The Future:
Ultra Wide Band Feeds
and
Focal Plane Arrays

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Overview

◆ Chalmers Feed
◆ Characterization of Chalmers Feed at Arecibo
◆ Focal Plane Arrays for Arecibo
◆ Conclusions
Chalmers’ Feed

- Developed by Rikard Olsson and Per-Simon Kildal for the US-SKA
- Bandwidth 1:10
- Small Size $\sim 0.5$ to $0.7 \lambda_{\text{max}}$
- Phase Center independent of Frequency
Chalmers’ Feed
Input Matching Characteristics

Chalmers’ Feed
Input Matching Characteristics

Evaluation of Chalmers Feed for Arecibo

From 1.5 to 12.0 GHz
Evaluation of Chalmers Feed for Arecibo

◆ Spherical Wave Expansion (SWE) of Chalmers feed data patterns from 150 MHz to 1.2 GHz
◆ Scaled SWE by a factor of 10: yielding 1.5 to 12.0 GHz
◆ Radiation Patterns:
Chalmers Feed Radiation Patterns 0
Frequency Scaled $\times 10$ for Arecibo Analysis

1.5 GHz

2.0 GHz
Chalmers Feed Radiation Patterns 1
Frequency Scaled \times 10 for Arecibo Analysis

1.5 GHz

2.0 GHz

Far-field patterns for Chalmers feed (R. Olsen, Oct. 16, 2004) 0.15 to 1.5 GHz

Far Field Pattern
Antenna Gain = 11.23 dBi
Polarization: Vertical
Freq = 1.500 GHz

Far-field patterns for Chalmers feed (R. Olsen, Oct. 16, 2004) 0.15 to 1.5 GHz

Far Field Pattern
Antenna Gain = 10.37 dBi
Polarization: Vertical
Freq = 2.000 GHz

60°
Chalmers Feed Radiation Patterns 2
Frequency Scaled $\times 10$ for Arecibo Analysis

3.0 GHz

4.0 GHz

Far-field patterns for Chalmers feed (R. Olsen, Oct. 18, 2004) 0.15 to 1.5 GHz

Far-field patterns for Chalmers feed (R. Olsen, Oct. 18, 2004) 0.15 to 1.5 GHz
Chalmers Feed Radiation Patterns 3
Frequency Scaled \times 10 for Arecibo Analysis

5.0 GHz

Far-field patterns for Chalmers feed (R. Olsen, Oct.18.2004) 0.15 to 1.5 GHz
Far Field Pattern
Antenna Gain = 10.48 dBi
Polarization: Vertical
Freq = 5.000 GHz

6.0 GHz

Far-field patterns for Chalmers feed (R. Olsen, Oct.18.2004) 0.15 to 1.5 GHz
Far Field Pattern
Antenna Gain = 10.21 dBi
Polarization: Vertical
Freq = 6.000 GHz

-15dB
Chalmers Feed Radiation Patterns 4
Frequency Scaled ×10 for Arecibo Analysis

7.0 GHz

8.0 GHz

Far-field patterns for Chalmers feed (R. Olsen, Oct. 18, 2004) 0.15 to 1.5 GHz

Far Field Pattern
Antenna Gain = 10.37 dBi
Freq = 7.000 GHz

Far Field Pattern
Antenna Gain = 10.36 dBi
Freq = 8.000 GHz

60° -15dB
Chalmers Feed Radiation Patterns 5
Frequency Scaled ×10 for Arecibo Analysis

9.0 GHz

10.0 GHz

Far-field patterns for Chalmers feed (R. Olsen, Oct.18, 2004) 0.15 to 1.5 GHz
Far Field Pattern
Antenna Gain = 10.06 dBi
Polarization: Vertical
Freq = 9.000 GHz

Far-field patterns for Chalmers feed (R. Olsen, Oct.18, 2004) 0.15 to 1.5 GHz
Far Field Pattern
Antenna Gain = 10.76 dBi
Polarization: Vertical
Freq = 10.000 GHz

-15dB
Chalmers Feed Radiation Patterns 6
Frequency Scaled ×10 for Arecibo Analysis

11.0 GHz

Far-field patterns for Chalmers feed (R. Olsen, Oct.18.2004) 0.15 to 1.5 GHz
Far Field Pattern
Antenna Gain = 10.77 dBi
Polarization: Vertical
Freq = 11.000 GHz

12.0 GHz

Far-field patterns for Chalmers feed (R. Olsen, Oct.18.2004) 0.15 to 1.5 GHz
Far Field Pattern
Antenna Gain = 10.58 dBi
Polarization: Vertical
Freq = 12.000 GHz

60° -15dB
Calculated Arecibo Antenna Performance with Chalmers Feed
Calculated Antenna Performance

- Antenna Sensitivity
- Antenna Noise Temperature
- System Noise Temperature
Calculated Antenna Sensitivity

- Chalmers Feed
- L-Band Wide
- ALFA, Pix-0
- ALFA, Ave
- C-Band Feed
- X-Band Feed

Graph showing the calculated antenna sensitivity in Kelvin/Jy (K/Jy) against frequency in GHz.
Calculated Antenna Noise Temperature

![Graph showing calculated antenna noise temperature with frequency on the x-axis and antenna temperature in Kelvin on the y-axis. The graph includes data for Chalmers Feed, L-Band Wide, ALFA, C-Band Feed, and X-Band Feed.](image-url)
Calculated System Temperature I

- Un-cooled Chalmers
- ALFA
- L-Band Wide
- C-Band Feed
- X-Band Feed

Frequency vs. System Temperature [K]
Calculated System Temperature II

**Graph Details:**
- **Y-axis:** Temperature (Tsys [K])
- **X-axis:** Frequency
- **Legend:**
  - Un-cooled Chalmers
  - Cooled Chalmers (70K)
  - ALFA
  - L-Band Wide
  - C-Band Feed
  - X-Band Feed

**Key Points:**
- The graph compares different system temperatures across various frequencies for different cooled and un-cooled systems.
- COOLED CHALMERS (70K) shows a lower system temperature compared to the others.
- ALFA and L-BAND WIDE have similar temperature trends.
- C-BAND FEED and X-BAND FEED show the highest system temperatures.
Calculated Antenna Performance

- Antenna Sensitivity
- Antenna Noise Temperature
- System Noise Temperature
- **Beam radiation Patterns**
- Cross-Polarization Levels
Arecibo Antenna Beam Pattern with Chalmers Feed
Freq= 3.0 GHz

Co-Polar Beam Pattern
-13.6 dB
-14.4 dB

X-Polar Beam Pattern
-19.0 dB
Arecibo Antenna Beam Pattern with Chalmers Feed
Freq= 6.0 GHz

5.5' x 5.5'

Co-Polar Beam Pattern

-16.6 dB

-17.1 dB

5.5' x 5.5'

X-Polar Beam Pattern

-18.6 dB
Arecibo Antenna Beam Pattern with Chalmers Feed
Freq= 9.0 GHz

Co-Polar Beam Pattern

-16.3 dB
-15.1 dB

X-Polar Beam Pattern

-20.6 dB
Cross-Polarization Level

![Graph showing cross-polarization levels for different feeds at various frequencies. The graph plots frequency [GHz] on the x-axis and cross-pol level [dB] on the y-axis. Different feeds are represented by distinct markers: Chalmers Feed (diamonds), L-Band Wide (triangles), ALFA (circles), C-Band Feed (squares), and X-Band Feed (diamonds). The graph data points indicate varying levels of cross-polarization across different frequencies.](image-url)
Conclusions: Chalmers’ Feed

- Great Bandwidth, and compact size
- Antenna Sensitivity less than current systems
- Antenna Cross-Pol level better than –19 dB, compared with –25 dB
- Large Spillover yields higher Antenna Noise Temperature.
- Moderate High Tsys. By cooling the feed to 70K, Tsys reduces from 43K to 33K
Focal Plane Arrays for Arecibo
Enabling Feed Technologies

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<tr>
<td>Corrugated Feed Horns</td>
<td>1.55:1</td>
<td>2:1</td>
<td>-25.0</td>
<td>GOOD</td>
<td>Single/Array</td>
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<tr>
<td>Quad-Ridge Feed Horn</td>
<td>2:1</td>
<td>3:1</td>
<td>-20.0</td>
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<td>Single/Array</td>
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<tr>
<td>ATA Feed</td>
<td>20:1</td>
<td>-----</td>
<td>-15.0</td>
<td>FAIR</td>
<td>Single/Array?</td>
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<tr>
<td>Chalmers Feed</td>
<td>10:1</td>
<td>-----</td>
<td>-6.0</td>
<td>POOR</td>
<td>Single/Array?</td>
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<tr>
<td>Vivaldi Feed</td>
<td>3:1</td>
<td>5:1</td>
<td>-15.0</td>
<td>FAIR</td>
<td>Phase Array</td>
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Possible Focal Plane Arrays Configurations for Arecibo

- TE11 mode Focal Plane Arrays
- Chalmers/Ingerson Feed based Focal Plane Arrays
- Vivaldi Focal Phased Arrays
- Others: Quad-Ridge …
Arecibo Gregorian Optics
Scanning Losses and Field of View

Displacement along X/Y Axis [cm]

Scanning Loss [dB]

Yscn, 1.375 GHz
Yscn, 3.000 GHz
Yscn, 5.000 GHz
Yscn, 7.000 GHz
Yscn, 9.000 GHz

ALFA
Chalmers/Ingerson Feed based Focal Plane Arrays

- Element Separation 0.5 to 0.7λ_{max}
- Max. Scanning loss across the band: 1.0 dB

Dimensions in mm

CHALMERS FP ARRAY
2 To 7 GHz
9 elements

CHALMERS FP ARRAY
4 To 8 GHz
21 to 37 elements
Arecibo Gregorian Optics
Scanning Losses and Field of View

Displacement along X/Y Axis [cm]
Scanning Loss [dB]

-30 -25 -20 -15 -10 -5 0 5 10 15 20 25 30

Yscn, 1.375 GHz
Yscn, 3.000 GHz
Yscn, 5.000 GHz
Yscn, 7.000 GHz
Yscn, 9.000 GHz

ALFA
TE₁₁ Mode Horns based Focal Plane Arrays

- Element Separation 1.19\(\lambda\)
- Max. Scanning loss across the band: 1.0 dB

Dimensions in mm

TE₁₁ Feed ARRAY
8 to 10 GHz
19 to 37 elements

TE₁₁ Feed ARRAY
6 to 8 GHz
7 to 19 elements
Vivaldi Feed Based Focal Phased Arrays

◆ Element Separation $0.5\lambda_{\text{min}}$

VIVALDI FP ARRAY
4 To 10 GHz
129 to 149 elements

Dimensions in mm
Focal Plane Arrays Possibilities…

- **VIVALDI FP ARRAY**
  - 4 to 10 GHz
  - 129 to 149 elements

- **TE11 Feed ARRAY**
  - 8 to 10 GHz
  - 19 to 37 elements

- **TE11 Feed ARRAY**
  - 6 to 8 GHz
  - 7 to 19 elements

- **CHALMERS FP ARRAY**
  - 2 to 7 GHz
  - 9 elements

- **CHALMERS FP ARRAY**
  - 4 to 8 GHz
  - 21 to 37 elements

- **ALFA TE11 Feed ARRAY**
  - 1.225 to 1.525 GHz
  - 7 elements
Conclusions Cont…

- Bandwidth of Focal Plane Array at Arecibo is determined by the scanning losses in the FOV.
- Un-cooled Chalmers Feeds are better suited for single pixel applications than for Focal Plane Array applications due to poor input matching and cooling requirements to reduce Tsys.
- Vivaldi type Phased Arrays could be located in away from the Gregorian Focal Plane…
- A 19 element X-Band TE11 mode focal plane array is feasible…
End