Modelling and Simulation of Conical Spiral Antennas

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Motivation

• Most antennas are not able to maintain characteristics across >2:1 bandwidth

• Consider antennas having true frequency independence
  – Beam pattern (width, co-polarisation etc.)
  – Impedance

• Higher gain elements
  – More 'effective area' per element
  – SKA station requires fewer elements to attain $A_e/T$
  – Economic implications (all digital array?)

• We examine conical antennas as example high-gain, frequency-independent antenna for SKA-low station studies
Conical Log Spiral

Conical spiral: early work

Beam pattern, impedance and axial ratio

Conical spiral: early work

Beam pattern, impedance and axial ratio

- Antenna characteristics with frequency
  - Nearly constant beam pattern
  - Low back-lobe at all but lowest frequency
  - Relatively small, smooth impedance variation
  - Good axial ratio maintained
Conical spiral: early work

Mutual coupling

Conical spiral: early work

Mutual coupling

- Spiral features
  - Low mutual coupling
  - Polarisation purity
  - Good isolation
Conical spiral: early work

Beamwidth

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Conical spiral: early work

Beamwidth

• Parameters control beamwidth
• Able to obtain wider beamwidth for better sky coverage
Dual polarised design derivatives

- Conical Log Spiral (CLS) is a single-polarised antenna while SKA-low requires a dual-polarised one.

- We are exploring designs for dual-polarised spirals

- One example
  - Opposite hand spirals wound on single former
  - Counter-wound Co-axial Conical Log Spiral (C3LS) antenna
Simulation of antennas

• Simulation of CLS antenna showed independent results which were similar to previously constructed spiral antennas
  – Motivating us to start our prototyping of the antenna.

• C3LS antenna simulation proving difficult
  – Two overlapping layers could not be distinguished by simulation software as two separate layers
  – Larger separation and finer meshing gives indication that antenna pattern might rotate through higher modes as a function of frequency

• It was decided to
  – Prototype C3LS antenna to study it in more detail
  – Improve simulation

• Work in progress
Return loss is less than -10 dB over operating bandwidth

Impedance is constant through operating bandwidth
Gain at zenith

>5.5dBi gain over the frequency range
Prototyping of the antennas

- 350-2250 MHz band CLS and C3LS antenna constructed (1/5 SKA-low scale)
- 3:1 BALUN to feed C3LS
- No BALUN for CLS
- Construction errors
  - Maintaining continuity of spiral arm over cone
  - Elliptical cone due to material tension
  - Non-rigid former for C3LS
- From measurements we found
  - Small mechanical errors on top end of spiral affected radiation and terminal characteristics
  - Without BALUN, asymmetry is introduced in radiation pattern
Measurement of the Prototypes

Chamber measurements

- Chamber measurements can be made only up to 1 GHz
- The floor was not absorbing
- Future measurements to include foam floor panels

Outdoor measurements

- Outdoor measurements influenced by reflections and (some) RFI
- Future measurements to include 3 m high masts and foam floor panels
Radiation pattern of the CLS antenna at 350, 650 and 1000 MHz

Note: Measurements made in chamber
Measured C3LS results

Very recent, still developing antenna & measurement process

Inner spiral

Outer spiral

Radiation pattern of the C3LS antenna at 476 MHz

*Note: Measurements made in chamber*
Continuing work

• Make mechanically robust and accurate antennas for testing
• Build mechanically robust antennas
• Build prototype array for testing and measurement
• Explore other spiral derivatives
  – Pyramidal Sinuous
  – Modulated Arm Width (MAW)
• Explore other high-gain, frequency-independent antennas for SKA system design
• Collaborate in lower-gain element development and testing