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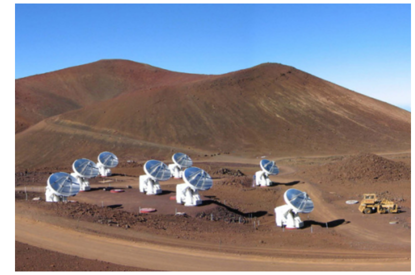
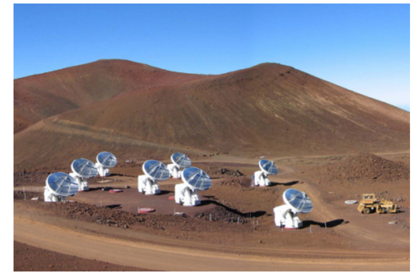


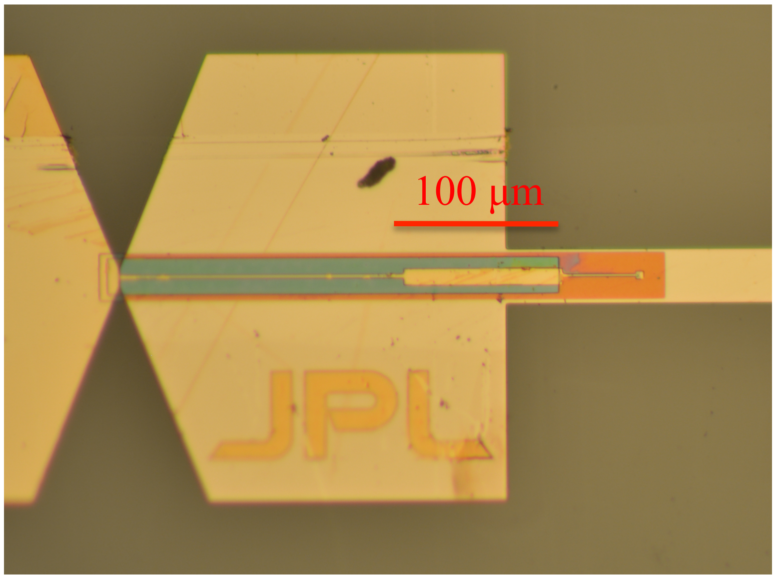
SMA Wideband Upgrade: Status

Cambridge Staff Members:
Jack Barrett, Paul Grimes, Robert Kimberk, Steve Leiker, Scott Paine, Cosmo Papa, Pat Riddle, John Test, Edward Tong

Hilo Staff Members: ALL

ASIAA Staff: *Johnson Han, Ming-Jye Wang, …*





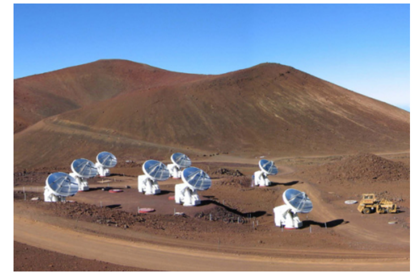
SMA 200 GHz Mixer Chip fabricated by JPL in 1990s. Work horse of SMA during its first decade of operation.

IF Bandwidth of SMA:
Initially 4-6 GHz (for 2 receivers)

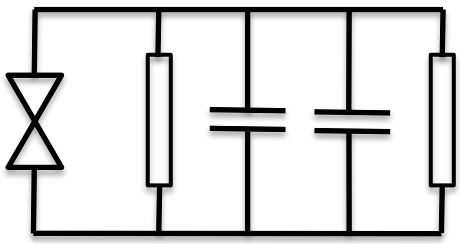
In late 2000s, we introduced the Bandwidth Doubling module which allows 4 – 8 GHz for single receiver operation.

IF Bandwidth was limited by capacity of correlator and output capacitance of SIS mixer.

In 2010, at last Advisory Meeting, we propose to launch a wideband upgrade to provide more IF Bandwidth.



IF Bandwidth of SIS Mixer



SIS R_{out} C_J C_{tune} R_{load}

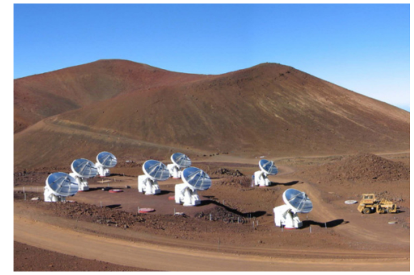
$$\text{IFBW} = \frac{1}{2\pi (R_{out} // R_{load})(C_J + C_{tune})}$$

$$\approx \frac{1}{2\pi * 50 * (C_J + C_{tune})} \qquad R_{load} = 50 \quad \textbf{and} \quad R_{out} >> R_{load}$$

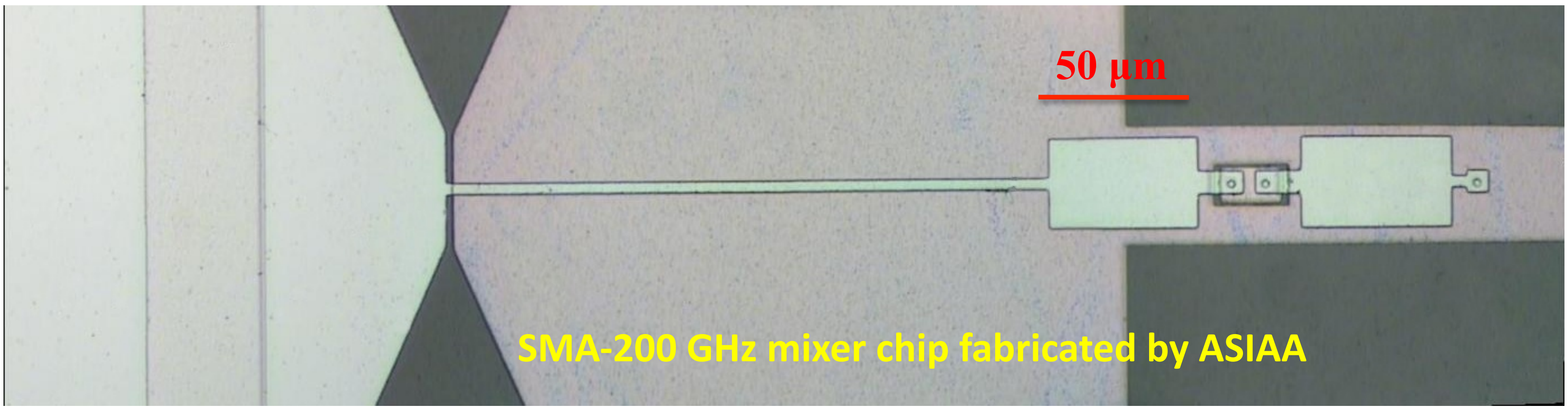
For Original SMA mixer design, $(C_J + C_{tune}) \sim 0.35$ pF,
IFBW ~ 9 GHz

To increase IFBW:

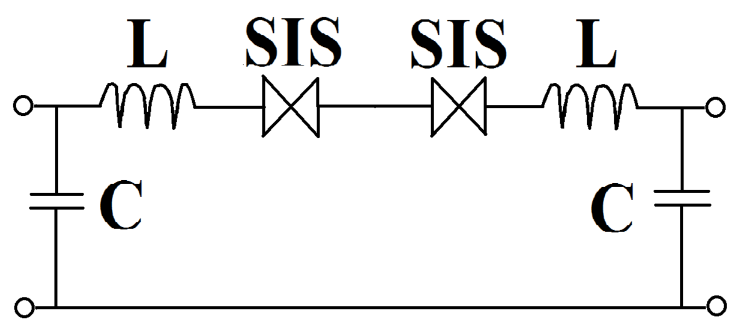
- Reduce Junction Capacitance – **use series junction array.**
- Reduce Tuning Capacitance – **use newer type of tuning circuit.**



SMA-200 GHz Wideband Mixer Chip. Version 1



- Transformer-coupled 3-junction design
- Synthesizes a transmission line section
- Current Density: 7 kA/cm^2
- Device Size: 1.6 μm diameter
- Resembles end-loaded stub



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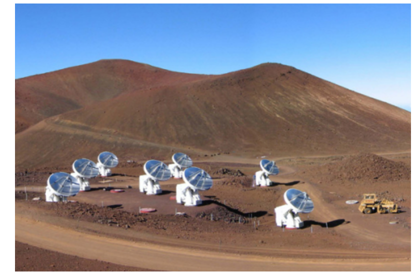
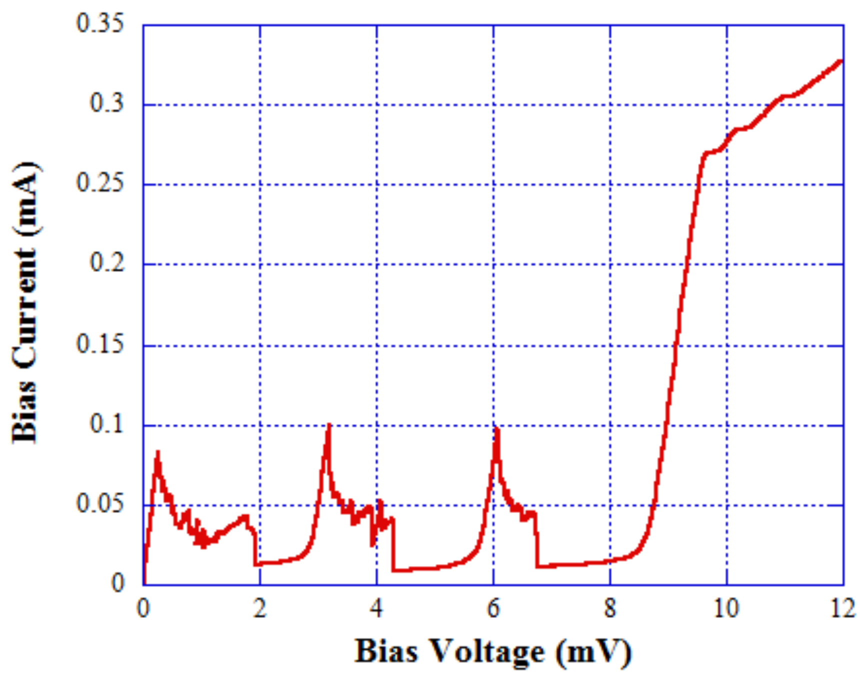
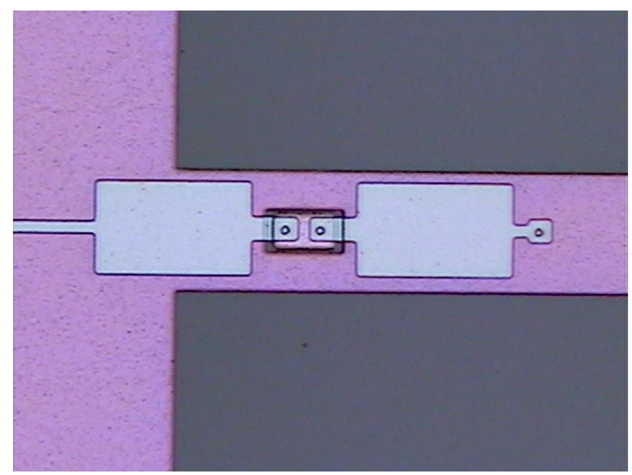




- R_N ~ 11 x 3 Ω = 33 Ω
- Q > 17
- V_{gap} ~ 2.88 x 3 mV = 8.65 mV
- C_{out} ~ 0.25 pF
- projected IF BW ~ 13 GHz

Typical I-V curve of 3-Junction SIS array produced by ASIAA (2011)
Actual J_c ~ 8 kA/cm^2



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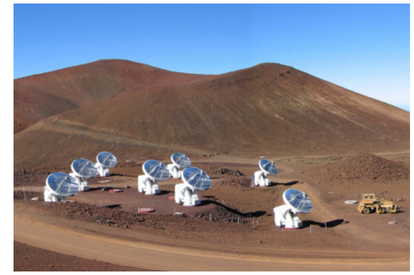
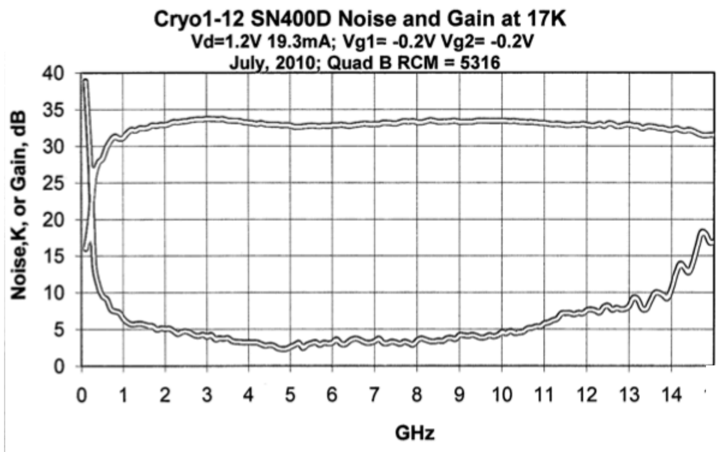
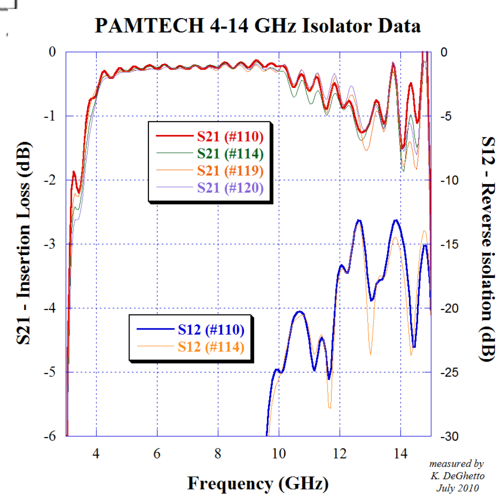


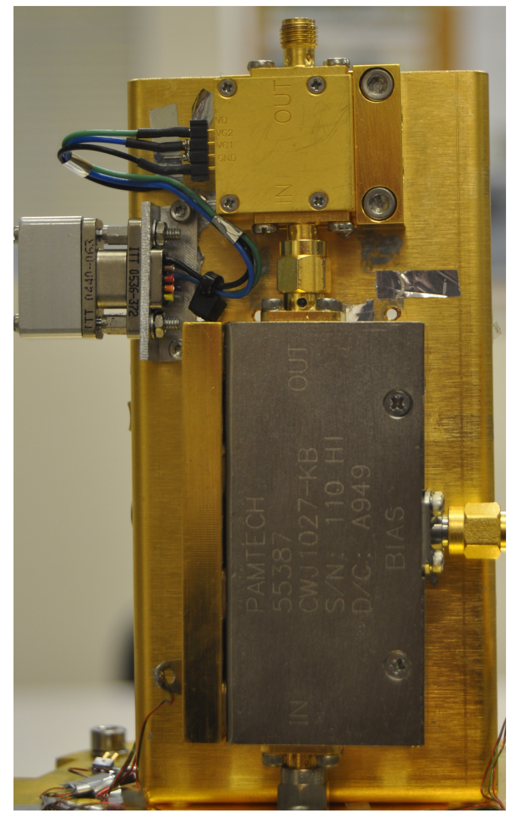


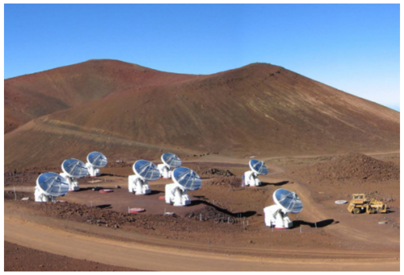
Selected units of CRYO1-12 features noise temp < 5 K up to 11 GHz and < 10 K up to 14 GHz.

PAMTECH/Quinstar 4 – 14 GHz isolator is an advanced version of the 4 – 12 GHz isolator in use in ALMA

- insertion loss < 0.7 dB
- reverse isolation > 15 dB

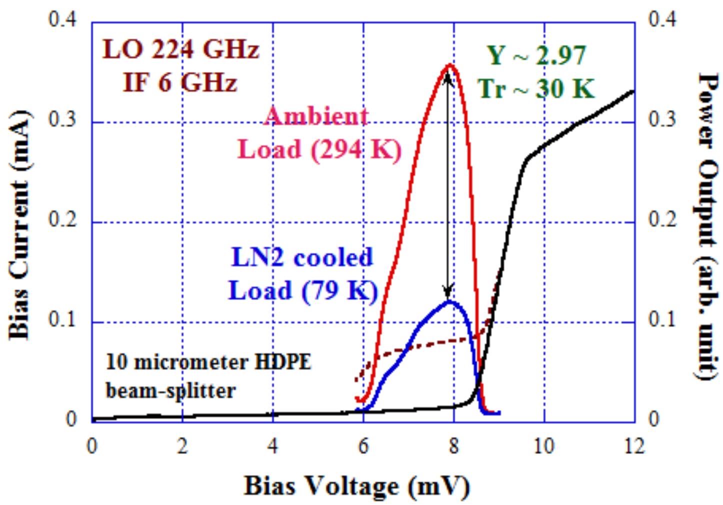




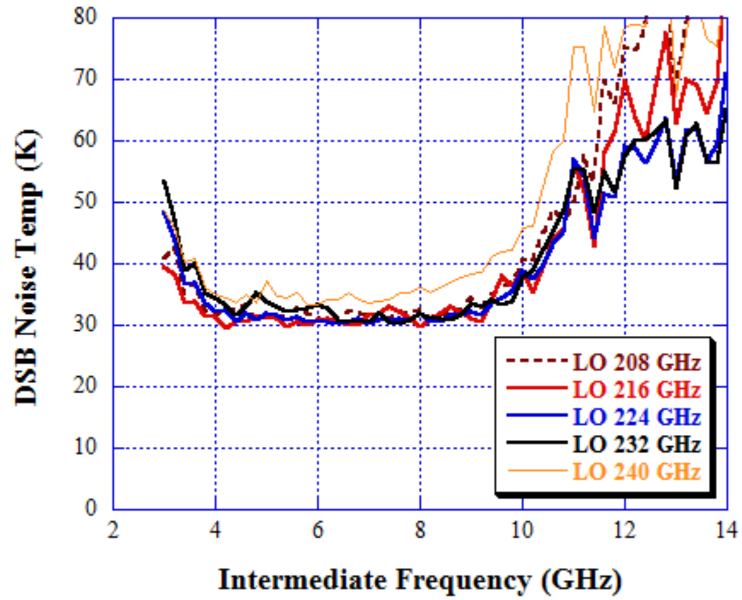


Laboratory Performance:

- Easy to couple magnetic field (generally operates at 2^{nd} null)
- Rout : 150 – 200 Ω
- Best Y-factor ~ 3, i.e. T_{DSB}~ 30 K or *hν/k* ~ 3



- Smooth P-V except for the lowest LO frequency (too inductive)
- Sensitivity rolls off significantly for IF > ~11 GHz



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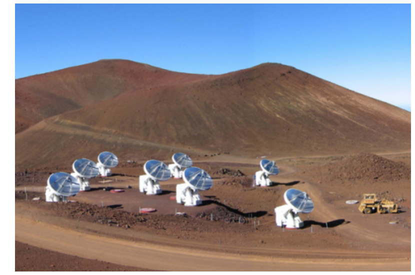
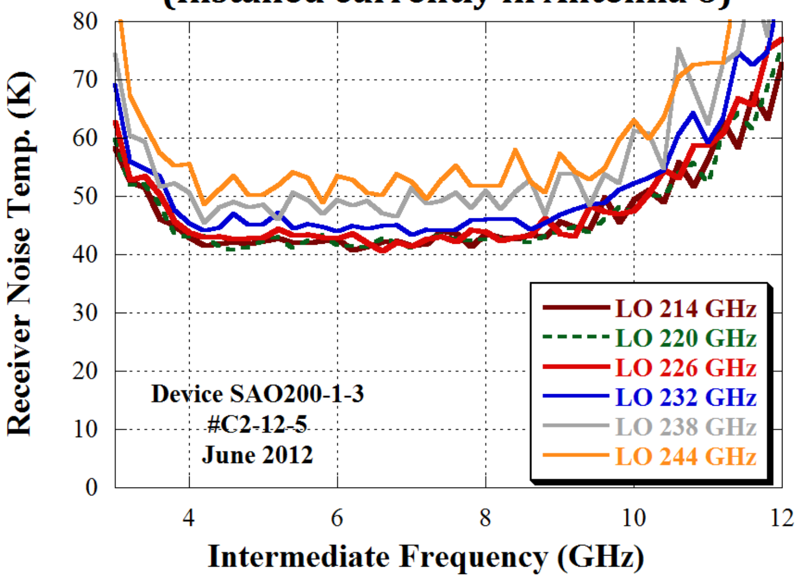
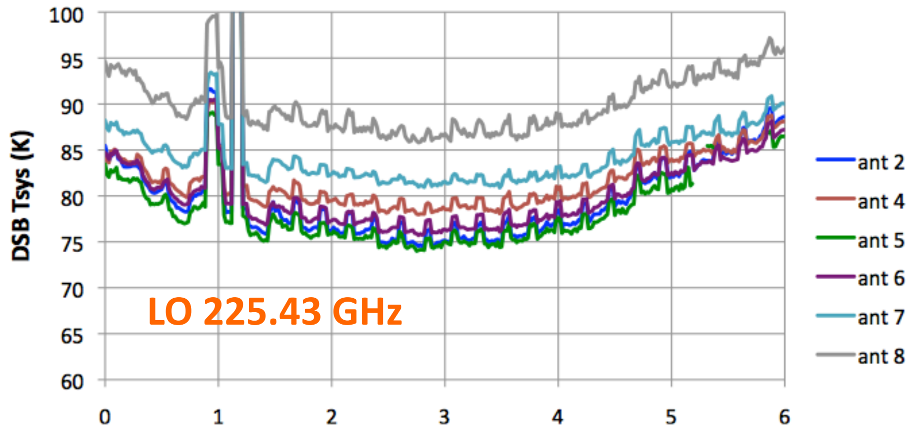


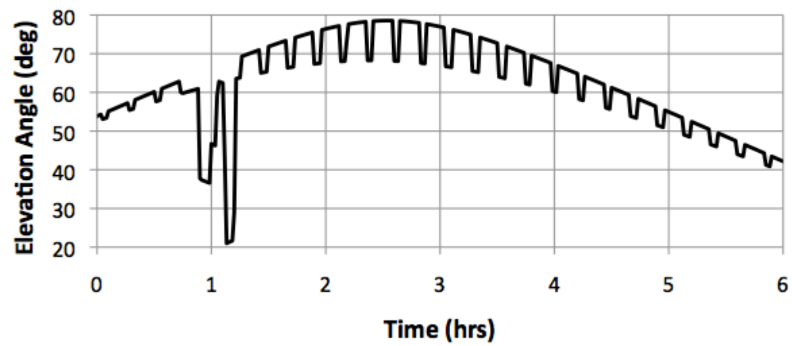
Lab Testing of Receiever Insert 200-C with full SMA Optics (Installed currently in Antenna 6)

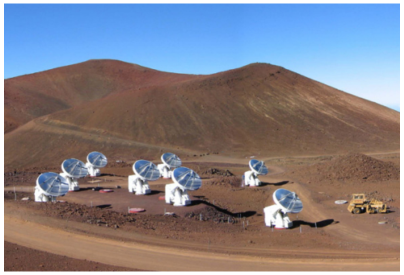


All SMA-200 Receivers have been upgraded in 2012 and are being used for routine observation.

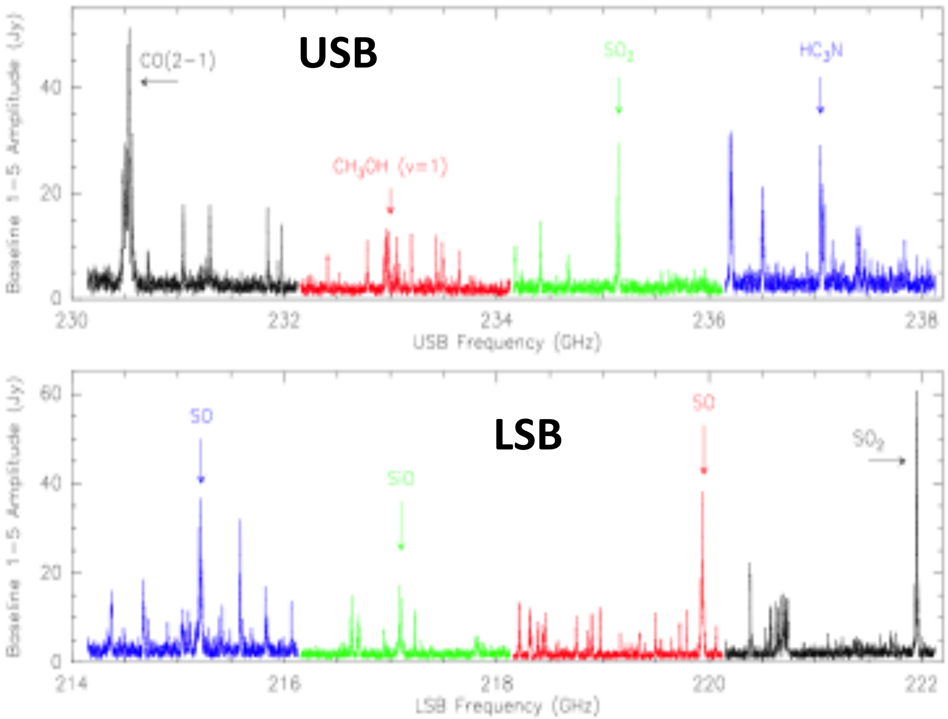
On sky performance of receivers on Jan 10, 2014. Opacity @ 225 GHz ~ 0.05 (good weather) Tsys Value for 4 – 6 GHz Band





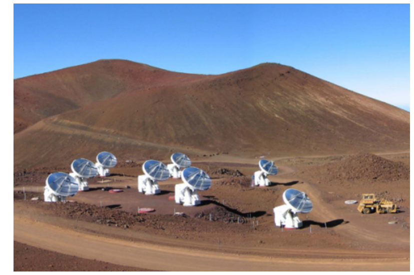


Test Observation Towards Orion BN/KL
LO 226.1 GHz

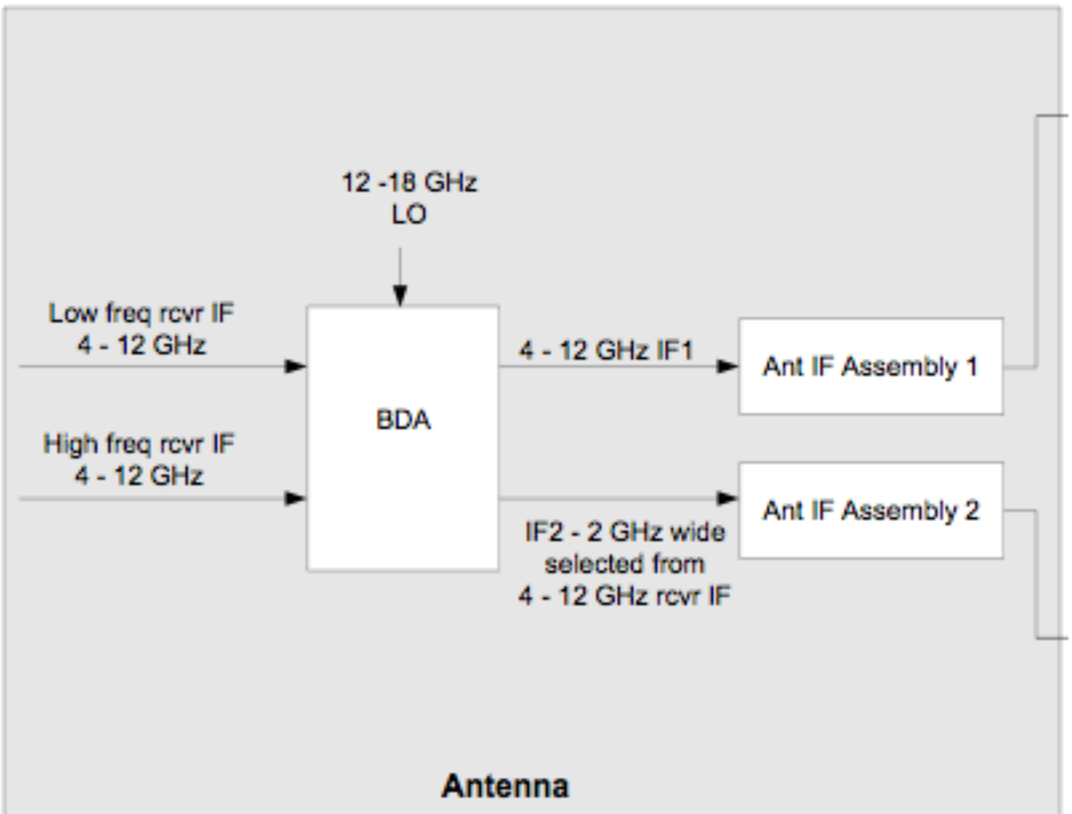


In the absence of the wideband correlator, the upper IF (> 6 GHz) can be read by the existing correlator using an additional downconverter in the BDA module in each antenna.

Any 2 GHz wide IF spectrum falling between 6 and 14 GHz can be mapped to correlator input.



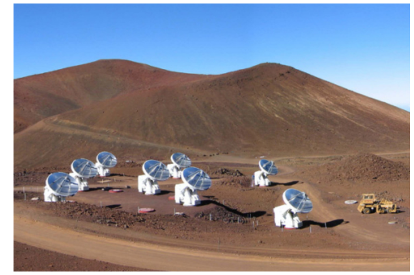
Bandwidth Doubler Assembly (BDA)



BDA provides access to the expanded IF through an extra down-conversion in each antenna.

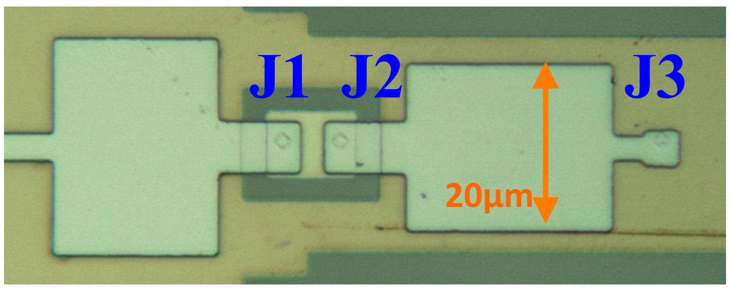
Increases throughput for single receiver operation.

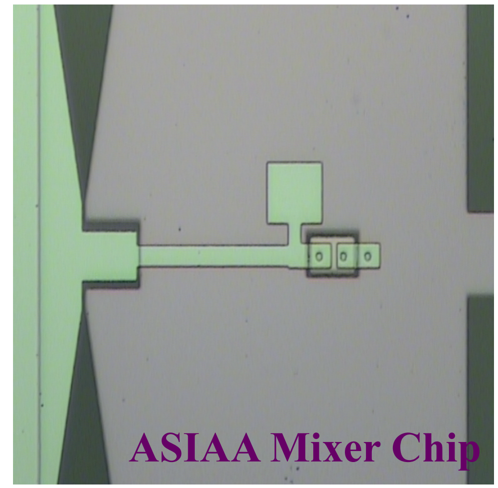
Great tool for the commissioning of the SWARM correlator.



300 GHz Receiver Upgrade

- Initial Mixer Chips came from IRAM





- Junction size ~ 1.1 µm^2 (E-beam written)
- J_c ~ 8 kA/cm^2 with low leakage
- Requires larger magnetic field
- Design is a scaled version of SMA-200
- Tuned to lower frequency because of larger spreading inductance.

- Junction: 1.5 µm diameter
- J_c ~ 7 kA/cm^2 with acceptable leakage (R_{sg}/R_n ~ 10)
- More compact design with low output capacitance (C_{IF} ~ 0.18 pF)
- Design tuned to higher frequency.

As of end 2013, half of SMA-300 is upgraded with IRAM chips and half with ASIAA chips.

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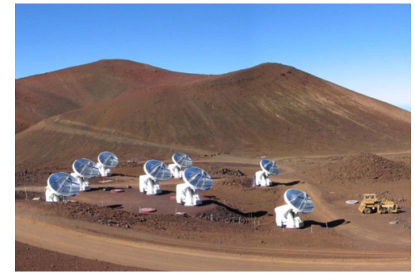
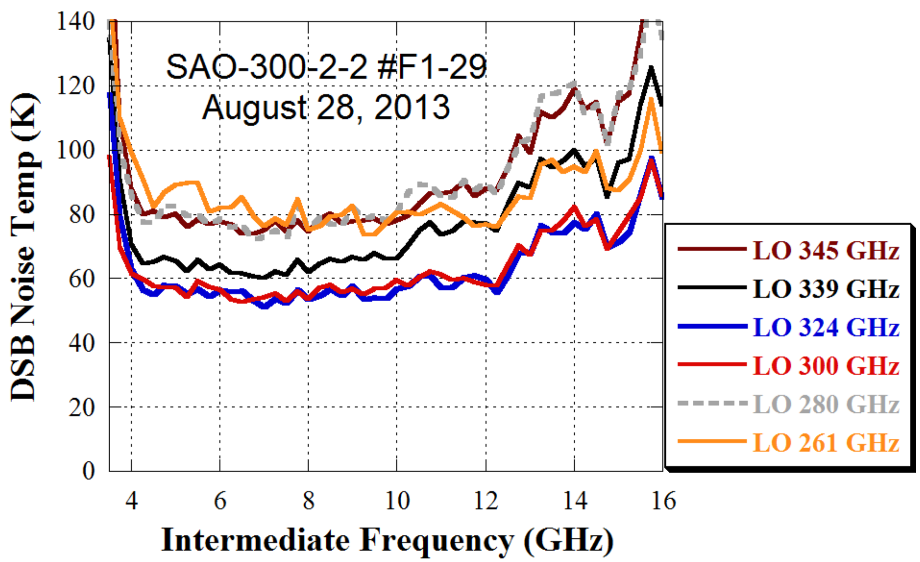
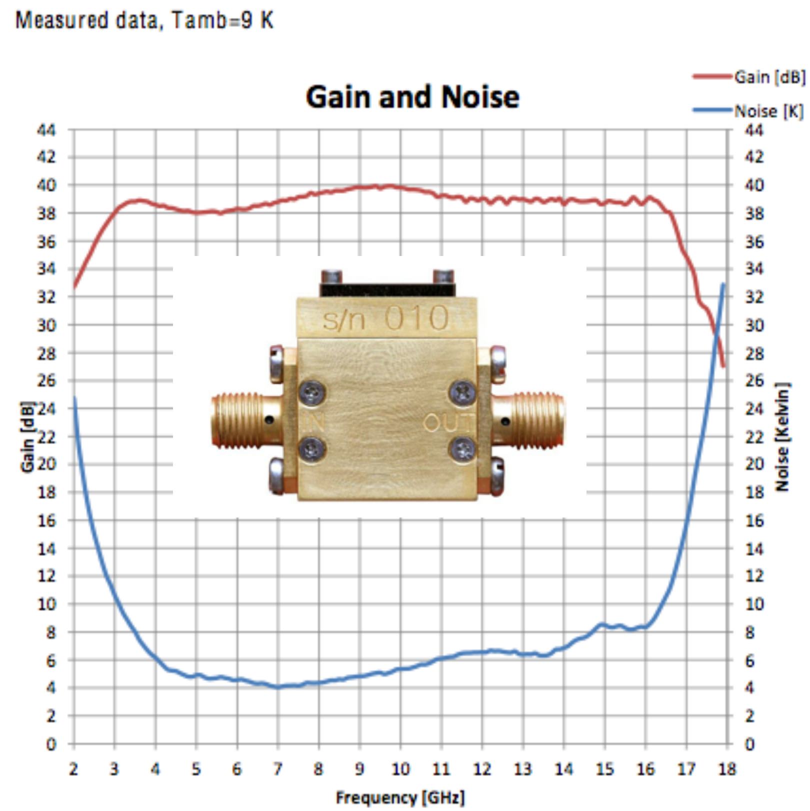


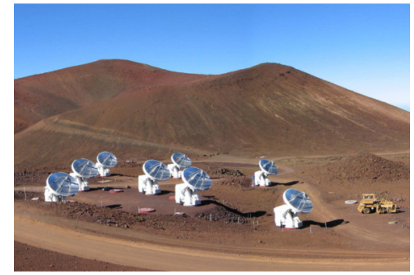
Wideband SMA-300 GHz Lab Data (in wet cryostat)



IF > 12 GHz made possible with new 4 – 16 GHz LNA from Sweden.

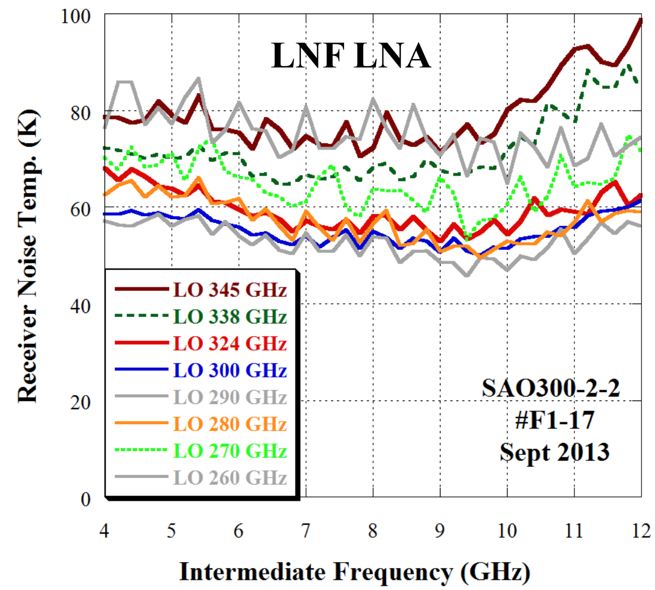


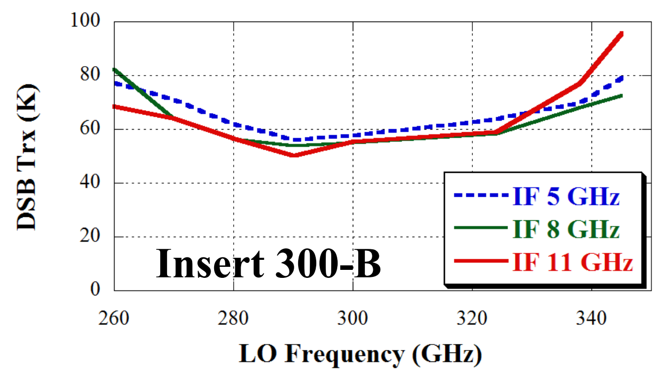
Low Noise Factory #LNF-LNC4_16A



Status of SMA-300 Receiver Set

- Upgraded to wideband chips end of 2013.
- Employs CRYO1-12 (Sandy) as LNA
- First unit with LNF amplifier to come online soon which should improve performance at high IF.
- Excellent sensitivity at mid-band (LO ~ 300 GHz)
- Sensitivity roll-off at 345 GHz due to lower conversion efficiency.
- Can be improved with lower leakage device.





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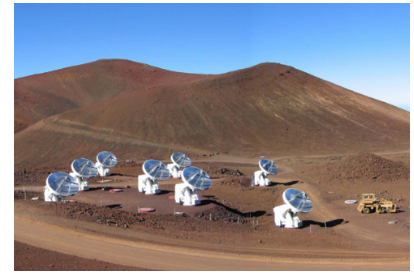
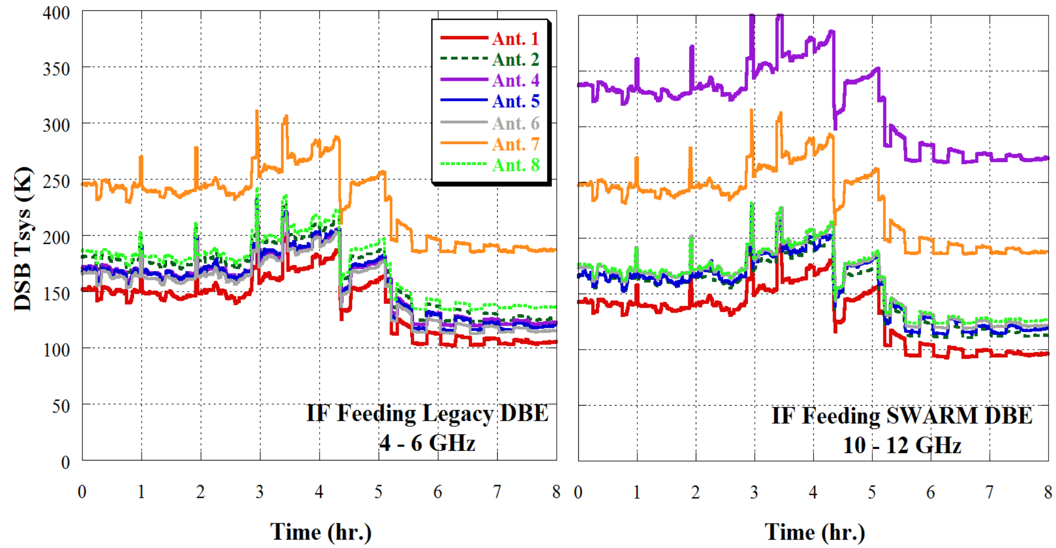
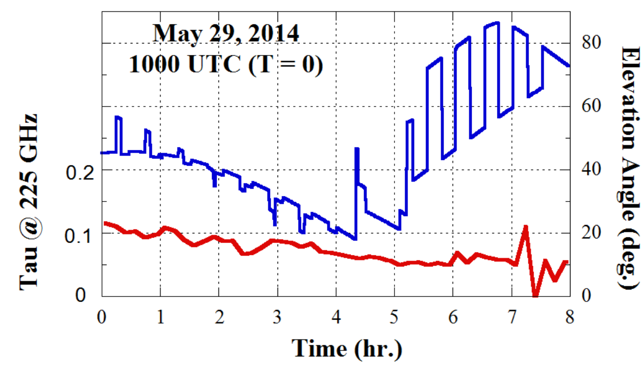


On-Telescope Performance of 300 WB Receivers

- SWARM test on May 29
- LO 278.8 GHz
- Most antennas perform within a tight range of Tsys .

	Tsys (11G) / Tsys (5 G)
Ant. 1	0.94
Ant. 2	0.92
Ant. 4	2.00
Ant. 5	0.99
Ant. 6	1.05
Ant. 7	1.01
Ant. 8	0.94





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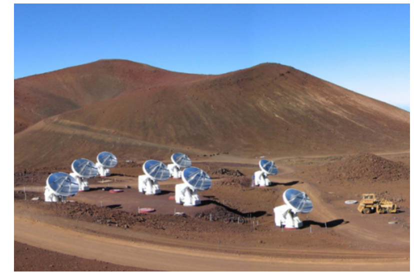
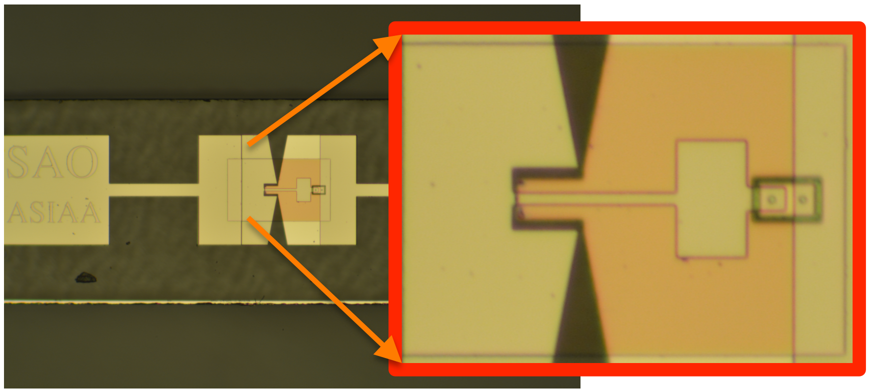
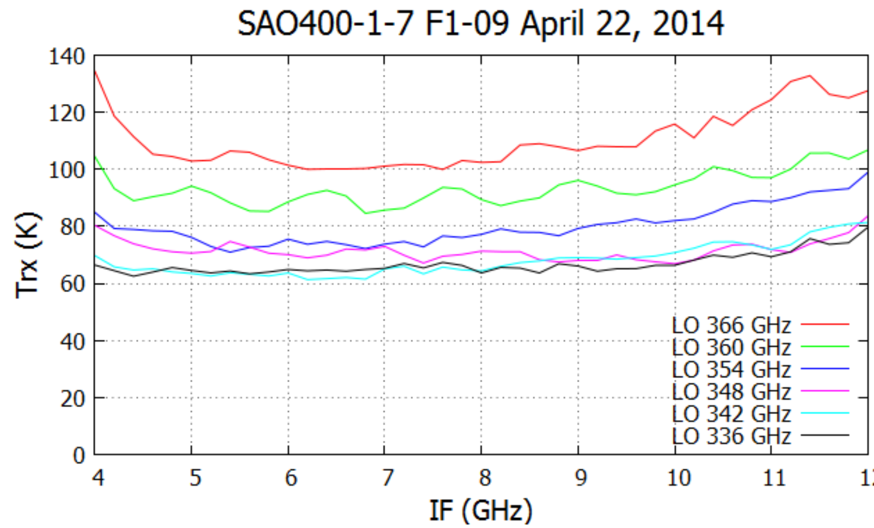
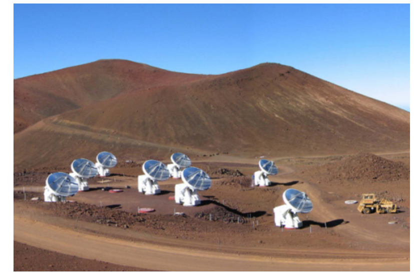




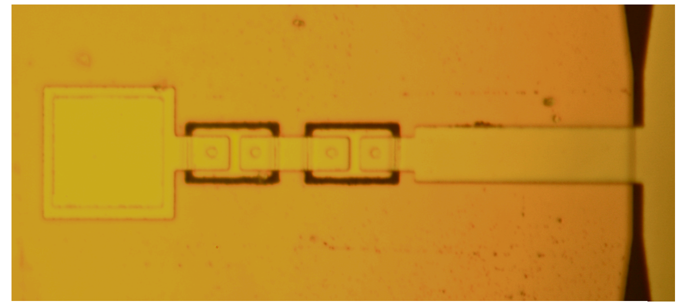


Ongoing 400 GHz Upgrade

- Design with 2-junction Array
- A few batches have been made by ASIAA
- Initial measurements performed in lab
- Junction size larger than design: mixer tuned low.
- Plan to install later this year pending on device supply.



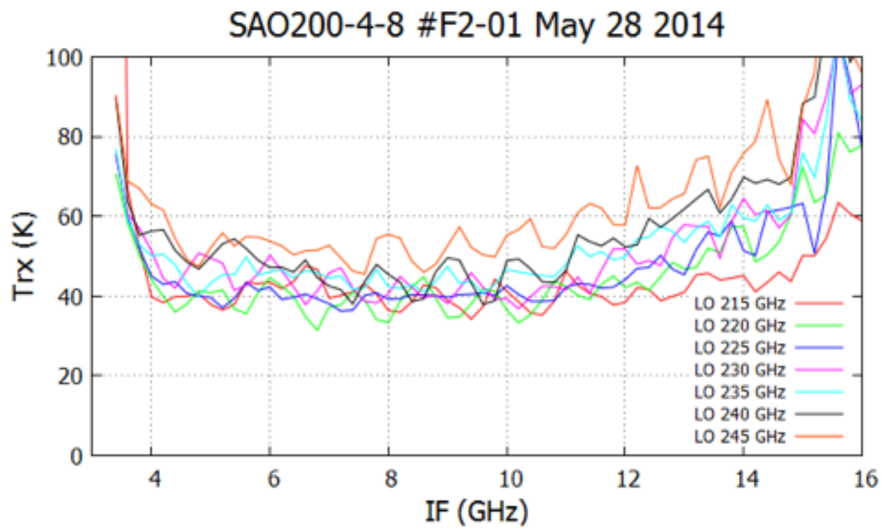
Ongoing 200 GHz Refinement

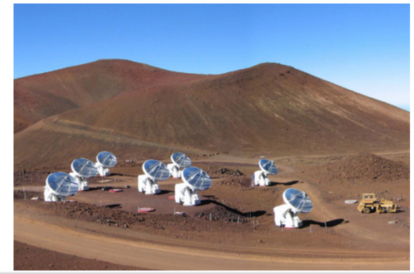


- The 3-junction design shows a drop in sensitivity above 11 GHz IF.

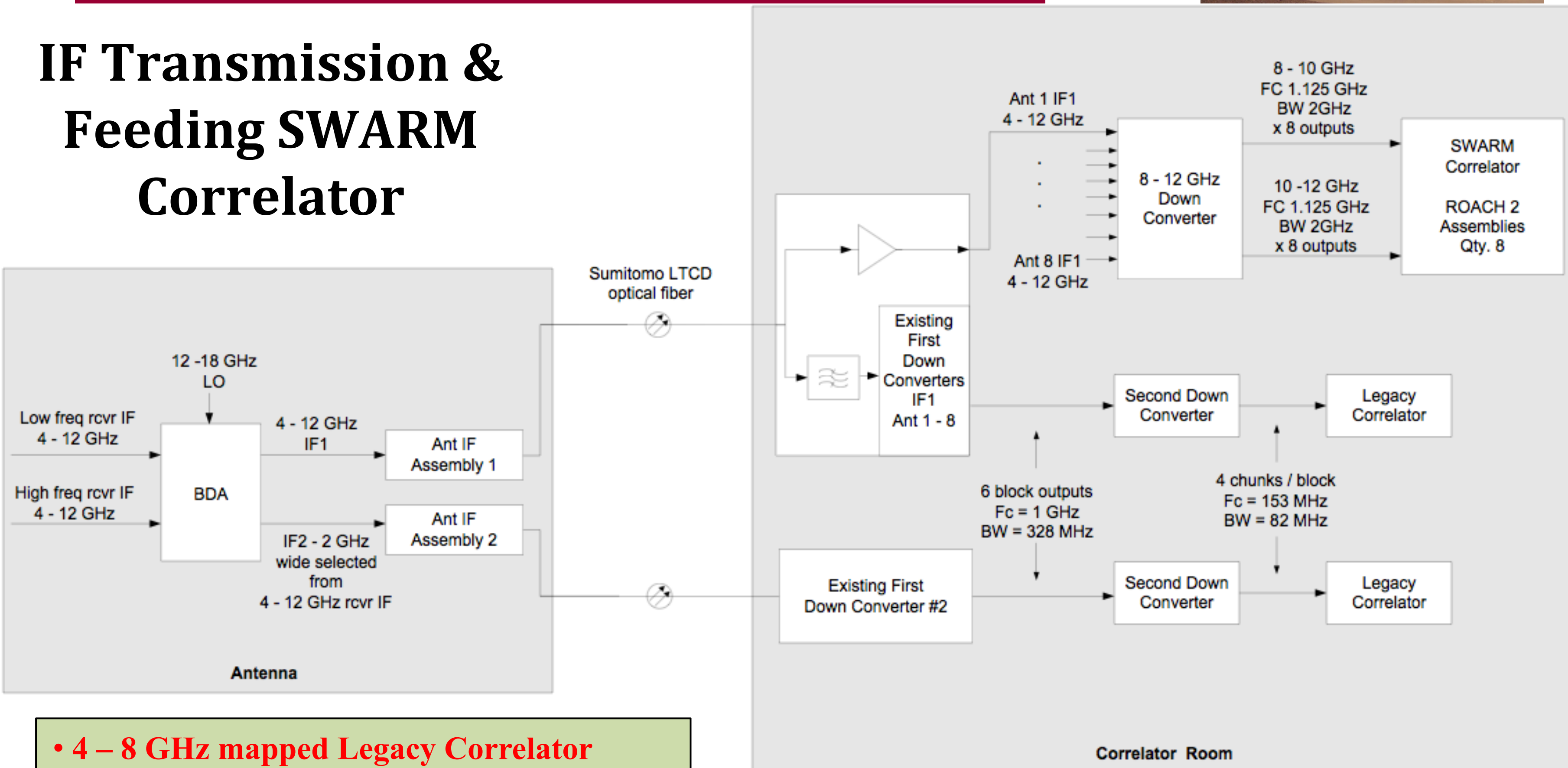
- Initial test with a 4-junction design in conjunction with the LNF amplifier gives good Trx up to 15 GHz IF.

- Refined 200 GHz mixers are expected to be in service by the end of 2014.

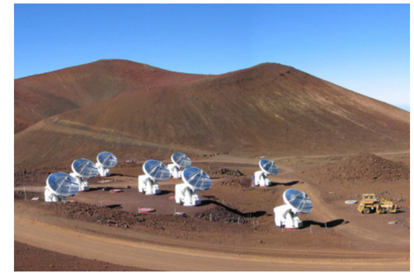




IF Transmission & Feeding SWARM Correlator

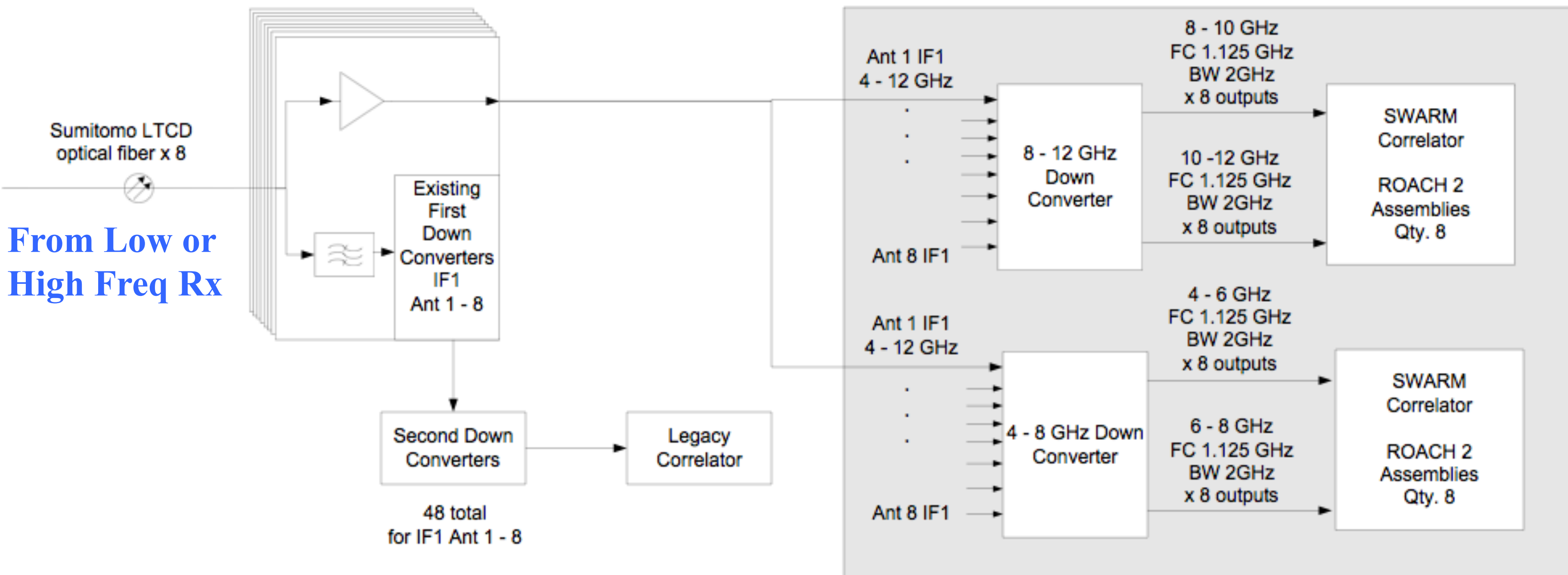


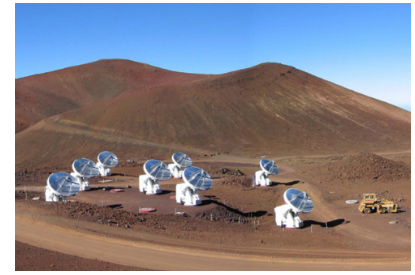
- 4 – 8 GHz mapped Legacy Correlator
- 8 – 12 GHz to SWARM Correlator
- Possibility of Dual 8 – 10 GHz on SWARM



Ongoing IF System Upgrade

New 4 – 8 GHz Downconverters will allow full SWARM operation on 4 – 12 GHz And/or 2 x (4 – 8 GHz) dual receiver operation.





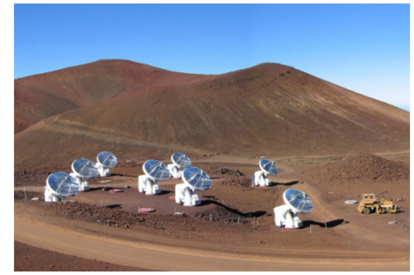
Medium Term Receiver Development Plans (2015 – 2016)

- Currently SMA allows dual-pol observation at around 345 GHz.
Propose to build one more receiver set (210 – 270 GHz) to allow dual-pol operation in the 200 GHz band.

- Upgrade all LNA with 4 – 16 GHz amplifiers to further expand IF band (requires more SWARM capacity).

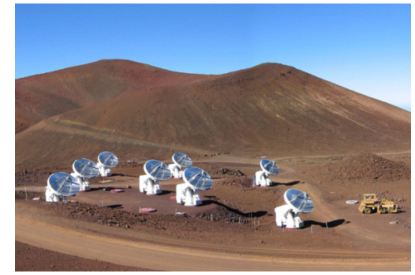
- Build more IF processors to keep pace with SWARM expansion.

- Develop YIG-based LO unit to replace Gunn-based unit to streamline tuning.



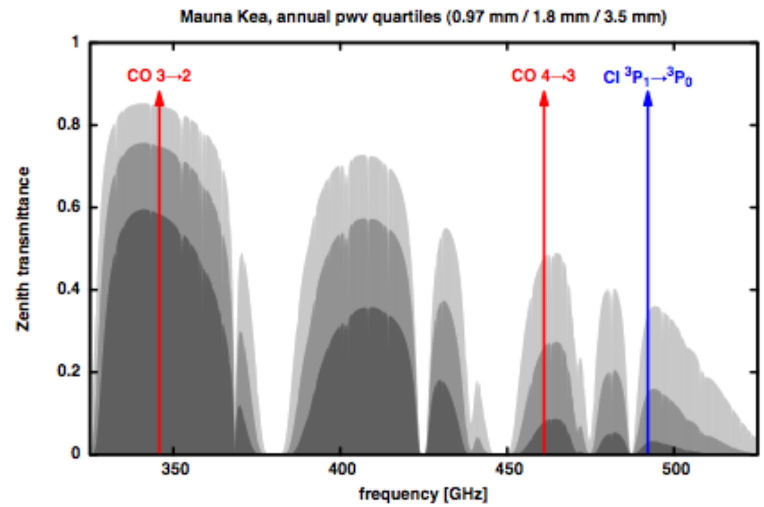
5-Year Time Scale Receiver Development Plan

- 460/490 GHz SSB Receiver Set
- 2SB Receiver Set for 270 – 370 GHz

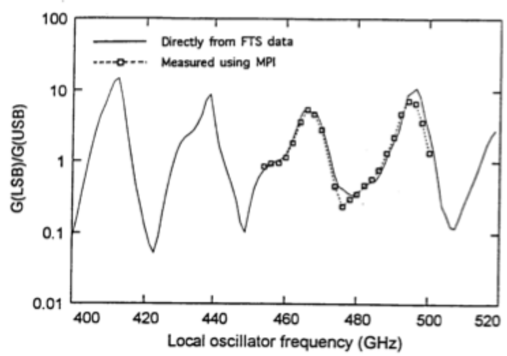


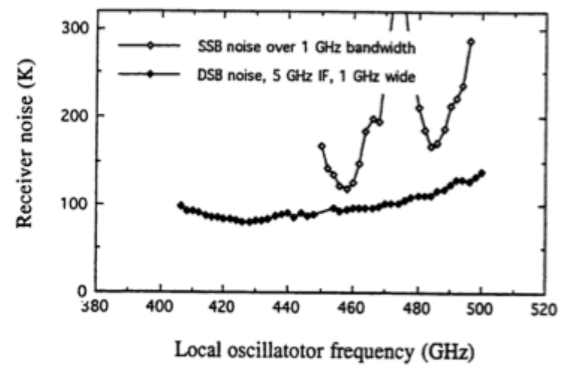
460/490 GHz SSB Rx

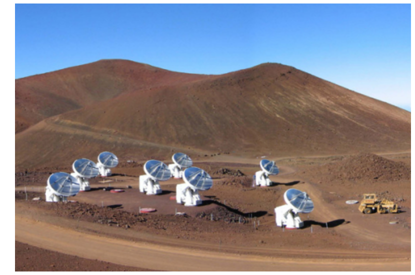
In 1990s, we have experimented with a 460/490 SSB receiver using a fixed backshort which nulled the image frequency at ~ 475 GHz



For projected T_{SSB} ~ 100 K, SSB Tsys to source of ~ 500 K (CO 4 – 3) and ~ 800 K (CI line) should readily be achievable.







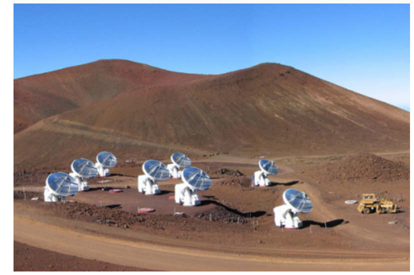
DSB Rx Vs 2SB Rx with Finite Image Rejection Ratio

Let the S/N ratio achieved by an SSB system be unity and α be the ratio of noise temperature.

$$\alpha = \frac{T_{\mathrm{DSB}}\ \text{(DSB system)}}{T_{\mathrm{SSB}}\ \text{(SSB system)}}$$

S/N ratio achieved by a DSB system compared to an SSB system	Infinite Image rejection ratio	Finite Image Rejection Ratio ρ
Continuum observation (both sidebands used)	$\frac{1}{\sqrt{2\alpha}}$	$\frac{1+\rho}{\alpha\sqrt{2(1+\rho^2)}}$
Spectral line observation (one side band used)	$\frac{1}{2\alpha}$	$\frac{1+\rho}{2\alpha}$

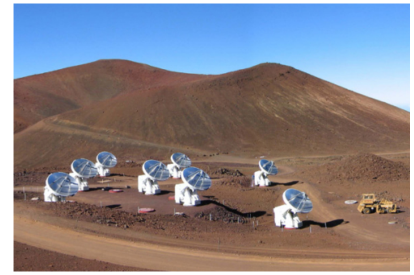
REF: *Thompson & Kerr ALMA Memo #168*



DSB Vs 2SB Receivers

Result from AM model for Mauna Kea: assuming 1.4 mm PWV 45-deg source

		230 GHz T_{atm}=32 K & T_R =35 K			**345 GHz** T_{atm}=85 K & T_R =50 K		
$\alpha = \frac{T_{DSB}}{T_{SSB}} \approx \frac{T_{atm} + T_R}{T_{atm} + 2T_R}$		**0.66**			**0.73**		
Image Rejection Ratio ρ		∞	**10 dB 0.1**	**6 dB 0.25**	∞	**10 dB 0.1**	**6 dB 0.25**
DSB : USB Relative Sensitivity	**Continuum**	**1.08**	**1.17**	**1.30**	**0.97**	**1.06**	**1.18**
	Spectral Line	**0.76**	**0.84**	**0.95**	**0.68**	**0.75**	**0.86**



- With a given available correlator BW, there is no significant advantage for 2SB observation in continuum for both 230 and 345 GHz.

- Spectral line observation at 345 GHz, however, can be enhanced by a 2SB system.

- For frequencies above 345 GHz, the impact of atmosphere is more significant. 2SB system extending to 370 GHz would be useful.

- There is currently a development of waveguide LO injection receiver development for GLT at the Receiver Lab. So, it would be a parallel development.

- Price tag of such a receiver set would be of the order of $1 million.

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