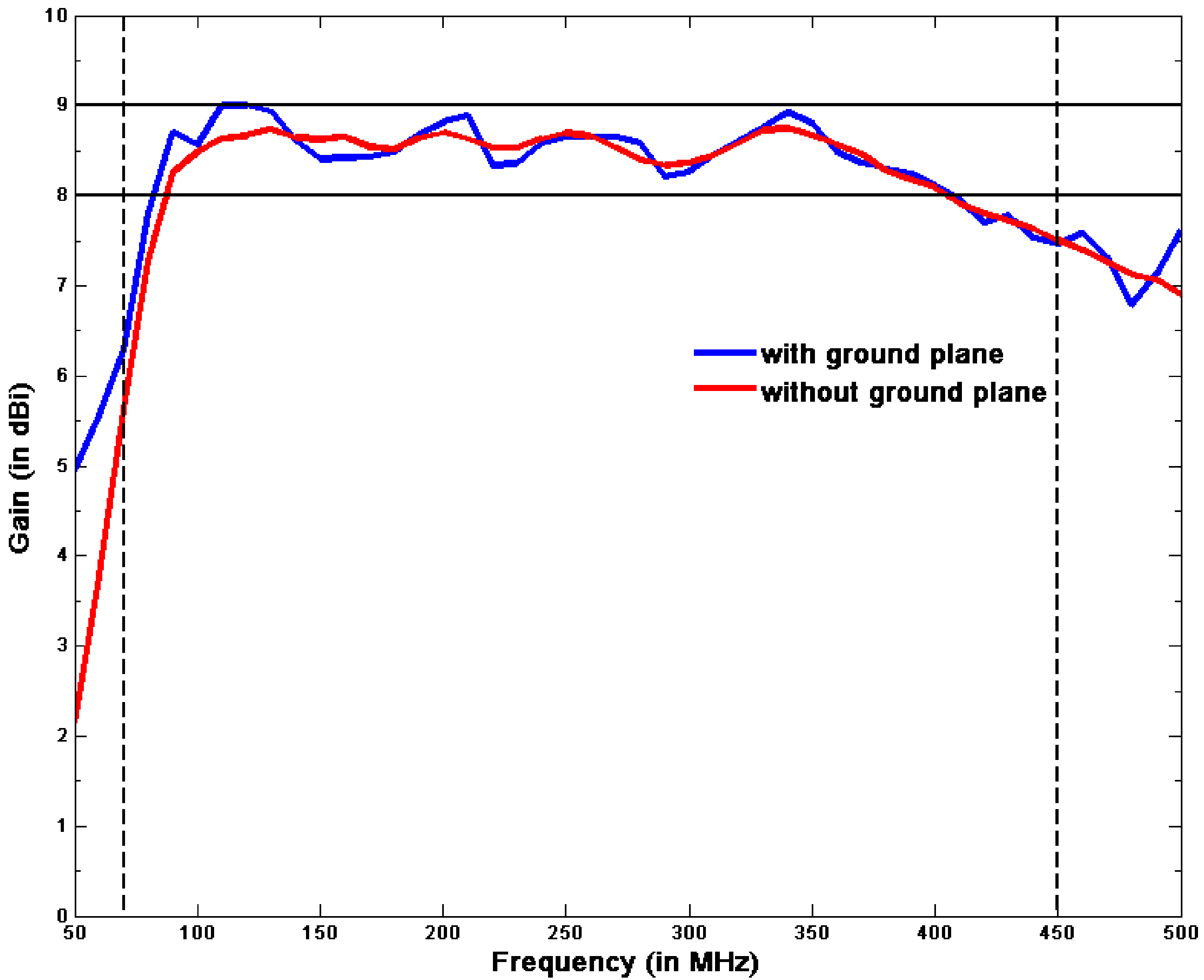




- Top left picture is of model with 5.7 x 5.7 x 2.4 m soil box under a spiral antenna model.
- The soil is modelled as generic desert soil with different moisture content:
  - Soil A = 2.5 %
  - Soil B = 5 %
  - Soil C = 10 %
- The moisture content changes the relative permittivity and conductivity of the soil (as calculated and plotted in top right figure).
- The effect of soil is seen only at the lower frequencies where the spiral has a larger back-lobe (as shown in the lower figure)

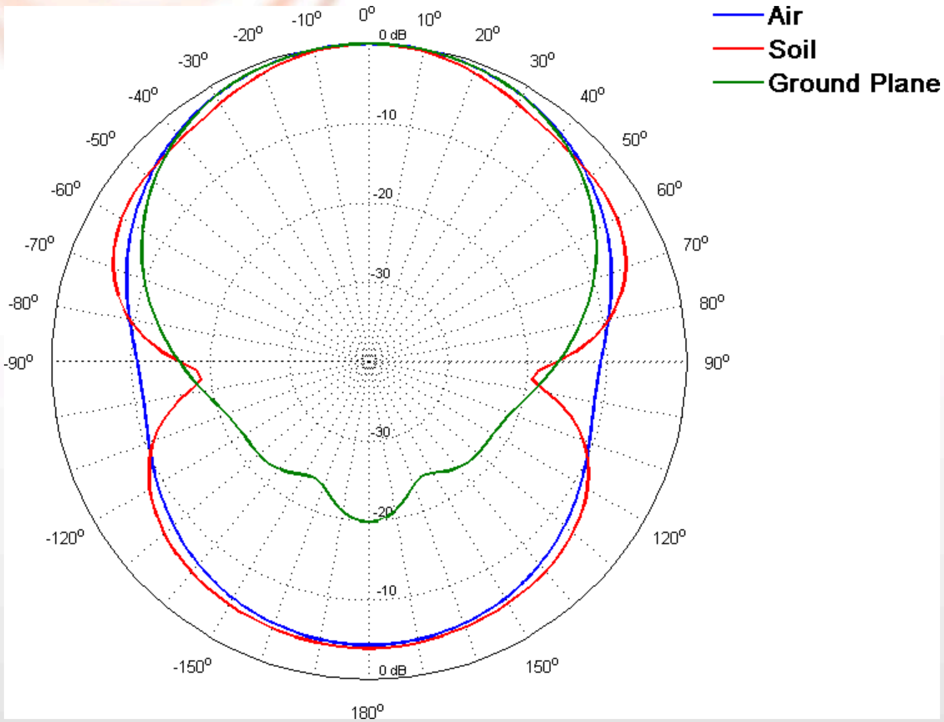


Calculated plot of noise due to back lobe

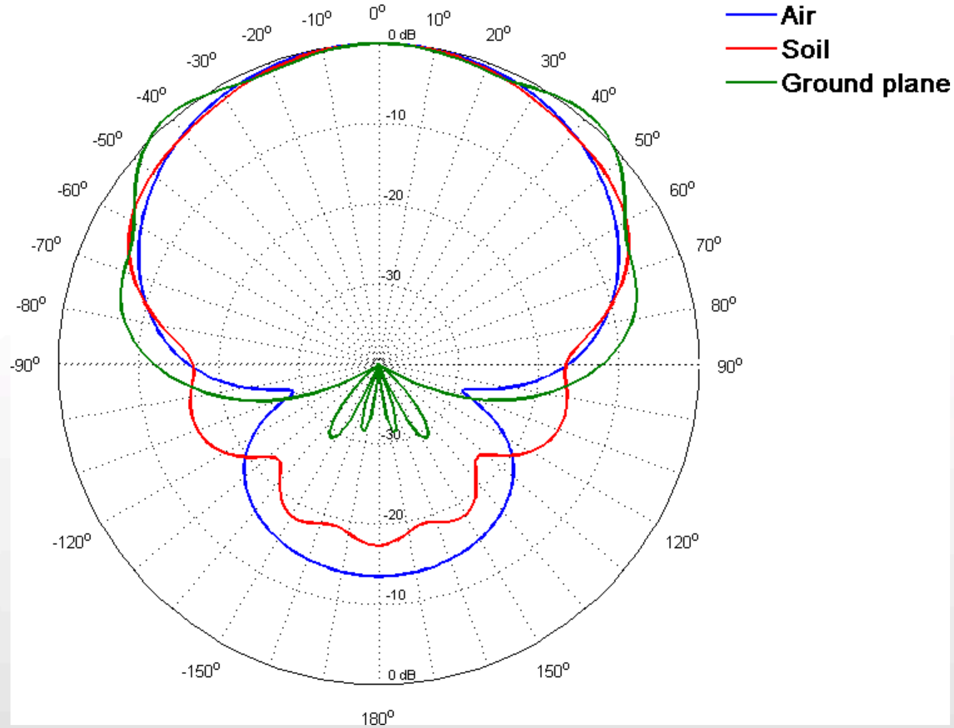


Calculated gain with and without ground plane

Do we require ground plane?



Calculated radiation pattern at 70 MHz

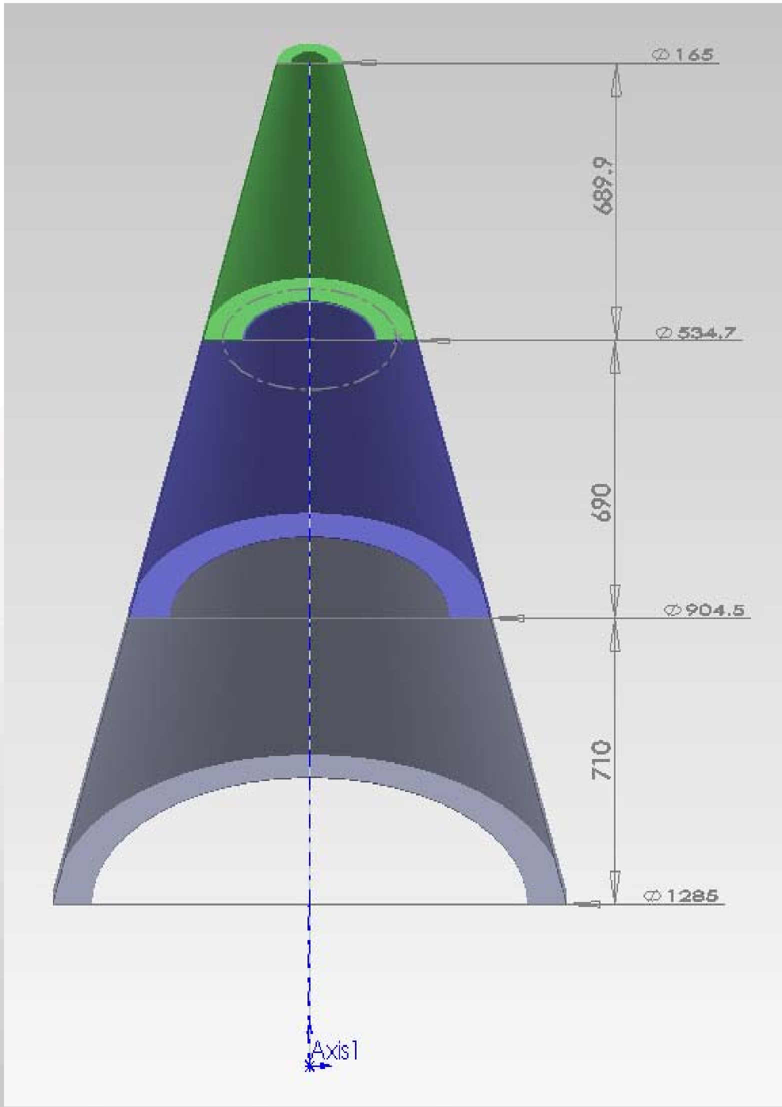


Calculated radiation pattern at 100 MHz

- Back lobes reduce to under -10dB at 100 MHz.
- Using meander line spiral will reduce back lobe at lower frequencies.

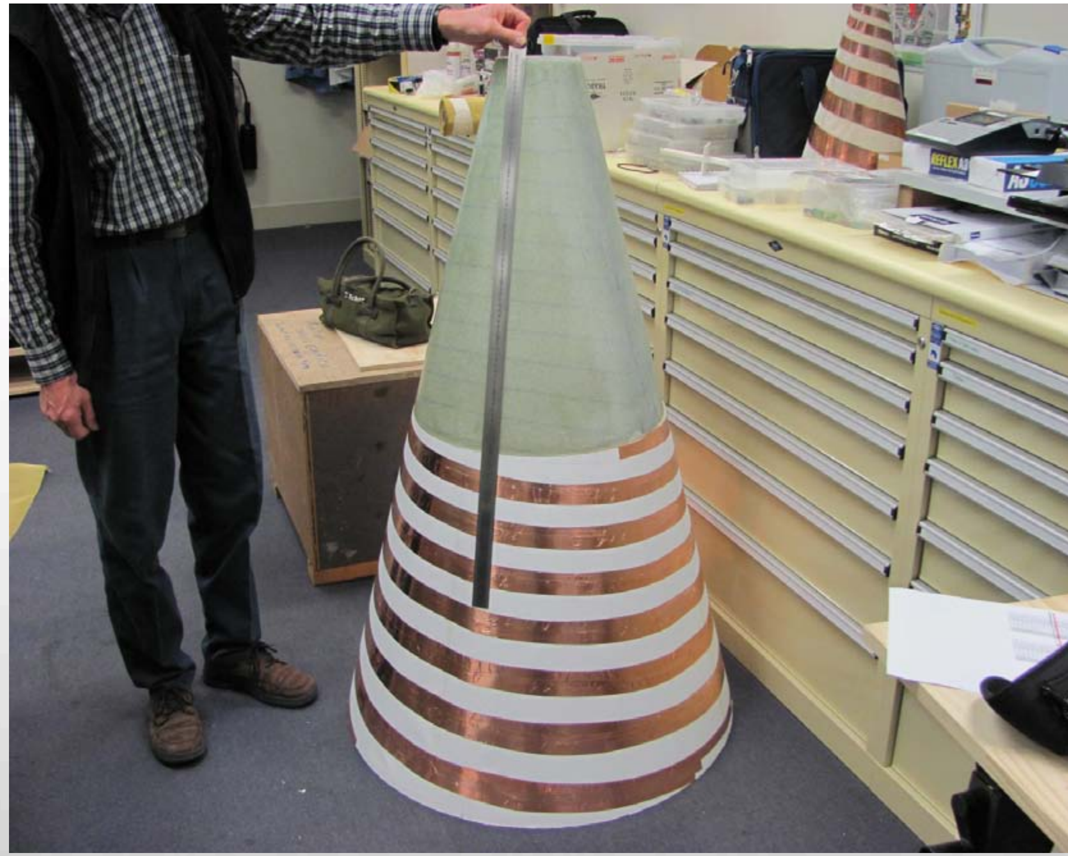
Antenna manufacturing cost

- Precise prototype made to study the antenna.
- Cost of a single precise fibre glass prototype is AUD 2000.
- Mass production of fibreglass former will reduce manufacturing costs.
- Investigating cheaper options e.g. skeletal struts.



Mechanical model of the conical spiral former


Attention
DAVID



Results and continuing work

- Results indicate that the counter-wound co-axial conical log spiral antennas is not suitable for the SKA-low.
- The dual sense array is able to maintain the benign broadband features of the single polarised conical spiral whilst providing dual circular polarisation.
- Cutting meander lines into the spiral arm improves radiation and terminal characteristics at lower frequencies.
- Ground plane is only effective at lower frequencies.
- Lower back lobes at low frequencies will reduce the need for the ground plane.
- Investigating alternative options to construct the antenna former.