wSMA – The wideband SubMillimeter Array

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The wideband Submillimeter Array (wSMA)

The wideband Submillimeter Array (wSMA) is a program to upgrade the Submillimeter Array (SMA) with a number of new systems to enable reliable continued operation and future upgrades.

The SMA has been operating on the summit of Maunakea for 15 years. A number of systems are now showing their age or reaching obsolescence, particularly the receiver cryogenics, for which spare parts are no longer produced. As such, the SMA has decided to replace the receiver systems with all new systems, taking advantage of the developments in the state of the art since the SMA receiver system was conceived and built. This also provides an opportunity to make enabling improvements to a number of other systems.

The wSMA upgrade has the key aims of increasing the instantaneous bandwidth of the SMA from 8 GHz to 16 GHz per sideband, and improving the polarization performance, a key observational niche for the SMA. The largest element in the wSMA program is the design and construction of 8 new receiver cryostats and cryogenic systems (plus spares used for testing receivers). To take full advantage of the upgrade, a number other systems will be upgraded or replaced.

The wSMA program will replace or upgrade the following systems:

- Receiver cryostats – existing cryostats will be replaced with a newly design cryostat system based on a low maintenance pulse-tube cryocooler, and using a new receiver insert system similar to ALMA's.
- Receiver optics – existing warm receiver selection and LO coupling optics will be replace with cooled receiver selection optics, inside the receiver cryostat, and waveguide LO coupling in the receiver.
- Receiver inserts – each pair of existing single polarization inserts will be replaced with a single dual polarization insert, one for each of the 230 GHz and 345 GHz frequency bands.
- New receiver designs incorporating a dual polarization feedhorn for improved co-alignment of orthogonal polarizations on the sky, waveguide/planar orthomode transducers, cold LO coupling, and new wideband DSB SIS mixers and new receiver control electronics.
- Reconfiguration of the array-wide LO distribution system to reduce crosstalk in dual frequency mode.
- Upgrades of the IF signal transport system for wider bandwidth operation and to carry more IF signals, with eventual deployment of DWDM optical fiber systems to enable digitization in the antenna.
- Deployment of additional correlator capacity to handle the increased bandwidth of the frontend receivers.

wSMA Specifications

The upgrade from the SMA system to the wSMA system will significantly increase the instantaneous bandwidth of the SMA, simplify the receiver optics and allow a number of other improvements.

In this table, we present a few key performance specifications showing the expected performance of the SMA now, following the upgrade to 4-16 GHz IF at the end of 2018, and after the full wSMA upgrade.

System temperatures and continuum sensitivities are calculated for atmospheric conditions appropriate for observing near the center of each band – 4mm PWV for the 230 GHz band and 2.5 mm PWV for the 345 GHz band

	SMA Receivers Start of 2018		Upgraded SMA Receivers End of 2018		wSMA Receivers 2020-2021	
Receiver Bands (LO Frequency)	SMA-200	186-242 GHz	SMA-200	186-242 GHz	wSMA-230	210-270 GHz
	SMA-240	210-270 GHz	SMA-240	210-270 GHz	wSMA-345	280-360 GHz
	SMA-300	271-349 GHz	SMA-300	271-349 GHz	Potential Guest/PI Receivers	
	SMA-400	330-420 GHz	SMA-400	330-420 GHz		
Receiver Selections	200/240, 200/400	300/240, 300/400	200/240, 200/400	300/240, 300/400	230 dual pol, 345 dual pol, 230/345 single pol dual frequency	
Polarization	Dual pol in overlap between 200/240 and 300/400 receivers, otherwise single pol				Dual pol in each band, potentially dual freq, dual pol with dichroic	
IF Bandwidth	4-12 GHz DSB per receiver		4-16 GHz DSB per receiver		4-20 GHz DSB per polarization	
Receiver Noise Temperature	SMA-200	50 K	SMA-200	50 K	wSMA-230	40 K
	SMA-240	55 K	SMA-240	55 K		
	SMA-300	75 K	SMA-300	75 K	wSMA-345	60 K
	SMA-400	80 K	SMA-400	80 K		
System Temperature (at zenith)	SMA-200/240	165 K (4.0 mm PWV)	SMA-200/240	165 K (4.0 mm PWV)	wSMA-230	145 K (4.0 mm PWV)
	SMA-300/400	345 K (2.5 mm PWV)	SMA-300/400	345 K (2.5 mm PWV)	wSMA-345	300 K (2.5 mm PWV)
Continuum Sensitivity (DSB, dual pol, 6 hour track)	SMA-200/240	0.32 mJy (4.0 mm PWV)	SMA-200/240	0.28 mJy (4.0 mm PWV)	wSMA-230	0.21 mJy (4.0 mm PWV)
	SMA-300/400	1.25 mJy (2.5 mm PWV)	SMA-300/400	1.05 mJy (2.5 mm PWV)	wSMA-345	0.75 mJy (2.5 mm PWV)

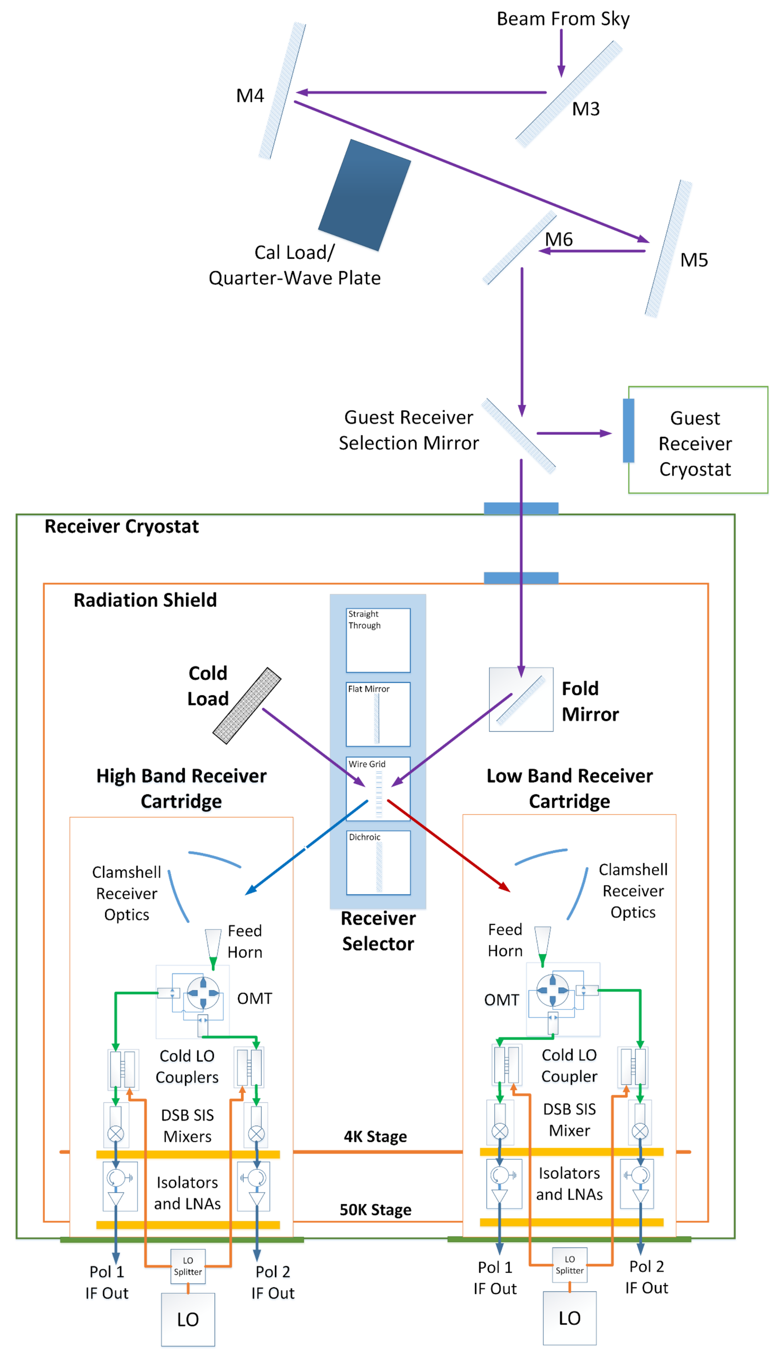
wSMA Receiver System

The major element of the wSMA upgrade is the replacement of the current SMA cryostat, receiver cartridges and optics inserts with a completely new cryostat and receiver cartridge system.

The new cryostat will hold two Receiver Cartridges, each with cold focusing optics, a dual polarized feedhorn, orthomode transducer (OMT), LO couplers, wideband DSB SIS mixers and wideband IF amplifiers. Local oscillator power is coupled to the LO couplers using overmoded WR-10 waveguide, fed by an LO unit mounted on the outside of the Cartridge's vacuum flange. IF signals from the receiver travel down the length of the cartridge to Warm IF Assemblies on the outside of the Cartridge's vacuum flange.

The Receiver Cartridge will be cooled using an automatic thermal link very similar in design to those used on the ALMA cryostats. These eliminate any need to reach inside the cryostat to attach thermal links to the cartridges. Since IF, bias and LO signals are also all coupled via the Cartridge vacuum flange, no cables need to be attached inside the cryostat either, which will greatly simplify the procedure for installing and removing Receiver Cartridges.

The Receiver Optics are entirely contained within the new Cryostat system, with a Fold Mirror and Receiver Selector Wheel mounted on the 50 K Radiation Shield of the Cryostat and the reflective final receiver focusing optics mounted on the 4K plate of the Receiver Cartridge. This both simplifies the optics over the current system and will reduce the noise introduced by the receiver optics.



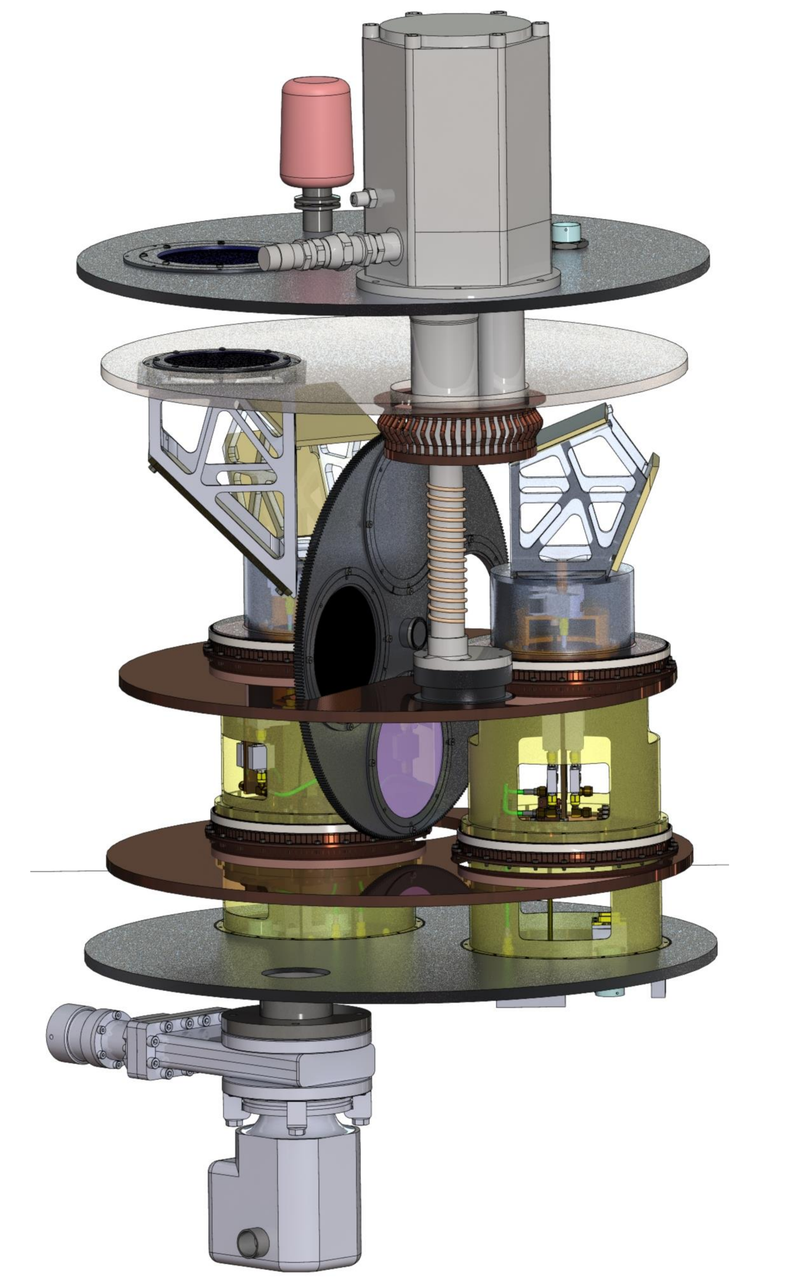
System diagram of new wSMA Receiver System. M3 to M6 are the existing SMA beam waveguide optics.

The new cryostat system will be based on a Cryomech PT407-RM pulse tube cooler, fitted with a pressurized helium pot temperature stabilization system. This cryocooler provides 0.7W of cooling power, with a temperature stability of better than 10 mK. Because the cooler has no moving parts inside the cryostat, cryostats will not need to be disassembled for maintenance, greatly reducing the difficulty of servicing the receiver system.

The pulse tube cooler will be powered by a variable frequency inverter driven compressor, which allows the cooling power to be adjusted, to allow rapid cooldowns followed by low power maintenance operation, reducing thermal load on the SMA antenna's cooling system.

The new cryostat system will be designed and built to SAO specifications by High Precision Devices, Inc. (Boulder, CO) under a design/build contract started in June 2018. Under this contract, HPD will design the cryostat this year, with a CDR in Dec 2018/Jan 2019, and delivery of two prototype cryostats in late summer 2019, when SAO will begin the integration of the receiver components onto receiver cartridge structures supplied by HPD. The contract contains priced build options to complete the set of cryostats required to replace all the cryostats on the SMA.

Since the new cryostat will be significantly smaller than the current SMA cryostat, and the Optics Cage will no longer be required, there will be space in the SMA Receiver Cabin to install addition small receivers and selection optics, for PI observations, demonstration, or to expand the range of SMA observations.



CAD model of the wSMA cryostat concept. The pulse tube cooler is to the front, the cryostat window to the top left, and two receiver cartridges to the rear left and right, either side of the receiver selector wheel.

Timeline and Deployment

The timeline for the development and deployment of the wSMA system is mostly driven by time required to design and deliver the new cryostat system, and to then integrate and test each cryostat in the Cambridge Receiver Lab and then deploy and install each cryostat on Maunakea.

We have endeavored to maintain compatibility between the current SMA receiver systems and the new wSMA receiver system, so that observations can continue with a mixed set of receivers in the field. However, the new wSMA receiver set has a somewhat narrower sky frequency range than the current SMA receiver set, and so observations will be limited once one or two wSMA receivers are deployed.

Polarization and dual frequency observing should be able to continue without issue during deployment.

The timeline to the right gives an overview of wSMA development and deployment activities over the previous year and next few years, ending with the deployment of the final wSMA receiver to Maunakea.