SMA Next Generation Receiver

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SMA Next Generation Receiver System: Overview

- Low Maintenance Pulse-tube Cryocooler
- Dual Band Receiver System
  1. Low Band (LO 210 – 270 GHz)
  2. High Band (LO 280 – 360 GHz)
- Even Wider IF Bandwidth: initial target of 4 – 18 GHz (stretch to 20?)
- Dual Polarization Operation with Waveguide Orthomode Transducer attached directly to SIS Mixer for improved sensitivity and enhanced polarimetry.
- Simultaneous dual-band observation mode through the use of either a wire grid polarizer, dichroic plate or time domain band switching.
- YIG or VCO-based Local Oscillator to simplify tuning. Module based on commercially available components to reduce cost.
- Cold Waveguide LO injection to improve performance.
- Double-side-band mixer for lower cost and continuation of technology
- Better logistics for polarimetry using a single Wideband Quarter Wave Plate (210 – 360 GHz)
- Possibility of guest/PI instrumentation
- New receiver has two dual pol receiver cartridges
- Receivers selected by four position rotating selector wheel
- Straight through, mirror, grid, dichroic options

### Cryogenic Receiver Selector

<table>
<thead>
<tr>
<th>Selection</th>
<th>Lo Band Rx</th>
<th>Hi Band Rx</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thru</td>
<td>Cold Load</td>
<td>Dual Pol</td>
</tr>
<tr>
<td>Grid</td>
<td>Pol. #1</td>
<td>Pol. #2</td>
</tr>
<tr>
<td>Dichroic</td>
<td>Dual Pol</td>
<td>Dual Pol</td>
</tr>
<tr>
<td>Mirror</td>
<td>Dual Pol</td>
<td>Cold Load</td>
</tr>
</tbody>
</table>

- Smaller cryostat allows space for possible “Guest Receiver”
- Selector mirrors between M6 and cryostat. Could allow dichroic or grid for operation alongside main receiver

### Guest (PI) Receiver Selector

<table>
<thead>
<tr>
<th>Selection</th>
<th>SMA Main Rx</th>
<th>Guest (PI) Rx</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thru</td>
<td>Inactive</td>
<td>Dual Pol</td>
</tr>
<tr>
<td>Grid</td>
<td>Single Pol</td>
<td>Single Pol</td>
</tr>
<tr>
<td>Mirror</td>
<td>Dual Pol</td>
<td>Inactive</td>
</tr>
</tbody>
</table>
Observation Modes

- Dual Pol Low Band (LO 210 – 270 GHz), IFBW 2 x 14 GHz DSB
- Dual Pol High Band (LO 280 – 360 GHz), IFBW 2 x 14 GHz DSB
- Dual Band observation can be accommodated by the use of either a wire grid (polarization combiner), a dichroic plate (frequency diplexing) or time domain band switching

- Wire Grid: one polarization (mixer) from each band is active. System sensitivity per band is 70% that of the dual pol mode.
- Dichroic Plate: all 4 mixers will be operational, opening up the possibility of dual band polarimetry with the help of a wideband Quarter Wave Plate. Some sacrifice of sensitivity per band is expected + issue of IF processing.
- Time Domain Switching: Switching between low and high band receivers over minutes time scale. For example 70% 345 GHz + 30% 230 GHz, to achieve similar sensitivity in good weather.
• Diameter of cryostat: about half of current one. Height is similar
• Two temperature stages – 50K for Radiation Shield and 4K
• Plan to use similar size turbo pump backed by a larger scroll pump – faster pump down.
• No Optics Cage – Cryostat Top Plate is higher.
• Single cryostat window and IR filter
• Two receiver inserts, each housing a dual pol receiver, to be inserted from bottom with a insert carrier, similar to ALMA
• Selector wheel mounted on radiation shield top plate
• Use automatic thermal links similar to ALMA
• No manual connections between cartridges and cryostat required
• Cryostat sits to one side of cabin
• M6 is moved 400 mm to raise height of cryostat
• Electronics for cryostat installed in rack under cryostat
Cryomech PT-405 RM Pulse Tube CryoCooler

- Remote Motor connected to Cold Head with a 0.5 m flex He line
- Water cooled CP2850 Compressor
- Power Consumption 4.9 kW @ 60 Hz
- Cold head to be operated only in upright position
- Required maintenance – compressor @ 20k hours, no cryostat dismantling req.
- Compressor CP2850: 19” x 18” x 24.5” 243 lbs. cooled by 2.3 gal/min @ 80 F
- Possibility of temperature stabilization with helium pot
Dual-polarization Receiver Module

- Feed horn scaled from existing designs
- Planar OMT module
- Cold LO waveguide injection in cross-guide coupler
- Mixer block design adapted from existing SMA design
- Each SIS mixer is permanently shunted by a 50-Ω inside mixer block.
- Four wire bias system using a modified version of existing bias circuitry.
- Mixer Bias and Magnetic Field Control goes through a Micro-D connector.
- Will try to use permanent magnet for Low Band Receiver.
Design of Mixer Block in Progress
Cryostat Development

- Plan to have outside company design and build cryostats
- Bid document under development
- Need a total of 10+ cryostats: 8 antennas and 2+ spare/lab test cryostats
- Contract will be structured as multiphase Design and Build contract
  - Initial deliverables
    - Documented ready-to-build design (licensed for reuse)
    - 2 prototype cryostats (Option for 3rd for ASIAA)
    - 4-6 blank receiver cartridges
    - End of 2017
  - Additional Build option
    - 5 (option for 7) production cryostats (with modifications identified in testing prototypes)
    - 14-16 blank receiver cartridges
    - Modifications to prototype cryostats to bring up to final spec
    - Delivery to fit receiver build and deployment schedule
Local Oscillator Module

- Mounted on the bottom below each insert
- Based on Power Amplifier similar to the new 240 GHz LO module
- Baseline: YIG Oscillator. VCO-based unit under development
- One module for each insert but each of the 2 mixers (polarization) to have independent LO power control
- Baseline design: motorized waveguide attenuator. Light-control waveguide attenuator under development (patent pending)
- Current PLL electronic module will stay, with Raspberry PI controller

IF Processor (Currently Bandwidth Doubler Assembly)

- One processor for each mixer (Total of 4).
- Will use parts rated for 20+ GHz.
- To include digital attenuator, power monitoring and equalizer.
- Remote gain setting envisioned (with Raspberry PI control?).
- Estimated input power from cryostat -40 to -45 dBm. Output power -10 dBm (?)
- Interfacing to Fiber driver, Continuum detector etc. needs further system planning.
**Receiver Electronic Rack**

- To replace existing cheeks mounted around cryostat
- Contains:
  - Analog Modules
  - SIS Bias Boards
    - Modify existing design to bias four mixers simultaneously
  - Magnetic Field Controllers
  - HEMT amplifier Bias Modules
  - IF processor
  - Receiver selection wheel driver
- Place rack under or beside cryostat
- Digital Modules: Raspberry PIs + DAC and ADC interface
- Each Raspberry PI to have its own IP and connected to ACC via ethernet
IF Processor

IF processor - Shown as 2 assemblies

IF1 A
Amp +25 dB → Slope Equalizer → Transfer Switch → VVA → Amp +25 dB → 4-way → IF1 A/B to IF Enclosure, IF1 A/B to Spectrometer, IF1 A/B to Level Detector → IF1 A/B to Cont Det 1

IF1 B
Amp +25 dB → Slope Equalizer → VVA → Amp +25 dB → 4-way → IF1 A/B to IF Enclosure, IF1 A/B to Spectrometer, IF1 A/B to Level Detector → IF1 A/B to Cont Det 1

IF2 A
Amp +25 dB → Slope Equalizer → Transfer Switch → VVA → Amp +25 dB → 4-way → IF2 A/B to IF Enclosure, IF2 A/B to Spectrometer, IF2 A/B to Level Detector → IF2 A/B to Cont Det 2

IF2 B
Amp +25 dB → Slope Equalizer → VVA → Amp +25 dB → 4-way → IF2 A/B to IF Enclosure, IF2 A/B to Spectrometer, IF2 A/B to Level Detector → IF2 A/B to Cont Det 2
Upgrade to Fiber Optic System
(from John Test)

• Move IF signals from 1310 nm to 1550nm to allow multiplexing multiple IF signals on single fiber with commercial equipment
• Plan to transmit all of the signals using DWDM channels around 1550nm
  • 8 DWDM channels for the 4 IFs + 2 DDS/200 + 2 MRG signals.
• Hardware needed:
  • 34 transmitters: 4x8 = 32 for IF + 2 for MRG.
  • 48 receivers: 4x8 = 32 for IF + 2x8 = 16 used to for MRG.
• Propose to use the existing 12 GHz 1310 nm Ortel/Emcore receivers located in the 1DCVs as MRG receivers. Therefore, we need 32 Optilab receivers: 30 GHz BW @1550 nm.
• 16 FiberSpan transmitters with DWDM channel spacing.
• Existing DDS receivers in the IF assemblies won’t need to be changed.
• 16 DWDM modules. 8 for the antennas and 8 to demultiplex analog room. For example: 200 GHz 8-channel multiplexers 1546 – 1557 nm @ $490 each. 3 dB insertion loss max.
Software Control (Tune7?)

• New controllers/hardware will be interfaced through RaspberryPI with IP access
• Some existing controller will stay, for example Optics Control board to control Cal Load/Waveplate Assembly
• Will rely more on Python code rather than C
• A search of the database shows that a set of 24 tune6 commands appear to form the bulk of receiver tuning
• As we are building up the system, and adding functionality, we will use the TUNE utility to direct commands to the relevant processor
• Separate future program to replace antenna computers is required – keep this in mind as development for new receivers goes ahead
OPEN ITEMS

• Correlator expansion to new 12 – 18 GHz IF Band – Jonathon’s job!
• Dual Band Operation with both receiver pairs and dichroic?
• New IF down-convertors for 12 – 18 GHz (depends on correlator)
• Continuum Detector
• Guest Receivers
• Water Vapor Radiometer for Phase Correction?