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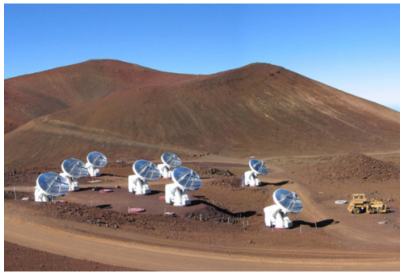

SMA Receivers – Recent Upgrades

Edward Tong *together with SMA staff*
Jack Barrett, Rob Christensen, Robert Kimberk, Steve Leiker, Cosmo Papa, Pat Riddle, Scott Paine, John Test ..

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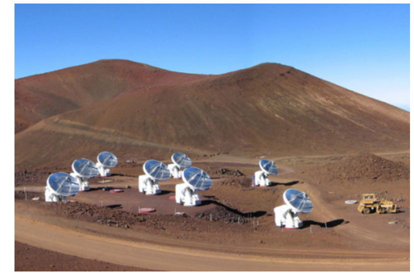
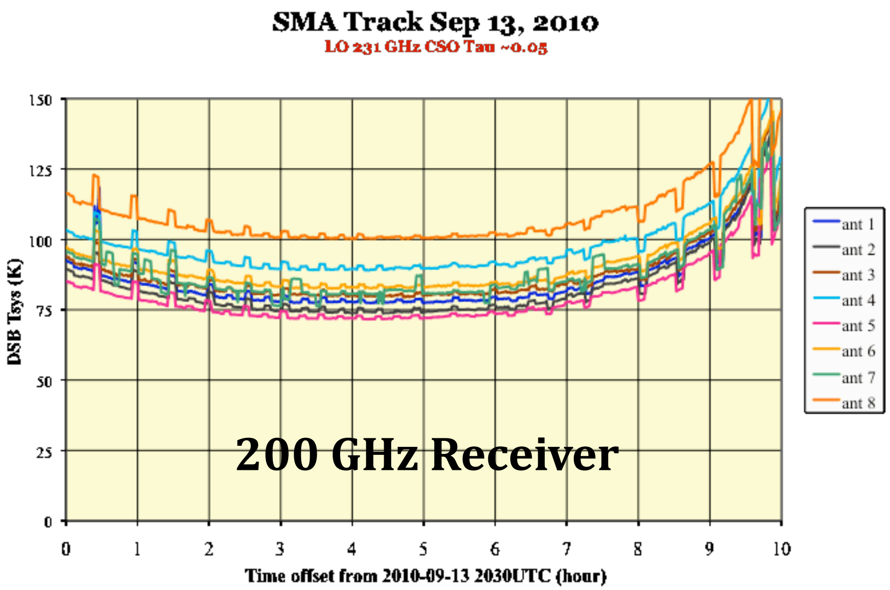
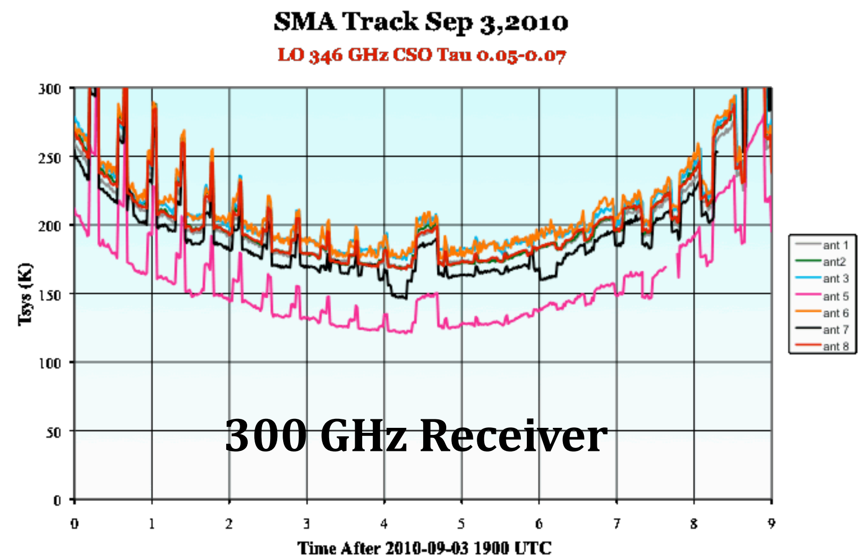


Current Performance of SMA Receivers

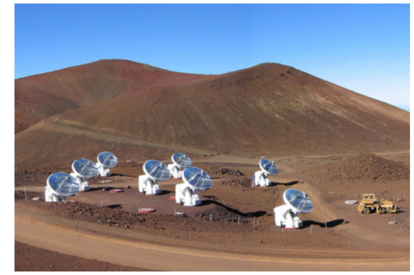




- Best Tsys ~75 K
- Tsys spread ~ ±10%
- Actual sensitivity is better because of gain compression to ambient calibration load
- Routine operation good or bad weather

- Performance at 345 GHz is mainly limited by atmosphere (Tsys > 2Trx)
- Best Tsys ~ 125 K @ 345 GHz
- Achieve 0.7 mJy RMS noise for this track
- High demand for 345 GHz operation

Credit: Shelbi Hostler for track screening



Bandwidth Doubling operation

- **Motivation: High frequency receivers are not always in use**
- **Provides full 4 GHz (DSB) correlator bandwidth for single receiver operation**
- **Introduces more combinations of receiver configuration**
- **More flexibility to scheduling and planning observations**

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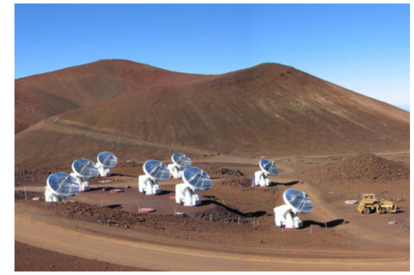
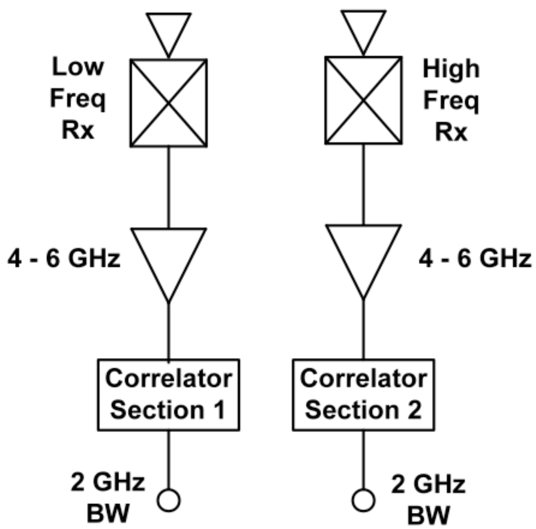
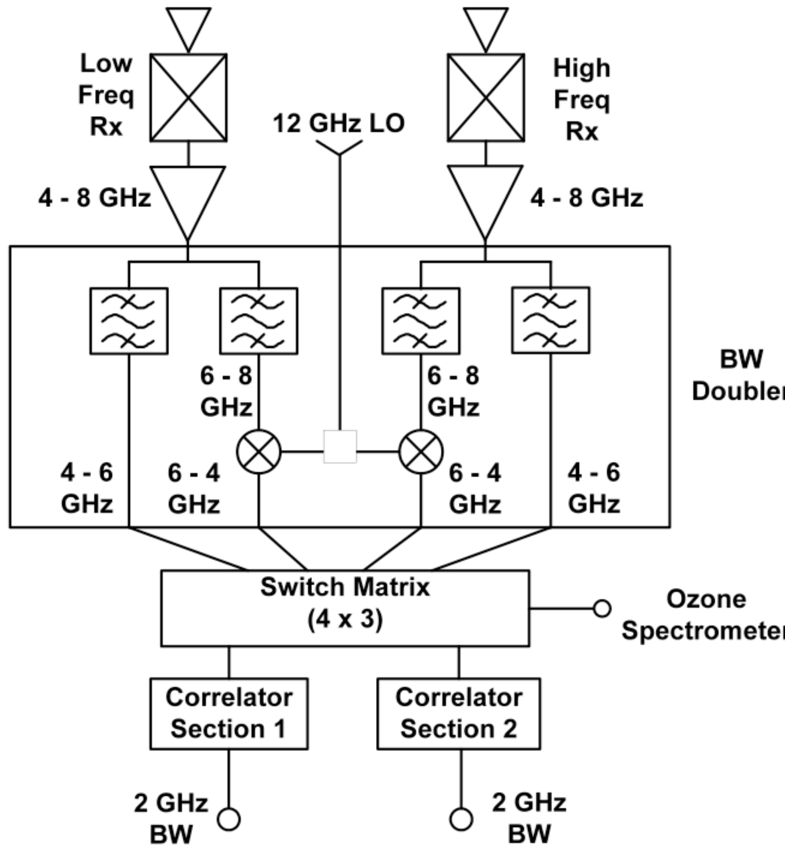


Original Configuration



New Bandwidth Doubled Configuration



Credit: John Test & Jack Barrett for implementation

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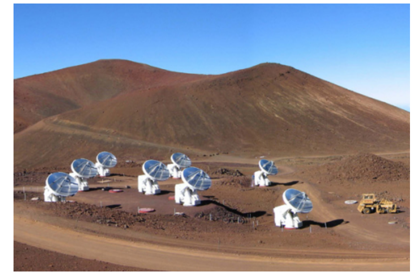
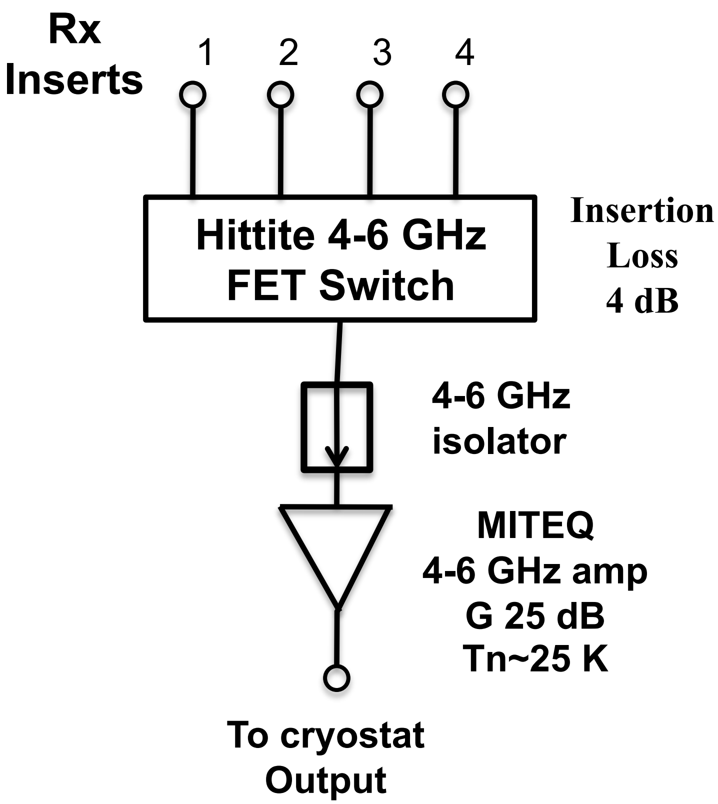
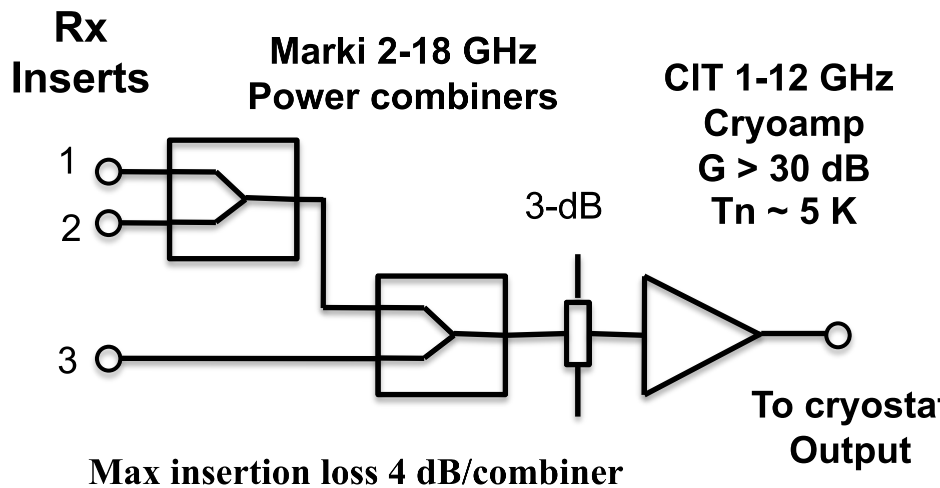


Upgrade of Second Stage (20 K) Amplifier Plate

Original Configuration



Upgraded Configuration



- reliable passive combiner
- wide BW coverage
- lower power consumption (~10% of original)
- usable between 1.5 and 16 GHz
- Two cryostats have been upgraded

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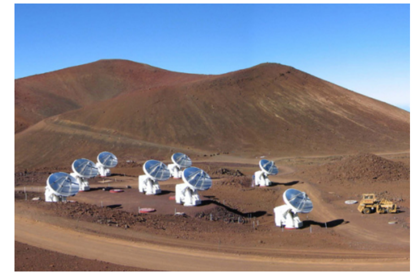
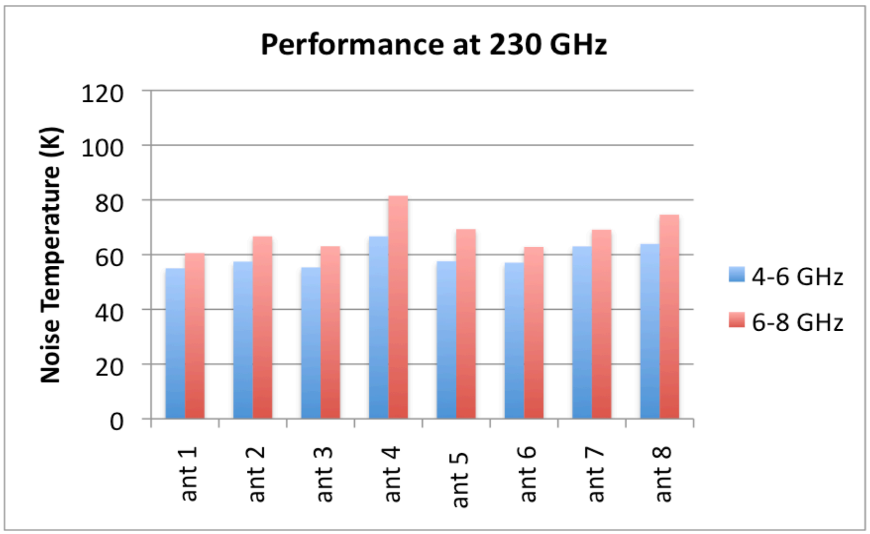
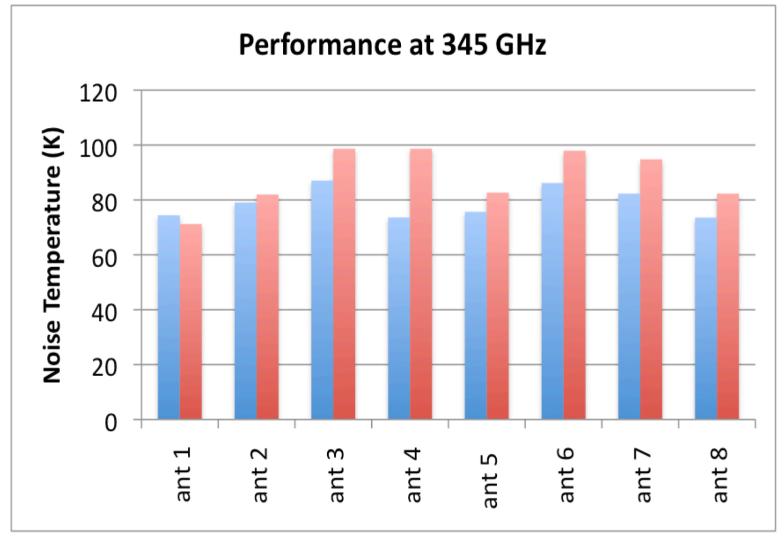


Comparing Receiver Performance at 4-6 and 6-8 GHz IF





- **Except for individual receivers, sensitivity for 6-8 GHz is 5-10% poorer than for 4-6 GHz**
- **Further fine tuning can bring the performance closer**

Credit: Rob Christensen and Brooks Rownd

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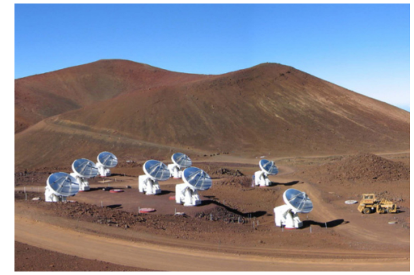
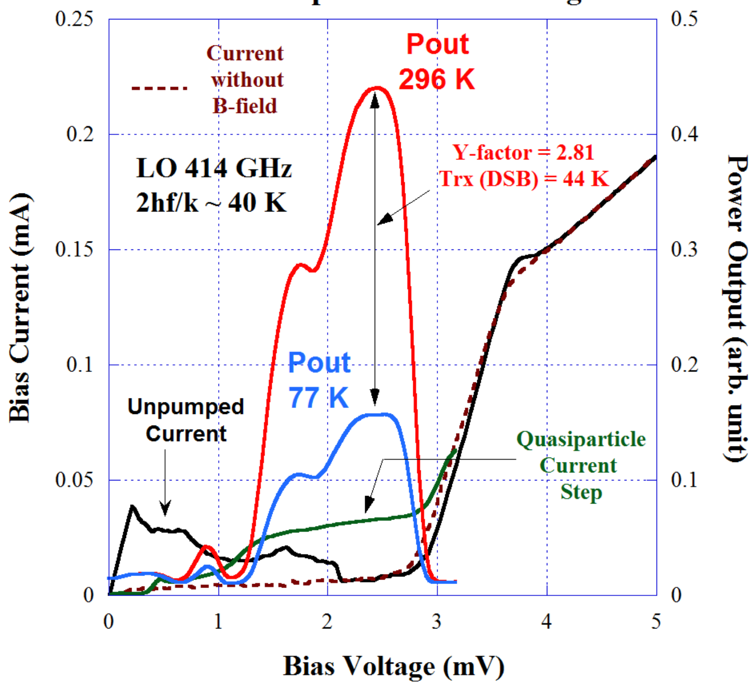


Upgrade of 400 GHz Receivers:
Replacement of old JPL devices with IRAM devices

IRAM 400 GHz Device
Batch 22-I-44 #4B-2606
Tested April 2010 Cambridge



Best Trx measured in our lab bench is ~42 K, corresponding to close to $2h\nu/k$

Best lab Performance recorded in terms of $h\nu/k$

Working with Karl Schuster to get more of these devices

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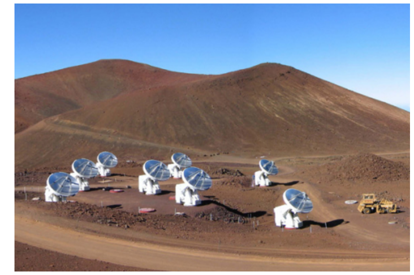
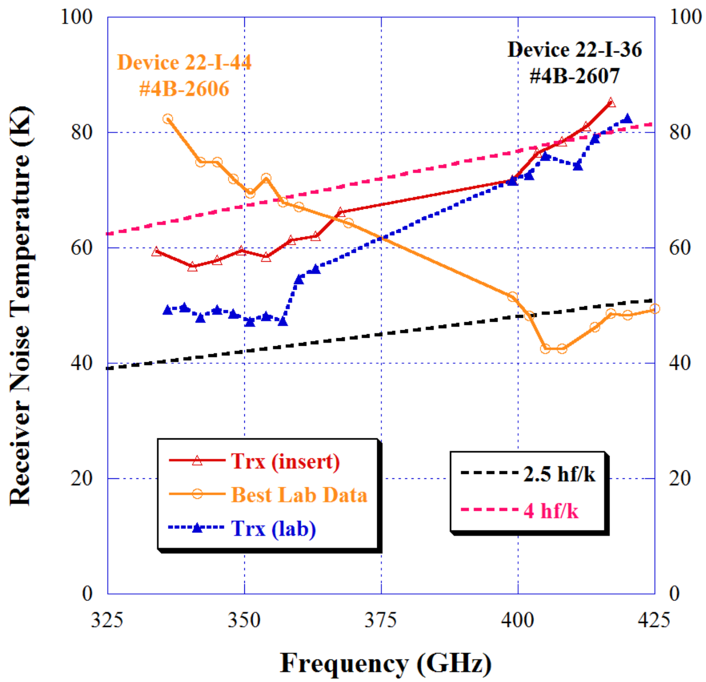
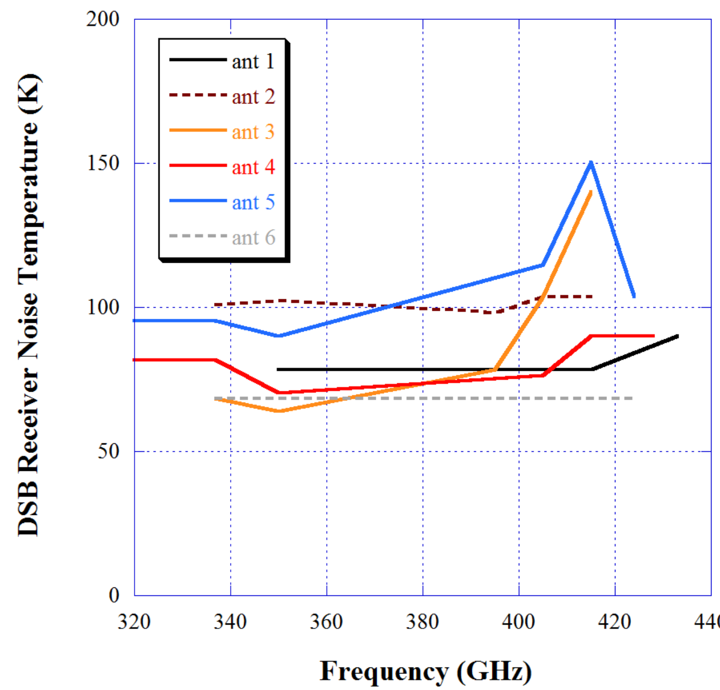


Current Performance of SMA 400 GHz Receiver

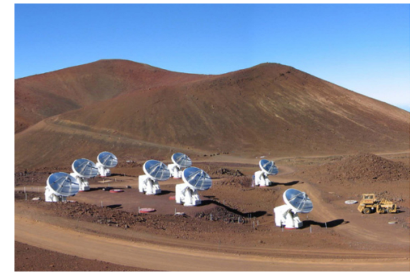
Sensitivity of SMA-400 Receivers with IRAM devices



Performance of SAO 400 GHz Receivers measured on Mauna Kea

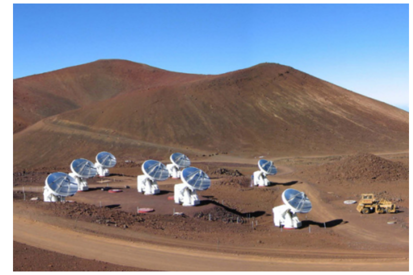


Credit: Rob Christensen (MK performance)



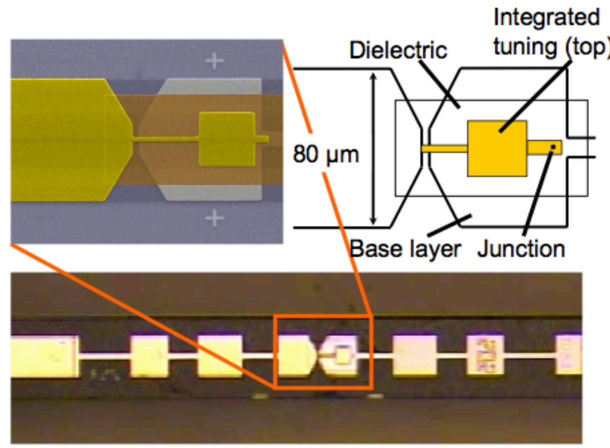
Summary of activities related to 400 GHz upgrade

- New devices from IRAM with quantum limited performance
- New mixer blocks from Rutherford
- Progress made in deploying the newer mixers in Hawaii
- Full polarization observation using dual 300/400 GHz receiver is being developed (useful between 330 and 355 GHz where the 2 bands overlap)
- Increased interest in observing H_2D+ line at ~372 GHz
- Upcoming line survey over 400 – 420 GHz window taking 8 GHz data per track in Bandwidth doubled mode
- Needs optics upgrade to take advantage of the quantum limited sensitivity



Upgrade on 600 GHz Receivers

- Work with University of Cologne
- Taken charge by a post-doc (Abby Hedden)
- Replace Martin Puplett diplexer with wire mesh LO injector
- New fixed tuned LO unit from VDI
- Three units deployed in Hawaii
- Unsolved issue: ESD problem with Cologne devices.
- Usage of 600 GHz receivers limited by weather



Above: Views of a fabricated CfA/Cologne device and end-loaded stub integrated tuning circuit.

Below: Design parameters for SIS device fabrication

Junction	J_C	12 kA/cm^2
	C_{sp}	90 fF/µm^2
	$A_{Junction}$	0.95 µm^2
Tuning Circuit Electrodes	Material: Nb	$\sigma_n = 2.2\times10^7\ \Omega^{-1}cm^{-1}$ $T_c = 9.2$ K, $2\Delta_0 = 2.8$ meV
	Base	150 nm
	Top	350 nm
Tuning Circuit Dielectric	Material	SiO, ε_r=5.7
	thickness	250 nm

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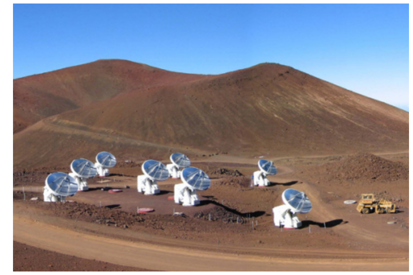
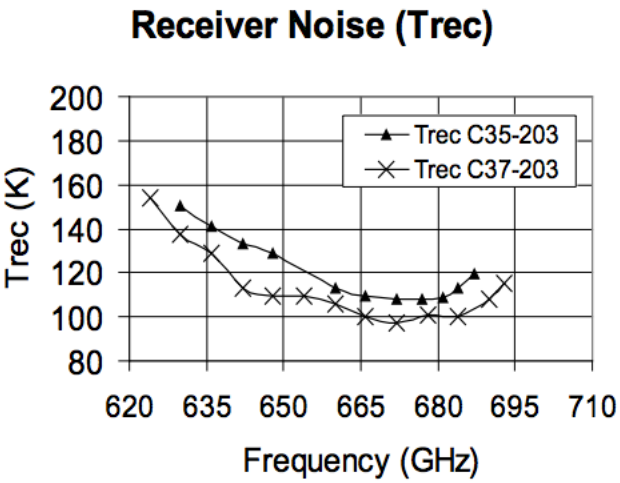
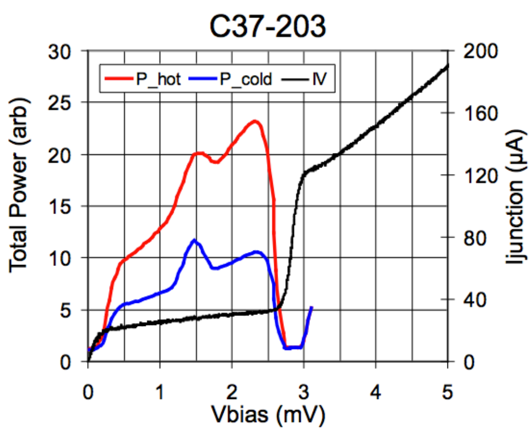
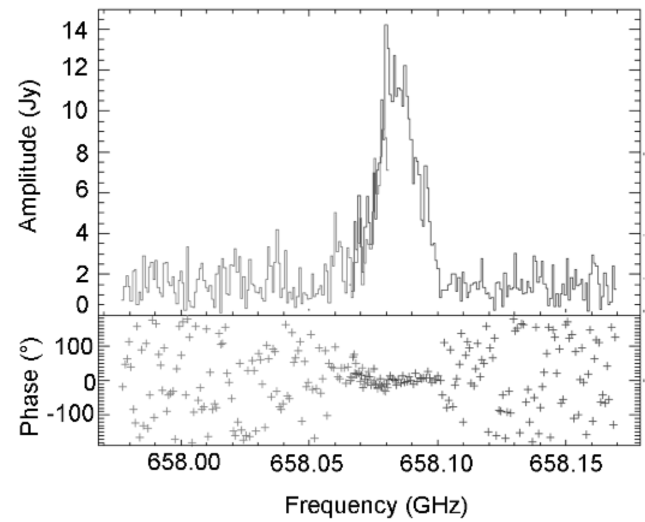




- Good lab performance achieved: ~100 K between 665 and 685 GHz (~ 3 *hν/k*)
- 600 GHz Inserts with new device and new optics perform better than original inserts (by up to 50% in sensitivity
- needs more manpower & resources to go forward



Above: Receiver total power curves for ambient (red) and cooled (blue) loads. A LO-pumped I-V curve is shown.



Above: *Left:* SMA cryostat with 600 GHz receiver insert, LO unit, and coupling optics in the lab in Cambridge, MA. *Right:* Observations of 658 GHz water maser line toward VX Sgr. Spectrum is a vector average of all baselines containing Antenna 2 (with upgraded 660 GHz receiver insert).

Credit: Abby Hedden

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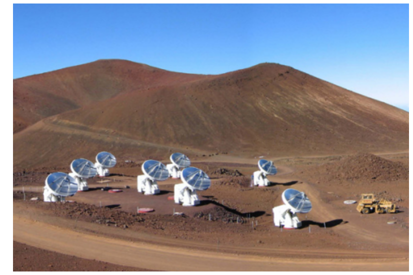

Dual Temperature Calibration Load Assembly

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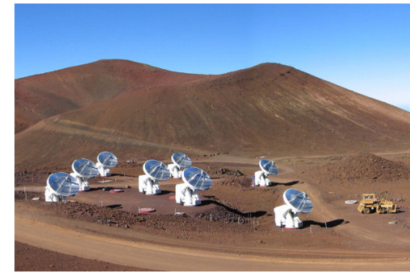
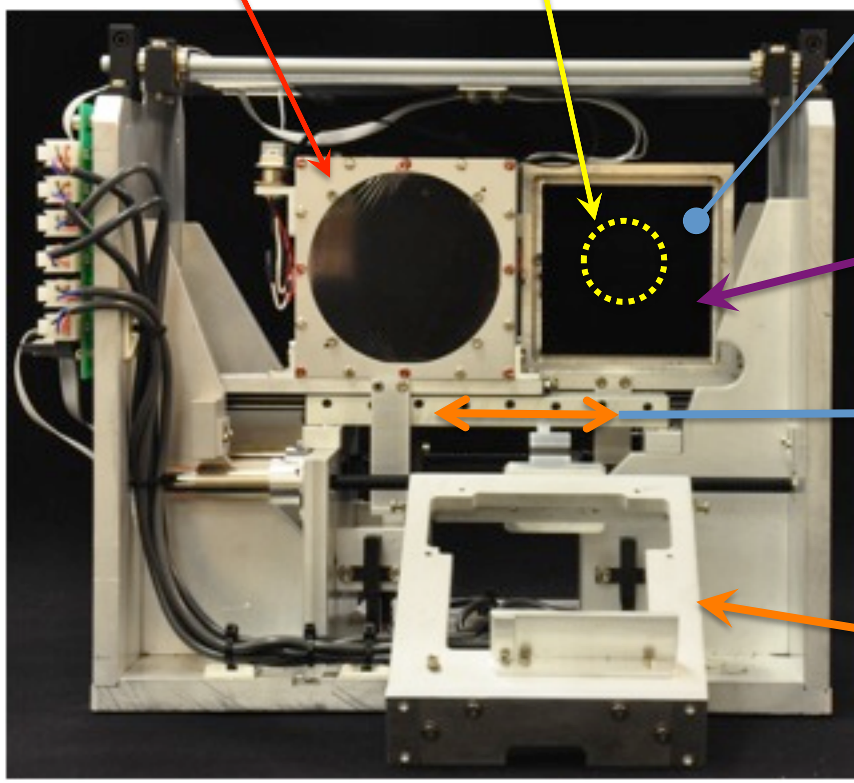


Calibration Load Assembly Installed in telescope optics

Heated Load (~60^{o}C)
Covered by 3 µm mylar film

Compact Image of telescope aperture

Load assembled from
3 x 3 TK RAM tiles
-35+ dB return loss for specular reflection



Ambient Load (~15^{o}C)
Tilted at 15 deg to beam to improve return loss

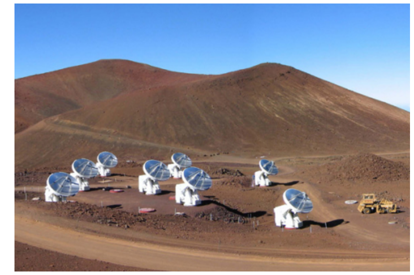
Computer-controlled linear motion carrying load in and out of beam

Carrier for quarter wave plate used in polarization measurements
(flipped over in this photo)

Status:

- Fully installed
- Calibration completed
- Need more software adjustment

Credit: Cosmo Papa, Steve Leiker for design and implementation



Use of SMA Calibration Unit

- Provide higher quality calibration for receivers
- Permit higher precision flux measurements especially for bright continuum sources
- Allow fast receiver tuning for noise optimization
- Enable us to troubleshoot receiver stability issues
- Help to diagnose spectral baseline problems
- Means of study of gain compression of receivers
- Important element for atmospheric phase correction using ozone spectroscopy

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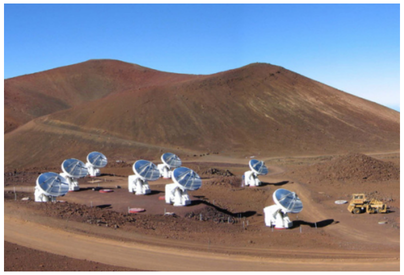

Cabin Beam Scanner/Aligner

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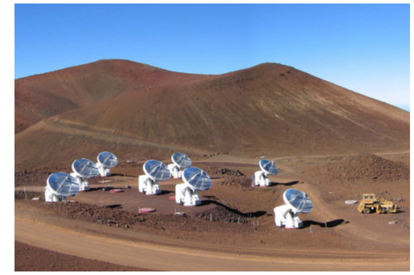
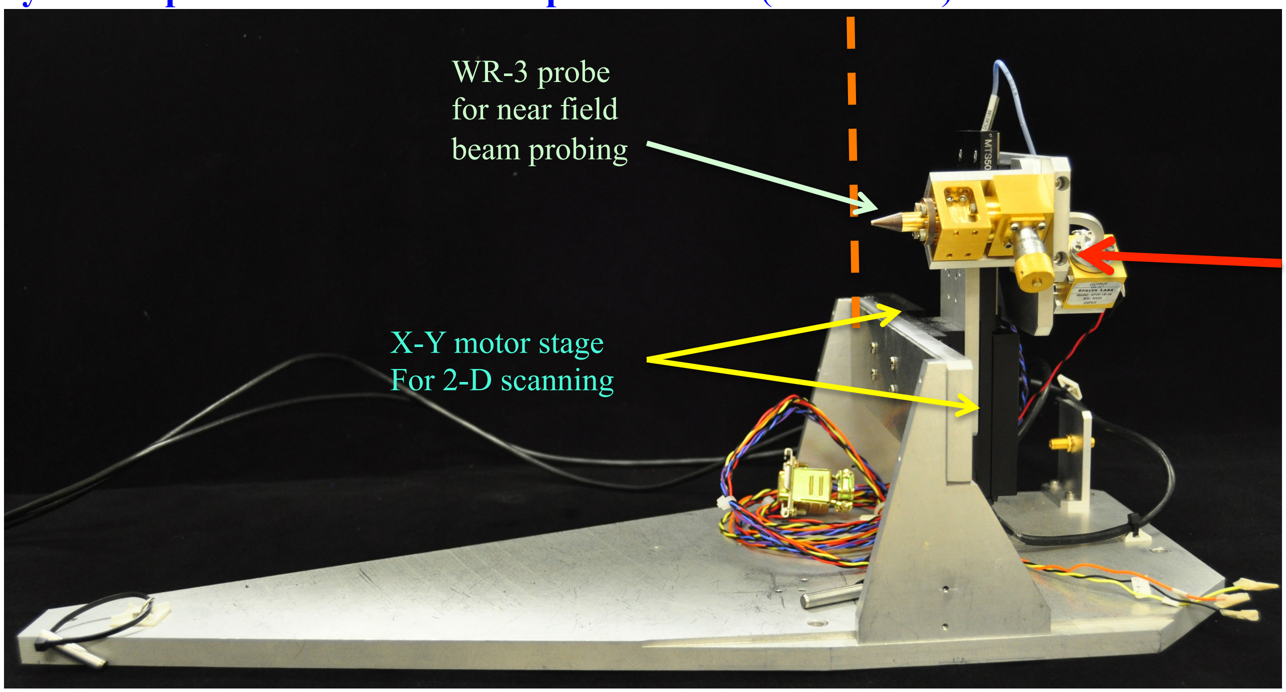


Receiver output is measured by a vector voltmeter against a reference signal taken from the LO subsystem to produce a 2-D beam map

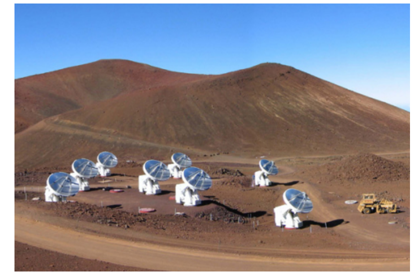
Image plane of telescope aperture (beam waist)



Harmonic generator powered by cabin YIG oscillator and power amp cascade

Scanner to be installed in Telescope Optics (in place of cal load assembly) when in situ beam alignment is needed

Credit: Mechanical design by Cosmo Papa, photo by Steve Leiker



Plan for Cabin Beam Scanner

- *In-situ* alignment of receivers --- useful for new insert installation
- Verification of relative alignment of various optics elements
- Improve illumination pattern of telescope
- Help to troubleshoot pointing issues

- **Lab testing phase has been completed**
- **Initial testing in telescope scheduled for Oct 2010**

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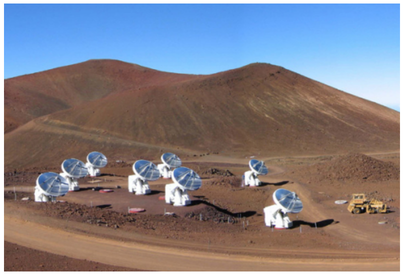
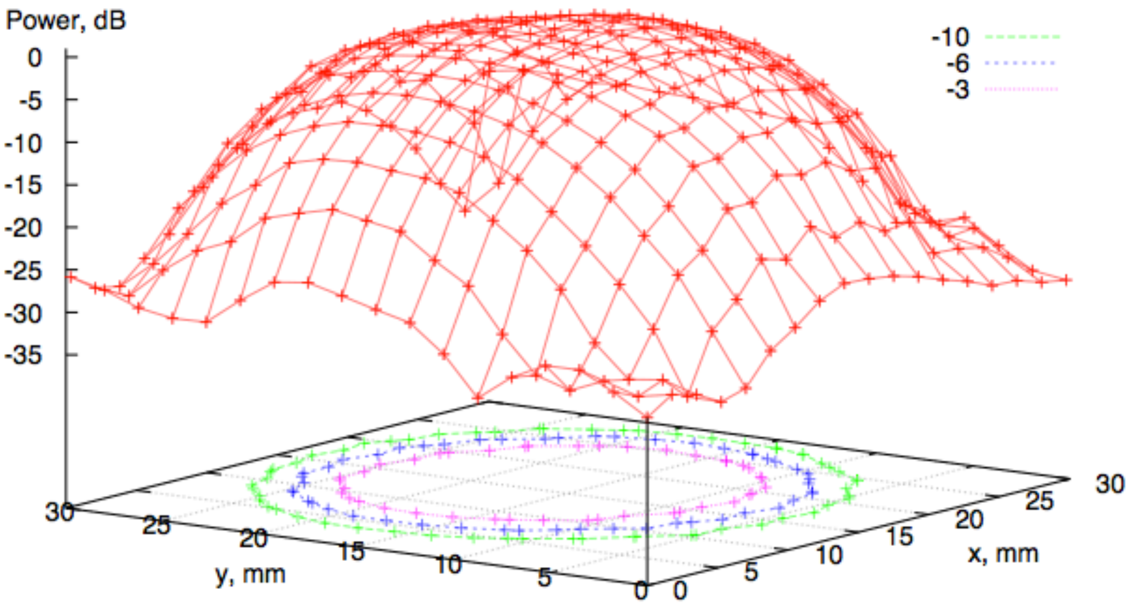
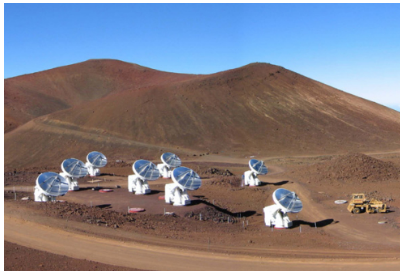


Beam map taken in Lab (August 2010)



- Signal Frequency 335.4 GHz
- 18 x 18 pixels
- 1.75 mm steps
- Scan time ~20 minutes
- SNR @ beam center ~40 dB
- Measured beam diameter (-10 dB points) 25 mm Vs design value of 24 mm
- Position accuracy of fitted beam center ~ 0.3 mm

Credit: T.K. Sridharan (testing) and John Test (software and hardware)



Summary

• SMA 200 and 300 GHz in routine operation, attaining ~ 1 mJy detection level per track.

• Band width doubling hardware provides full 4 GHz BW per track.

• Upgrade of 2nd stage IF subsystem will permit use of receiver insert with very broad IF bandwidth.

• Quantum limited performance achieved with 400 GHz receiver in lab. Further improvement needed in field.

• Upgrades of 600 GHz receivers require more resources.

• Dual Temperature Calibration Unit gearing up for full exploitation.

• Cabin Beam scanner for *in-situ* beam alignment is ready for deployment.