A tri-band cryogenic receiver for the RAEGE project antennas

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Tri-band receiver pros & cons

Main pros:
• S, X and Ka band simultaneously => Backward compatibility
• Feed horn cooled down to 20 K
• Simultaneous dual circular polarization
• Traditional cryo LNA designs (unbalanced LNA’s)
• Easy NoiseCal and PhaseCal signal injection in front of the LNA’s
• Less sensitive to RFI than broad-band receivers
• Ka-band receiver very useful during antenna commissioning
• Simultaneous X/Ka-band reception
• Compatibility with new TTW antennas

Main cons:
• 180º and 90º hybrid circuits are necessary => cooled low-loss design to reduce impact on overall Trx
• Not fully continuous coverage of 1-14GHz band
Tri-band feed design

• Tri-band feed horn for future VLBI2010 radiotelescopes

• Three simultaneous frequency bands:

  S (2.2-2.7 GHz)    X (7-9.5 GHz)    Ka (28-33 GHz)

• Coaxial feed for S and X bands and a conventional conical feed (Ka band), all working in the TE$_{11}$ mode.

• 4-port excitation needed to generate the TE$_{11}$ mode (broadside radiation) in the coaxial waveguides. The desired phase shifts for RHCP/LHCP operation are performed by 180° and 90° cryogenic hybrid couplers.
Cryostat content
S-band LNA’s

Hybrid design

Measured performance:
- Freq: 2 .. 4.8 GHz
- $T_n < 4$ Kelvin
- $G > 24.5$ dB
- $IRL = -13.4$ dB
- $ORL = -17.4$ dB
S-band hybrids

<table>
<thead>
<tr>
<th>Serial Number</th>
<th>YH90S 1003</th>
</tr>
</thead>
<tbody>
<tr>
<td>Description</td>
<td>3dB 90° cryogenic hybrid</td>
</tr>
<tr>
<td>Frequency Band</td>
<td>1.1 – 4.5 GHz</td>
</tr>
<tr>
<td>Nominal Coupling</td>
<td>3 dB</td>
</tr>
<tr>
<td>Connector</td>
<td>SMA female, sliding pin</td>
</tr>
<tr>
<td>Weight (typ.)</td>
<td>56 g (1.97 oz)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Temperature</th>
<th>297 K</th>
<th>20 K</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. E. Insertion Loss dB (max.)(^1)</td>
<td>0.53 dB</td>
<td>0.26 dB</td>
</tr>
<tr>
<td>Return Loss (max. any port)</td>
<td>-21.2 dB</td>
<td>-19.2 dB</td>
</tr>
<tr>
<td>Amplitude Unbalance (max.)</td>
<td>± 0.3 dB</td>
<td>± 0.35 dB</td>
</tr>
<tr>
<td>Phase Unbalance (max.)</td>
<td>± 3.7°</td>
<td>± 4°</td>
</tr>
</tbody>
</table>

\(^1\): Average Equivalent Insertion Loss (dB), \(L_{eq}=10 \log_{10} (|s_{11}|^2+|s_{21}|^2+|s_{13}|^2+|s_{14}|^2)\)
S-band downconverter module

- BPF 1: 2.2 – 2.7 GHz
- AMP 1
- ISO 1
- MIX 1
- ATT 1: 3 dB
- BPF 3
- ISO 3
- MIX 2
- ATT 2: 3 dB
- BPF 4
- ISO 4
- MIX 2
- ATT 4
- AMP 4
- COUP 2
- COUP 1

- SR IF out
- SR IF monitor
- SL IF out
- SL IF monitor

- PLO 1.7 GHz +15 dBm

- BPF 3
- IF
- PLO
- BPF 1
- RF

- GHz

- L = 0.5 dB

- SR

- SL
X-band LNA’s

Hybrid InP design

Measured performance:

- Freq: 4 .. 12 GHz
- Tn = 5.3 Kelvin
- G = 34 dB
- IRL = -3 dB
- ORL = -12.5 dB

Notes:

- Same LNA as those provided for ALMA Band 9
- IRL to be improved with cryogenic isolator
X-band hybrids

<table>
<thead>
<tr>
<th>Description</th>
<th>YH90X 1005</th>
</tr>
</thead>
<tbody>
<tr>
<td>Serial Number</td>
<td></td>
</tr>
<tr>
<td>Nominal Coupling</td>
<td>3 dB</td>
</tr>
<tr>
<td>Frequency Band</td>
<td>4 - 13 GHz</td>
</tr>
<tr>
<td>Connector</td>
<td>SMA female, sliding pin</td>
</tr>
<tr>
<td>Weight (typ.)</td>
<td>36 g (1.27 oz)</td>
</tr>
<tr>
<td>Temperature 297 K</td>
<td>20 K</td>
</tr>
<tr>
<td>A. E. Insertion Loss dB (max.)</td>
<td>0.6 dB</td>
</tr>
<tr>
<td>Return Loss (max. any port)</td>
<td>-20 dB</td>
</tr>
<tr>
<td>Amplitude Unbalance (max.)</td>
<td>± 0.25 dB</td>
</tr>
<tr>
<td>Phase Unbalance (max.)</td>
<td>± 1°</td>
</tr>
</tbody>
</table>

*1: Average Equivalent Insertion Loss (dB), $L_{eq}=10 \log_{10} (|s_{11}|^2 + |s_{12}|^2 + |s_{13}|^2 + |s_{14}|^2)$
X-band downconverter module
Ka-band LNA’s

MMIC design

Expected parameters:

- Freq: 25 .. 35 GHz
- $T_n = 15 .. 16$ Kelvin
- $G > 24$ dB +/- 1dB
- $RL < -10$dB
Ka-band downconverter module
NoiseCal module

Noise Source
ENR=26-32dB
NS1
On/Off/80Hz
Noise Ctrl
Box
PIC16F84A
80Hz
I2C
Phase Cal
Input
Ka Test
Tone input

ATT1
3dB
DIV1
DIV2
4-way
L=10dB
SRn
SLn
XRn
XLn

ATT2
1
3dB
DIV3
DIV4
KaRn
KaLn

Noise Source
ENR=23dB
NS2
Trans

ATT2
3dB

Estimated receiver performance

<table>
<thead>
<tr>
<th>Band</th>
<th>Range (GHz)</th>
<th>Trx (Kelvin)</th>
<th>Rx gain (dB)</th>
<th>Inst. BW (MHz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>S</td>
<td>2.2 – 2.7</td>
<td>13</td>
<td>58 .. 89</td>
<td>500</td>
</tr>
<tr>
<td>X</td>
<td>7 – 9.5</td>
<td>18</td>
<td>53 .. 84</td>
<td>500</td>
</tr>
<tr>
<td>Ka</td>
<td>28 - 33</td>
<td>25</td>
<td>57 .. 88</td>
<td>500</td>
</tr>
</tbody>
</table>
Future work

• Tri-band feed tests
• Integration of X and Ka-band downconverters
• Integration of NoiseCal module
• Dewar design, construction and assembly
• Cryostat integration and tests
• Monitor/Control software
• Receiver lab tests

Deadline: September ’2012
Thank you for your attention

Picture by F. Moreno.