Development of a Cooled 1-14 GHz Eleven antenna for VLBI 2010

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Content

• Per-Simon Kildal (15min)
  • Introduction to Design of Eleven Feed for SKA and VLBI2010
  • Selection of Geometry and Port lay-out

• Leif Helldner (15min)
  • Cryogenic and Mechanical Design for the Eleven Feed

• Jian Yang (15min)
  • Numerical Optimization of log-Period Antennas and Measurements

• Per-Simon Kildal (15min)
  • Summary of Performance and What Next
  • Questions
Idea behind Eleven feed new invention

- Two parallel dipoles over ground (Eleven configuration)
  - from book by Christiansen and Högbom Radio Telescopes
  - equal E- and H-plane patterns
  - phase center is locked to the ground plane
  - low far-out sidelobes and backlobes.

- Decade bandwidth by
  - Logperiodic
  - Folded dipoles
Directivity 11 dBi over more than a decade bandwidth

And $11 > \text{decade}$
Size and complexity for $f_{\text{min}} = 500$ MHz

ATA feed:
Problem with phase center variations

Eleven feed:
No problem with phase center variations
Efficiency vs. subtended half angle

Optimum subtended angle $>50$ deg
Figure of Merit

optimum F/D = 0.4 (i.e. 64 deg)
F/D=0.33 also OK (i.e. 75 deg)
History

- Description of Eleven feed (invention from 2003)
- Different low frequency models:
  - 2005: 150-1500 MHz model for Green Bank in US
  - 2007: 150-700 MHz for GMRT in India
  - 2008: 500-3000 MHz for RATAN in Russia
- 2008: 1-13 GHz un-cooled model.
  - Worked for linear polarization only
- From Sept 2008: Developments of a 2-14 GHz cooled model
Team for developing cooled hardware from Sept 2009

- **Department of Signals and Systems:**
  - Prof Per-Simon Kildal, Dr Jian Yang, Yogesh Karandikar

- **Department of Radio and Space Sciences:**
  - Dr Miroslav Pantaleev, Leif Helldner

- **Department of Microtechnology and Nanoscience**
  - Niklas Wadefalk

- **Chalmers IndustriTeknik (CIT) for helping to commercialize:**
  - Anna Aspgren, Henric Rhedin, Stephan Mangold, Johan Felix

- **Enabled by hardware orders from Vertex and Statkart**
The following choices were done during the project

- All materials MUST stand cryogenic environment
- 4 separate panels (petals) with log-periodic dipoles
- PCB technology for antenna petals
- Minimize thickness of dielectric in center
- 2x4 ports with no crossing lines in center puck
- Differential feed line impedance 200 Ohms
- Experimental model has 2x4 coaxial ports, transf to 50 Ohms
- This concept requires 4 differential 200 Ohms LNAs, 2 per polarization
Results
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Summary of measurement results

- **Hardware**: Good. Appears solid and appealing
- **Matching by calibrating out poser dividers**:
  - $S_{11} < -10 \, \text{dB}$ up to 13 GHz
- **Independent gain measurements at Technical University of Denmark**
  - **Losses**: Uncertain due to multiple reflections between 180 deg hybrid, 3dB power divider and antenna. We believe $<-0.5 \, \text{dB}$. Were not calibrated out.
  - **Radiation patterns**: Good between 2.5 and 9 GHz. Outside this band low BOR1 efficiency
  - **Feed efficiency**: $>2 \, \text{dB}$ between 2.5 and 9 GHz
What to do next

• Verify that low BOR1 efficiency above 9 GHz is due to surface waves (1 Month)
• Redesign feed to remove surface waves (3 months)
• Include octagonal “Dewar box” in electrical design to improve low frequency performance (2 months)
• Cryogenic tests of existing hardware (1 month?)
• More things needing additional funding:
  – Realize more hardware
  – Design room temperature LNA
  – Design cryogenic LNA
  – More testing (patterns and noise temperature)
Simulations and Measurements
Reflection coefficient including centre puck
Simulations and Measurements

Measured mismatch efficiency
Measured Sub-efficiencies
Measured Radiation Efficiency

- Not very accurate due to the multiple reflections in the feeding network, specially for high frequencies.
Measured patterns in 45 deg plane, 2-3 and 3-4 GHz
Measured patterns in 45 deg plane, 4-5 and 5-6 GHz
Measured patterns in 45 deg plane, 6-7 and 7-8 GHz
Measured patterns in 45 deg plane, 8-9 and 9-10 GHz
Measured patterns in 45 deg plane, 10-11 and 11-12 GHz
45 deg patterns 12-13 and 13-14 GHz

The diagrams show the amplitude in dB as a function of theta (degrees) for different frequencies ranging from 12GHz to 13.9GHz. The patterns are represented for both 12-13 GHz and 13-14 GHz frequency ranges.
Measured Radiation Patterns of BOR1 Components, 2-3 GHz, 3-4 GHz
Measured Radiation Patterns of BOR1 Components, 4-5 GHz, 5-6 GHz

![Graph showing measured radiation patterns for different frequencies ranging from 4.00 GHz to 5.90 GHz. The graphs display relative level in dBi against angular position θ in degrees.]
Measured Radiation Patterns of BOR1 Components, 6-7 GHz, 7-8 GHz
Measured Radiation Patterns of BOR1 Components, 8-9 GHz, 9-10 GHz
Measured Radiation Patterns of BOR1 Components, 10-11 GHz, 11-12 GHz
Measured Radiation Patterns of BOR1 Components, 12-13 GHz, 13-14 GHz
Measured Sub-efficiencies
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Eleven Antenn – Development Roadmap

The Eleven Antenna will be further developed in cooperation between Chalmers Industriteknik, Chalmers Antenna research department and Onsala Space Observatory.

Antenna design, 2-14 GHz

Cryogenic verification

Fully verified prototype

Product documentation

Production process

Commercially available

2009

2010
STIFTELESEN CHALMERS
INDUSTRITEKNIK

- Foundation within Chalmers University of Technology
- 61 MSEK annual revenue
- 62 employees of which 31 with PhD degrees
Mission

• Research and development for industrial companies on commercial terms

• Find industrial projects for Chalmers University of Technology

• Project managers for projects carried out at Chalmers University of Technology
Contacts

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9-pin Nano-D for DC

SMA output
Descrambler board prepared for dual polarization feed

Ground plane

LNA assembly mounted on antenna ground plane with 4*M2
Two coax lines going to antenna terminals
LNA module without sublid

- MMIC
- DC-board
- 100 ohm balanced input