wSMA Upgrade Plans

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Governing Board Meeting, Dec 2016

wSMA Upgrade Program

- Program has three major components
    1. IF/LO transport system upgrades to accommodate 4 wide bandwidth IFs for dual pol, dual receiver operation
    2. New receiver system, with new cryostat and receiver inserts
    3. Add additional correlator capacity on top of full SWARM to handle more IF from new receivers

- Each builds on previous, but can be developed and deployed somewhat independently

- First two components deliver advantages before next is completed – e.g.
    1. New IF/LO transport will move all signals to one of the three fibers to each pad, offering greater redundancy, and using new COTS components
    2. New receiver system replaces existing end-of-life cryogenics, will have lower system temperature, better polarization properties and better co-alignment of beams on sky

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

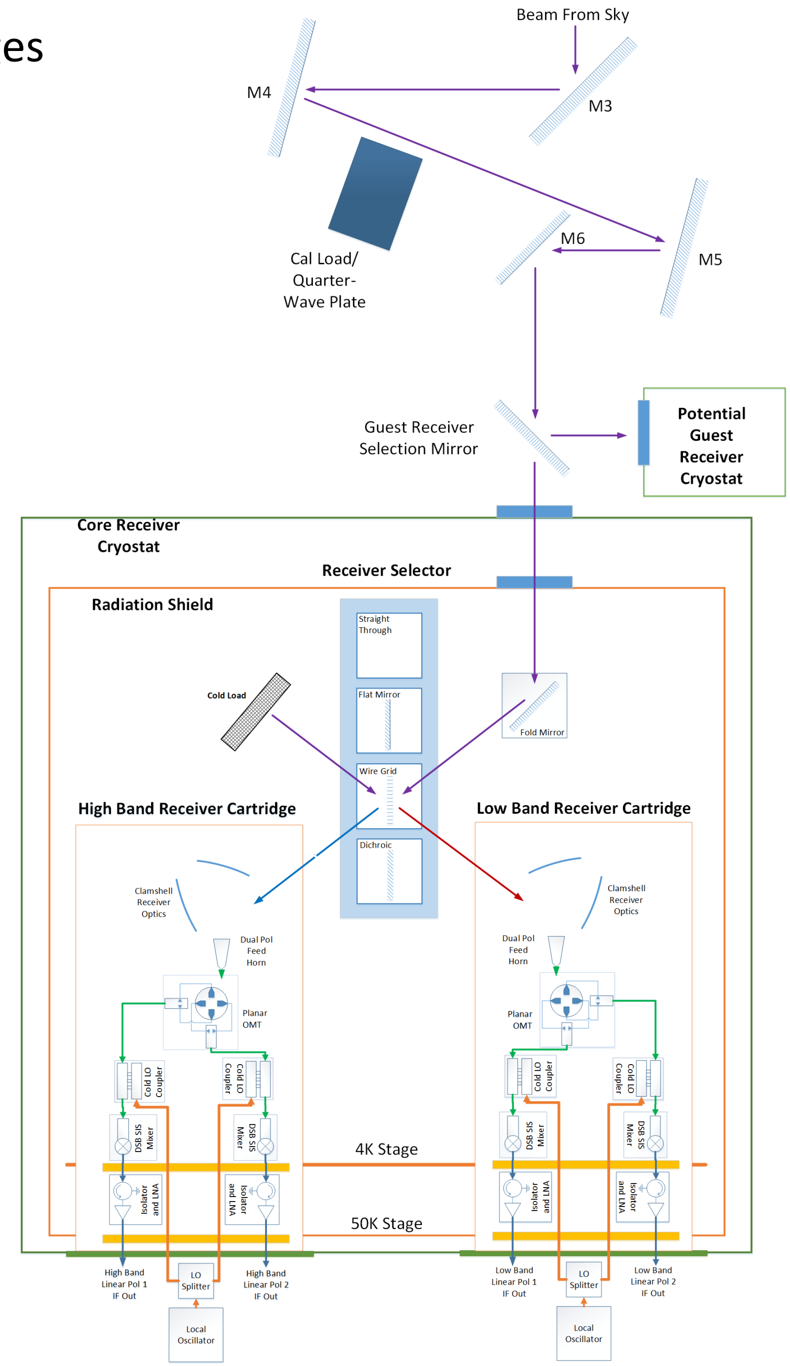
Cryogenic Receiver Selector

Selection	Lo Band Rx	Hi Band Rx
Thru	Cold Load	Dual Pol
Grid	Pol. #1	Pol. #2
Dichroic	Dual Pol	Dual Pol
Mirror	Dual Pol	Cold Load

- 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

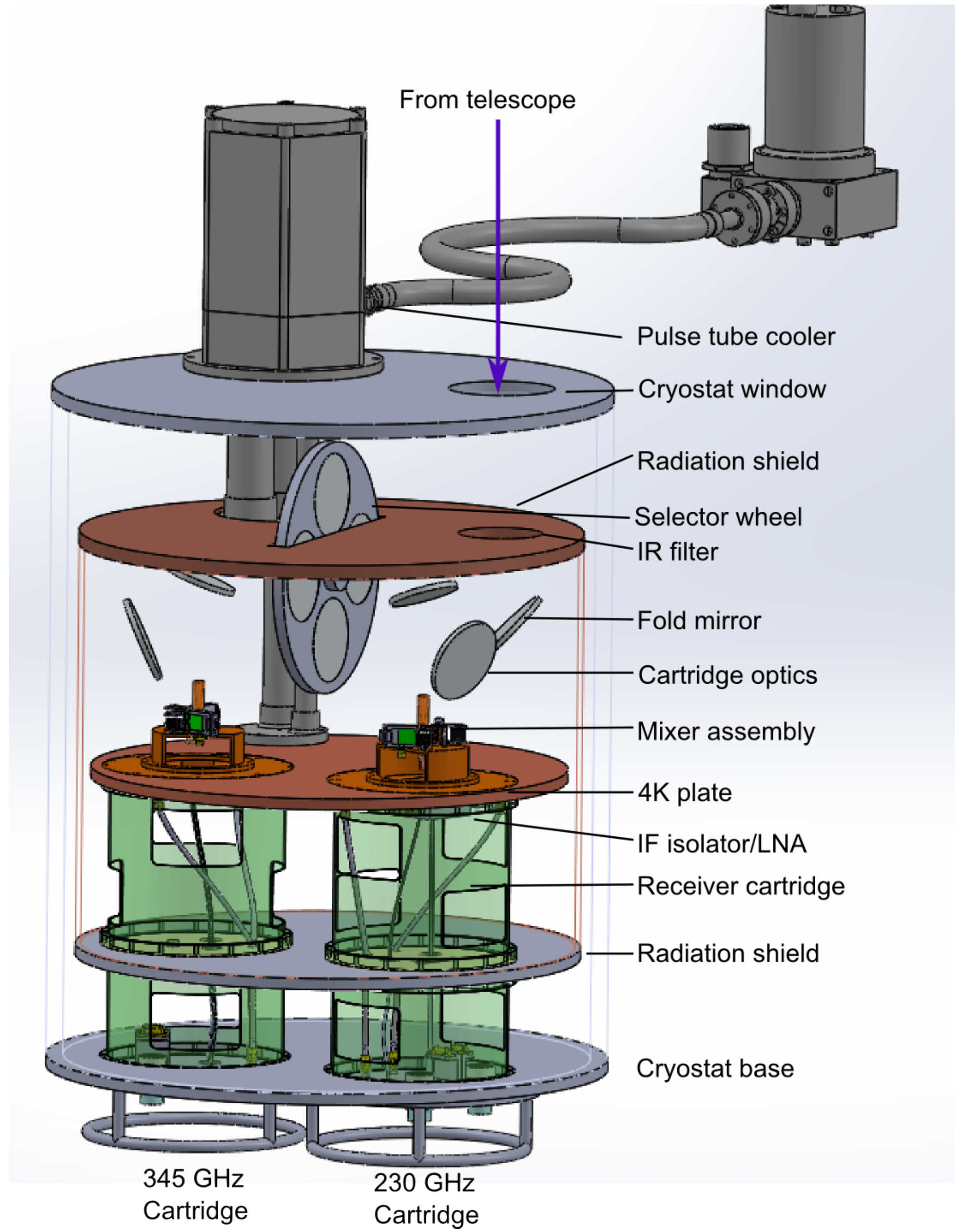
Selection	SMA Main Rx	Guest (PI) Rx
Thru	Inactive	Dual Pol
Grid	Single Pol	Single Pol
Mirror	Dual Pol	Inactive



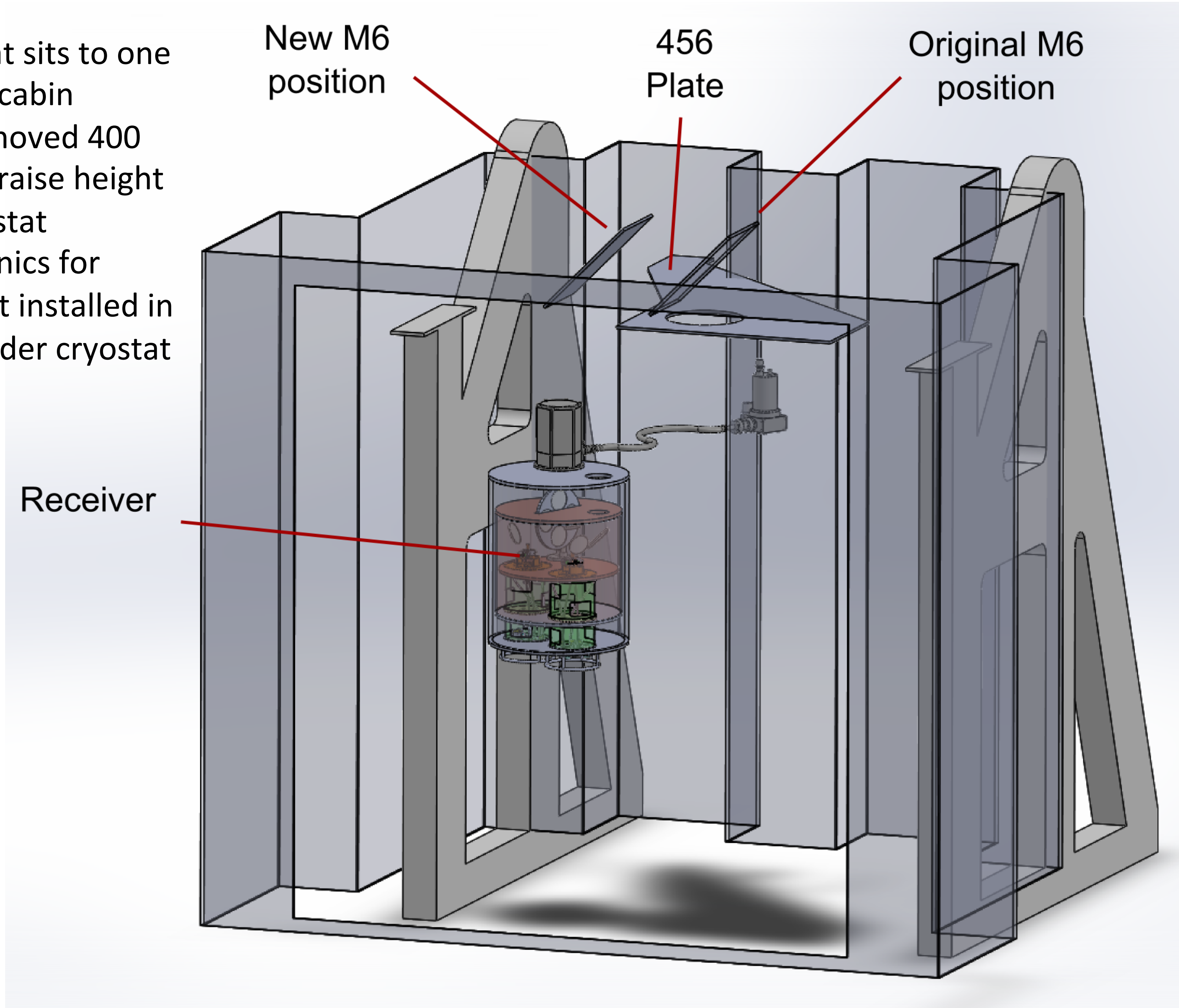
Observation Modes

- 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.

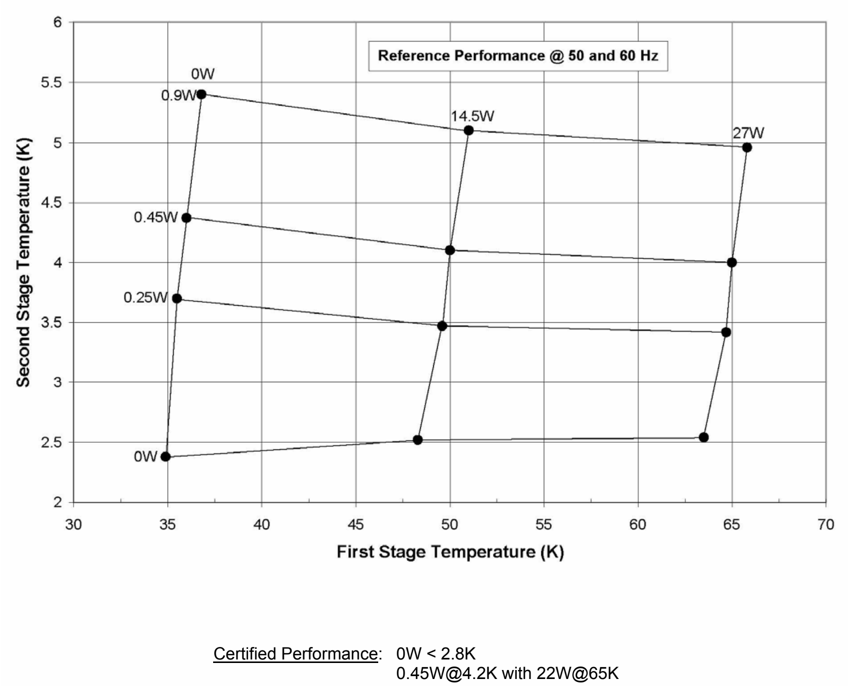
- Diameter of cryostat: about half of current one. Height is similar
- Two temperature stages – 50K for Radiation Shield and 4K
- Plan to use similar size turbo pump backed by a larger scroll pump – faster pump down.
- No Optics Cage – Cryostat Top Plate is higher.
- Single cryostat window and IR filter
- 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

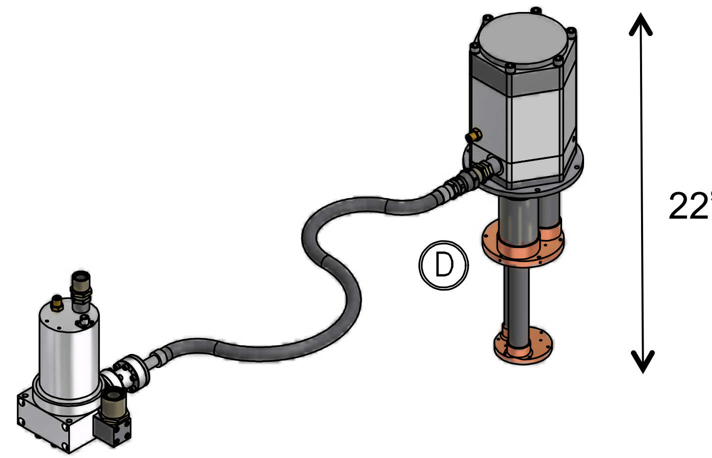


- Cryostat sits to one side of cabin
- M6 is moved 400 mm to raise height of cryostat
- Electronics for cryostat installed in rack under cryostat

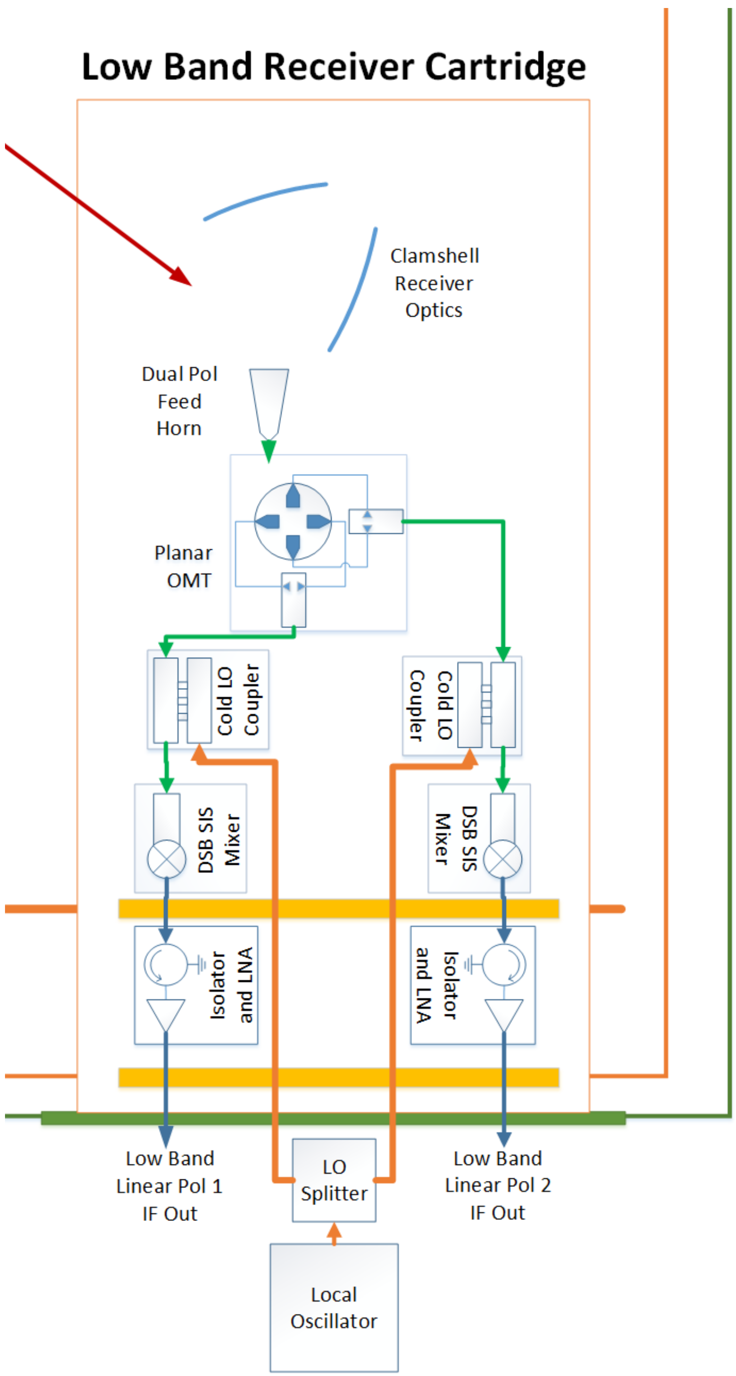


Cryomech PT-405 RM Pulse Tube CryoCooler





- 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



Low Band Receiver Cartridge
Clamshell Receiver Optics
Dual Pol Feed Horn
Planar OMT
Cold LO Coupler
Cold LO Coupler
DSB SIS Mixer
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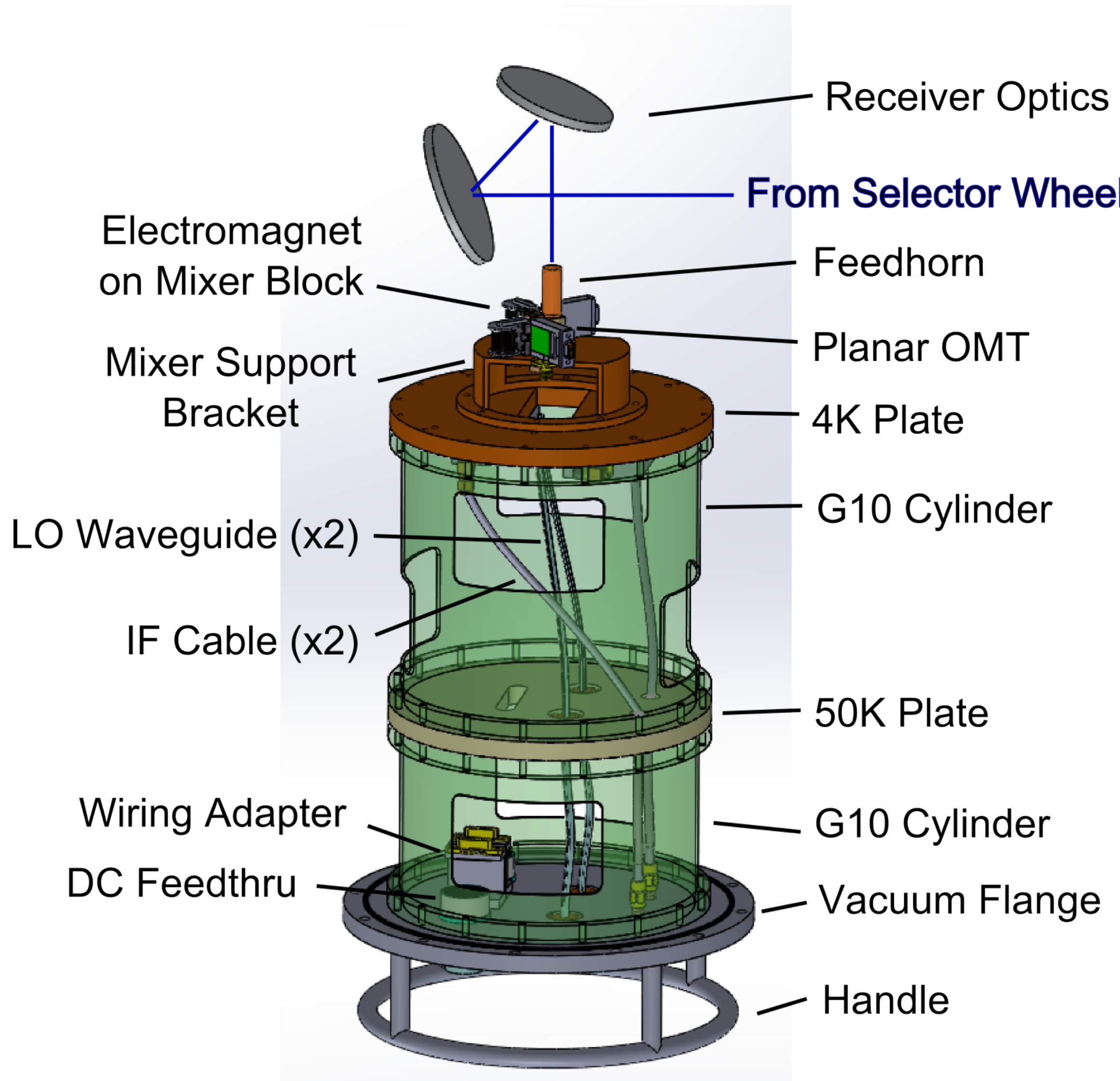
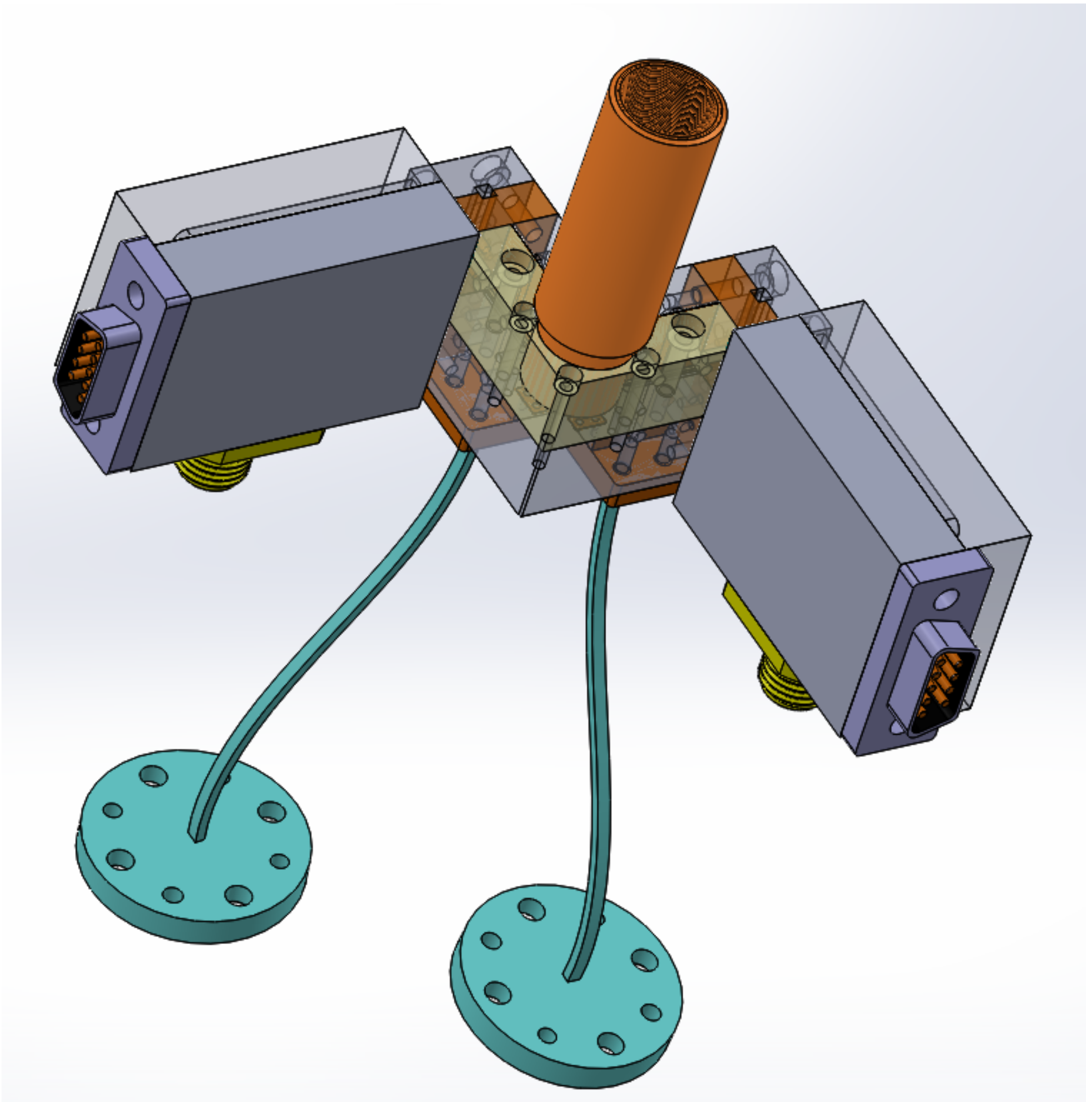
Isolator and LNA
Isolator and LNA
Low Band Linear Pol 1 IF Out
LO Splitter
Low Band Linear Pol 2 IF Out
Local Oscillator

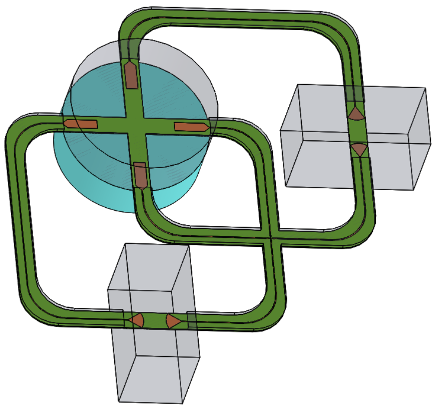


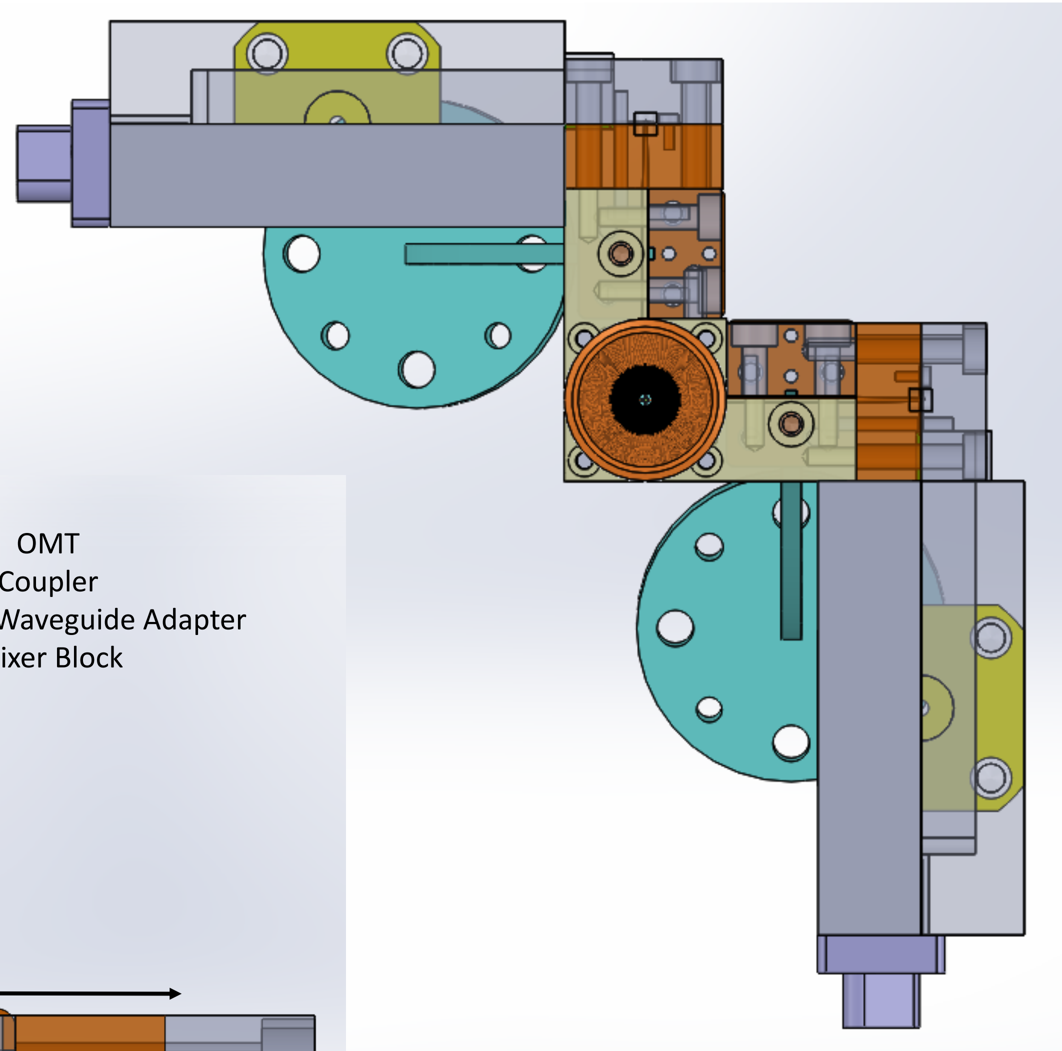
Receiver Optics
From Selector Wheel
Electromagnet on Mixer Block
Feedhorn
Mixer Support Bracket
Planar OMT
4K Plate
G10 Cylinder
LO Waveguide (x2)
IF Cable (x2)
50K Plate
Wiring Adapter
G10 Cylinder
DC Feedthru
Vacuum Flange
Handle

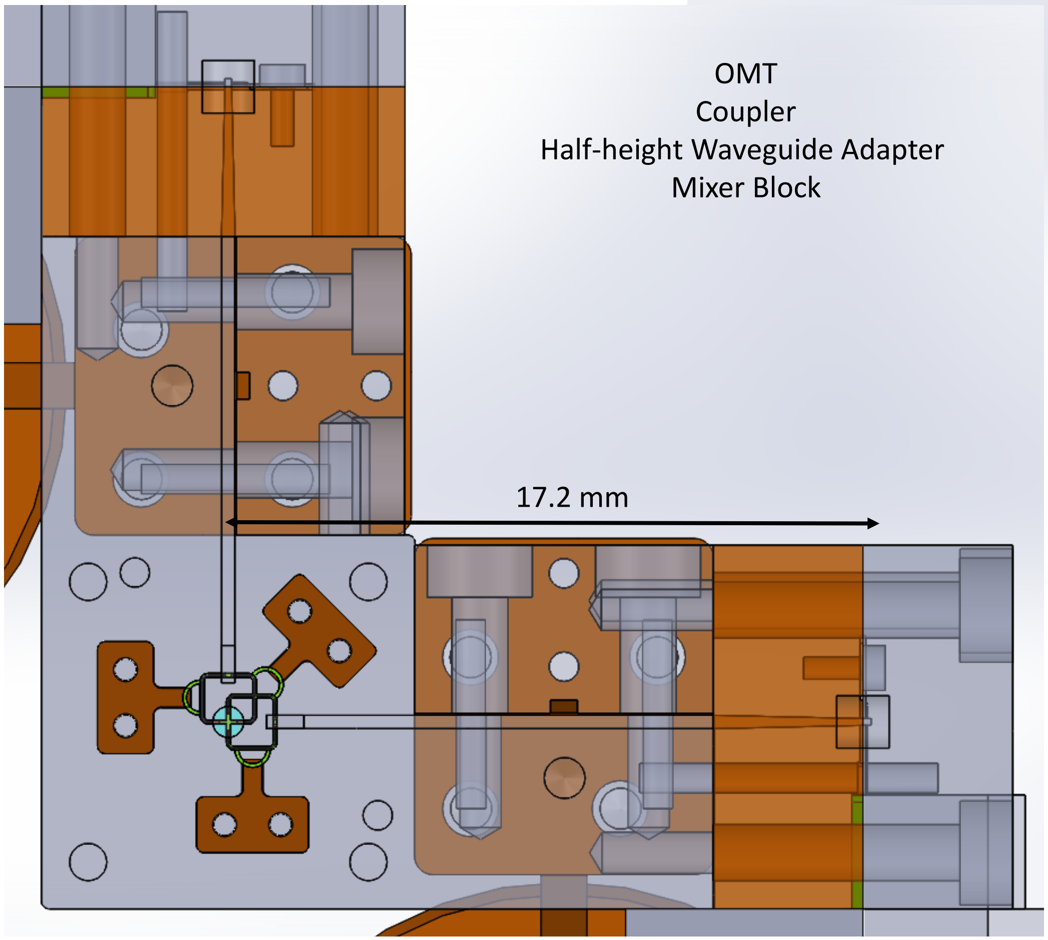
Dual-polarization Receiver Module



- 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
- Possible parallel design effort in ASIAA
- Need a total of 10 cryostats: 8 antennas and 2 spare/lab test cryostats for Cambridge and Taipei
- Contract will likely 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 options
        - 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

Antenna Modifications for New Receivers

(in addition to IF/LO fiber upgrades)

- Remove old cryostat
- Move M6 40cm towards side of cabin to place new receiver on left side of cabin
    - Move cabin spectrometer to make room
- Install new cryostat support and cryostat alignment structure
- Rearrange electronics rack
- Install new compressor (smaller than current Daikin system)
- Cooling system modifications
- Install new vacuum pump system
- Install new receiver

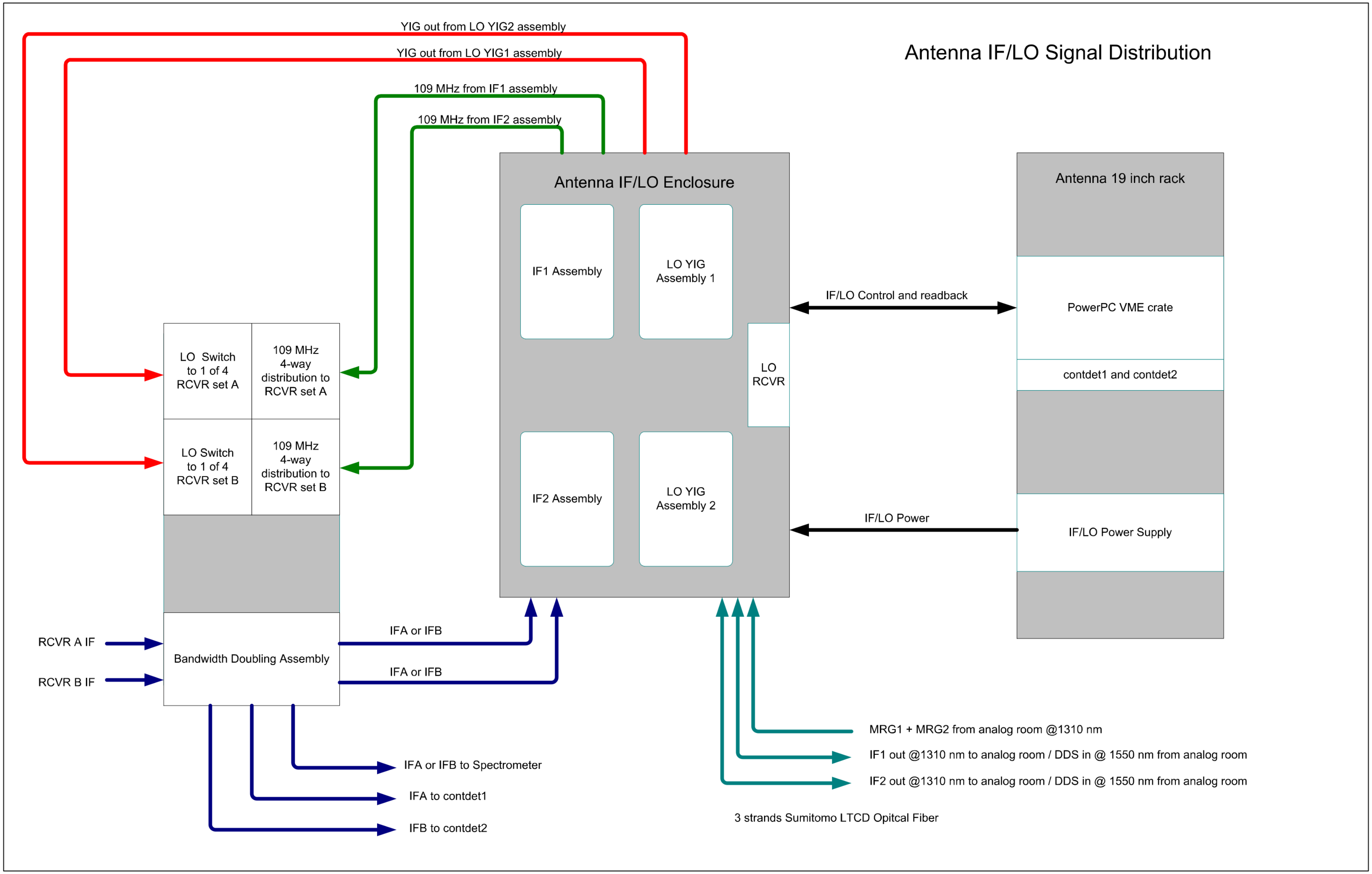
- Will be done in hangar
- Will proceed one antenna at a time and combine with other maintenance

Upgrade to Fiber Optic System and IF/LO processing

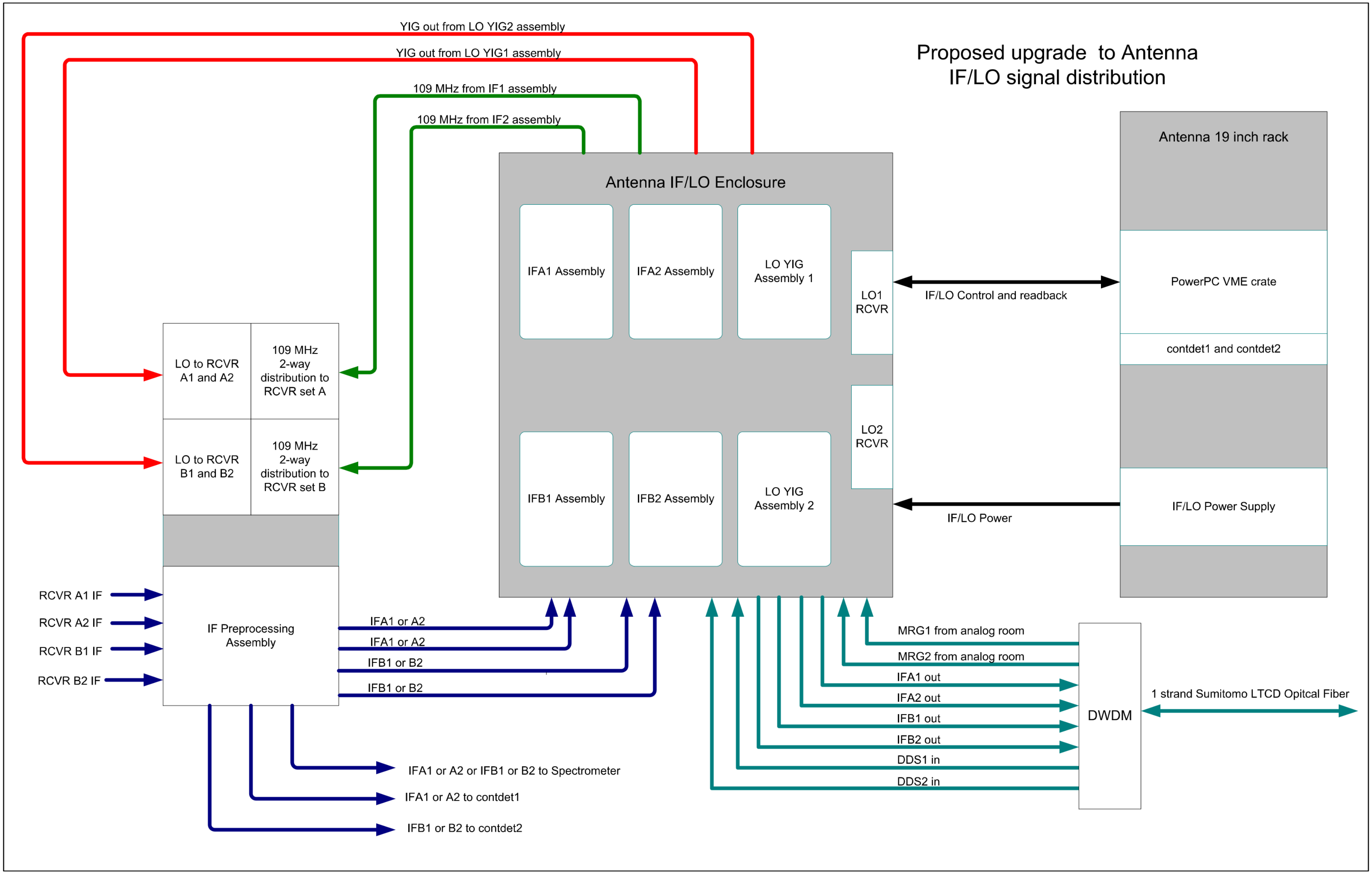
*(from **John Test**)*

- 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.

IF/LO Distribution



IF/LO Distribution



Software Control (Tune7?)

- New controllers/hardware will be interfaced through RaspberryPI on Ethernet
- 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
- Study group set up in Cambridge to work on this, led by Taco and Bob Wilson

OPEN ITEMS

- Correlator expansion to new 12 – 18 GHz IF Band – baseline is more SWARM, but other options may come to light with ALMA future correlator study going on in Cambridge
- Dual Band Operation with both receiver pairs and dichroic – how soon is this achievable with correlator and IF transport?
- New IF down-convertors for 12 – 18 GHz (depends on correlator choice)
- Continuum Detector and Cabin Spectrometer upgrades
- Guest Receivers and Receiver Selector

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    1. IF/LO transport system upgrades to accommodate 4 wide bandwidth IFs for dual pol, dual receiver operation
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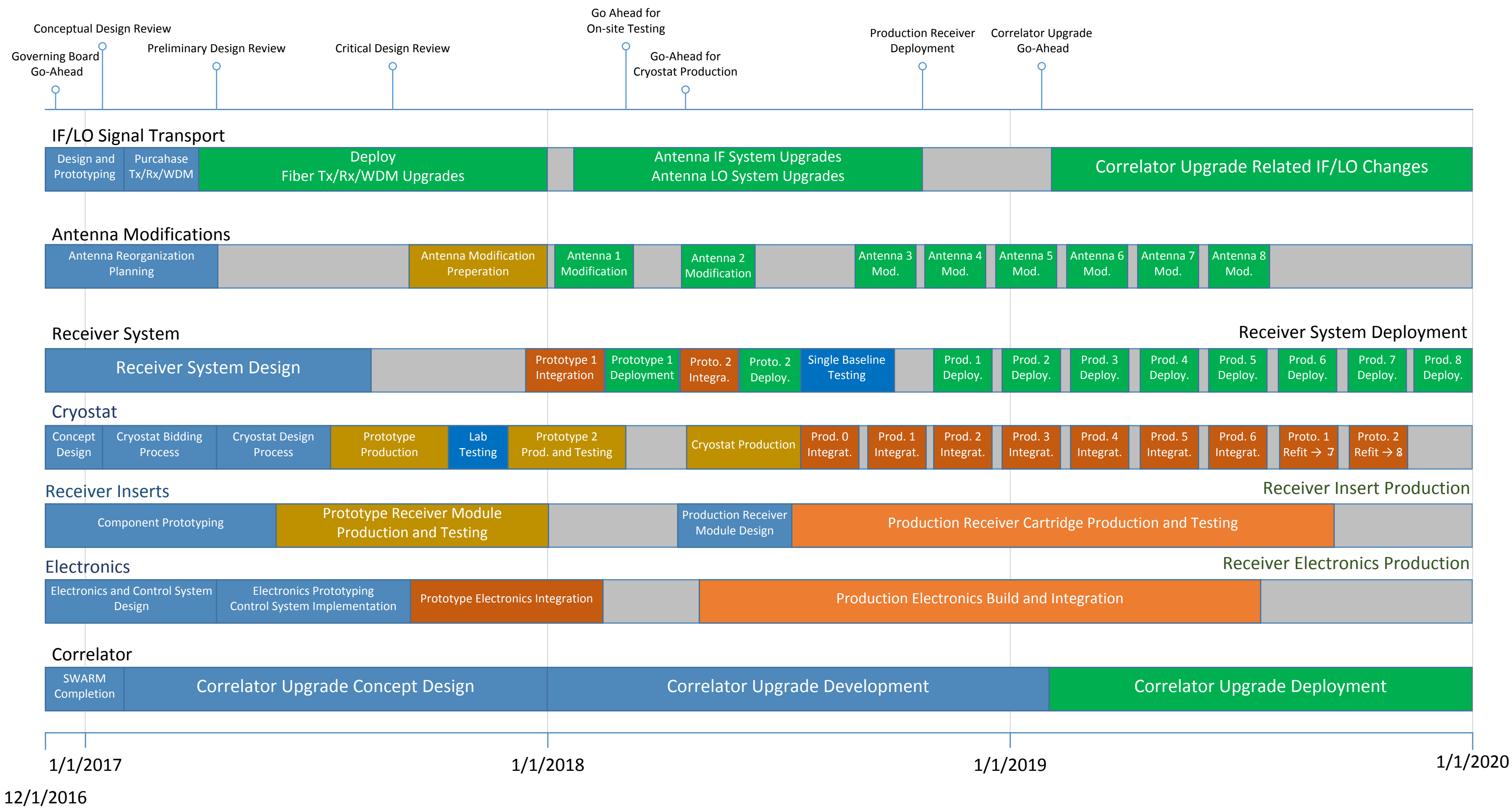
- Propose to carry out IF/LO transport upgrade first in 2017, as it can go ahead after a short development period using off-the-shelf hardware
- Receiver development will go ahead in parallel with this through 2017
- Will then carryout Receiver System prototype deployment and field testing in early 2018 before starting Receiver System production phase in mid 2018
    - New receivers will be compatible with old receiver systems for most observations, so prototypes will stay in field
- Final Receiver System deployment in 2019, alongside correlator upgrades

Time Line



Blue – development

Yellow/Orange – production and integration

Green – deployment with operational impact.