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Center for Astrophysics

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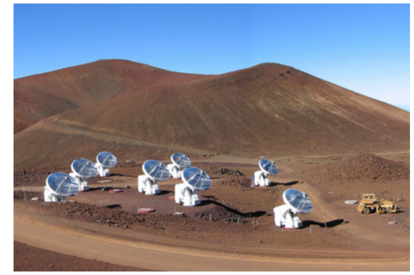


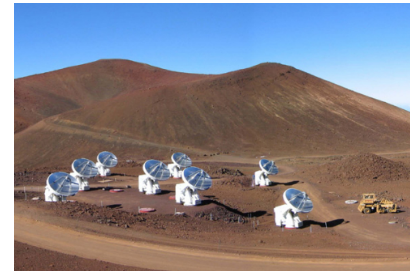
Ultra-Wide IF Operation for SMA

Why do we want to pursue very wide IF?

- **Increase continuum sensitivity:** $\Delta T = \frac{T_{sys}}{\sqrt{B\tau}}$

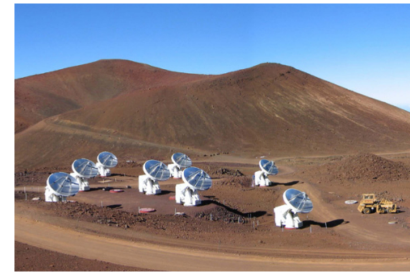
- **Catch more spectral lines with a single tuning**

- **With very wide IF, the extent of the spectral coverage (F_{LO} ± $F_{IF\text{-}max}$) may be able to cover 2 emission lines with different transition orders from red-shifted objects.**



A little of History …

Late 70s	SIS starts. L-band (1.5 GHz) pre-amp common BW 0.5 GHz
Early 80s	IRAM operates C-band IF on 30 m. 3.5-4.5 GHz
Early 90s	SMA decides to use 4 – 6 GHz IF
Late 90s	ALMA moving to 4 – 8 GHz IF
Early 2000s	4 – 12 GHz IF operation reported by some ALMA bands
2004	Tong *et al* reports on wide band SIS mixing up to 20 GHz



Realizable IF Bandwidth of SIS Mixers

• Real life SIS mixers carry extra capacitance due to the matching circuit

• SIS mixers operated by a Local Oscillator exhibits high output dynamic resistance, $\boldsymbol{R}_{\text{dyn}}$, typically many times the value of $\boldsymbol{R}_{\text{n}}$.

• SIS mixers are connected to an IF load of 50-ohm.Since this load impedance is much lower than $\boldsymbol{R}_{\text{dyn}}$, it dictates the extrinsic time constant.

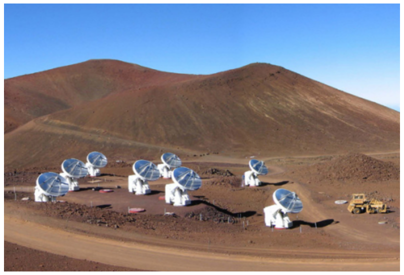
$$F_{\text{BW}} = \frac{1}{2\pi \cdot 50 \cdot (C_j + C_{\text{tune}})}$$

For current SMA receivers,

$$(C_j + C_{\text{tune}}) \approx 0.3\, p\text{F}$$

yielding F_{BW} ~ 10 GHz

Key: Reduce capacitance!



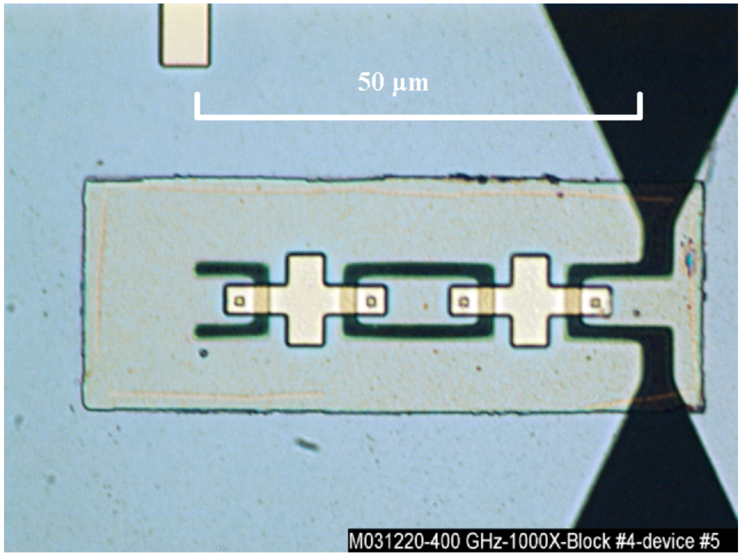
How to reduce mixer capacitance?

• Putting SIS devices in series: would also help to alleviate saturation effects with the wider IF bandwidth

• Avoid low impedance sections which add more capacitance

• A revolutionary design was proposed in 2003, devices made later that year by JPL and tested in 2004.

• The 4-junction series array synthesized a distributed mixer with a wide IF bandwidth > 20 GHz



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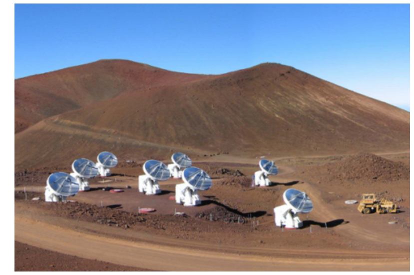
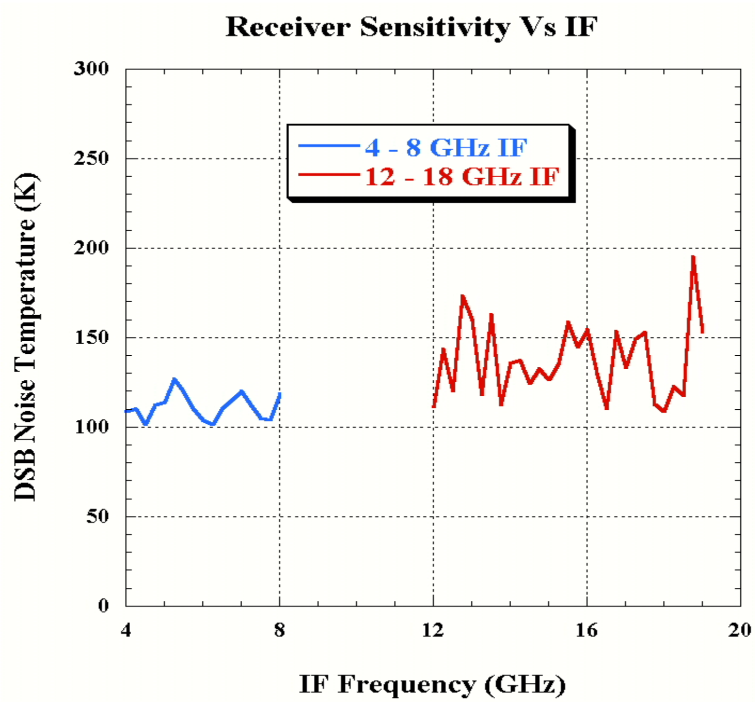




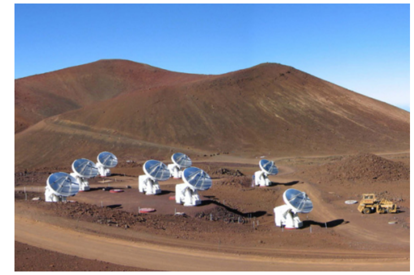
The data shown assumes a double-side-band response, although the side-band ratio is not unity at high IF. DSB noise temperature reflects the average of T_{USB} and T_{LSB}, weighted by the side-band ratio.

Y-factor measured at High IF is comparable to that measured at 5 GHz.

Example: Y ~ 2.1 @ 18 GHz IF Vs
Y ~ 2.2 @ 5 GHz IF

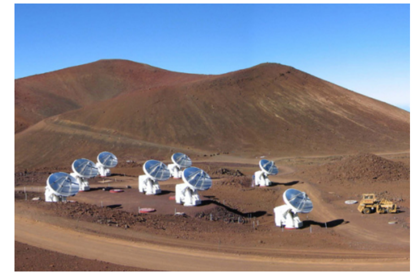
For the 4 – 8 GHz measurement, noise temperature of IF system is 4 – 5 K, compared to a minimum of 10 K in the 12 – 18 GHz measurement.

T_{DSB} at high IF shows large fluctuations due to mismatch between the mixer, bias-tee and amplifier. In the 4 – 8 GHz measurement, a circulator is used. For high IF applications, the amplifier and bias-tee should be integrated close to mixer chip.



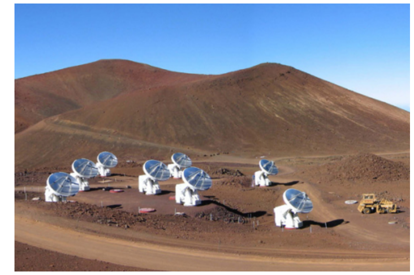
Enabling Technologies:

- ultra-wide band low noise cryogenic amplifier
- wide band cryogenic isolator

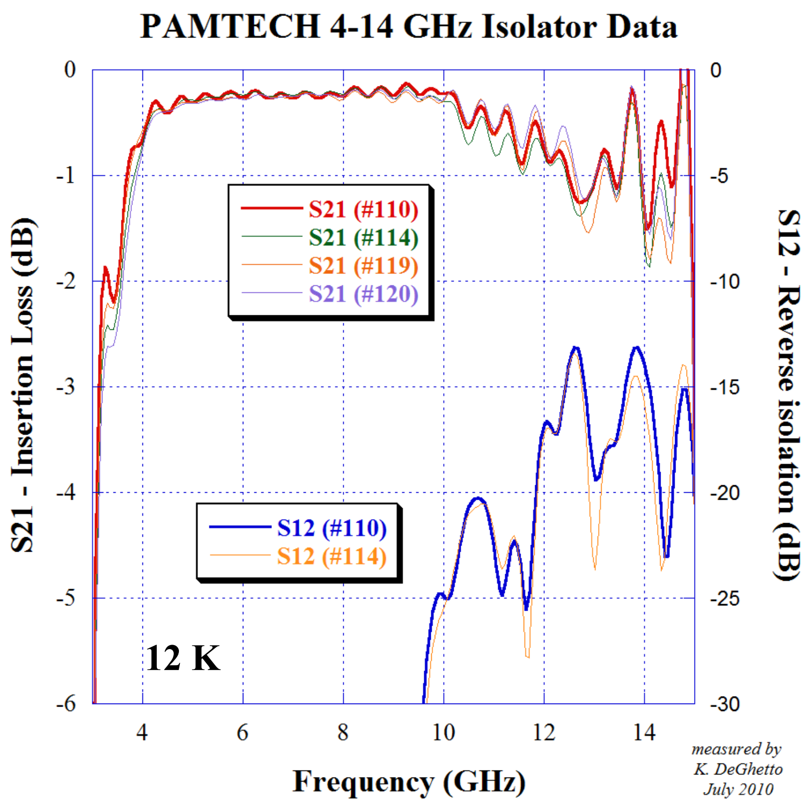


Challenges of ultra-wide IF operation

- Huge data rate
- availability of components, especially for cryo temperature
- wide bandwidth microwave components generally present a poorer match — standing wave issues
- stainless steel coax cables for cryogenic operation becomes very lossy at higher frequencies.
- achieving a compact package to fit into existing receiver infrastructure



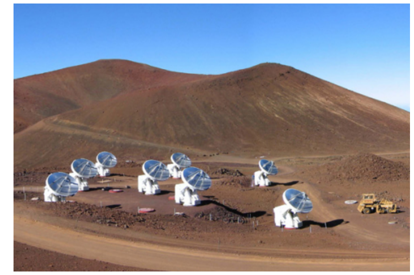
Wide Band Cryogenic Isolators



The 4 – 14 GHz isolator is an improved version of the 4 -12 GHz isolators used in some ALMA bands

- Insertion Loss < 1.2 dB for 3.5 – 14 GHz
- Good isolation up to 10 GHz; above 10 GHz 14 dB reverse isolation
- Input & Output return loss < -15 dB

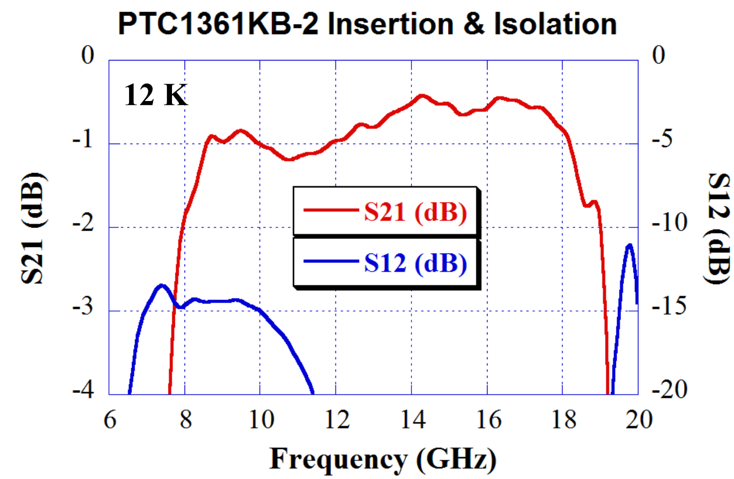
- PAMTECH is now owned by Quinstar
- Ship us 10 of these isolators in 12 weeks

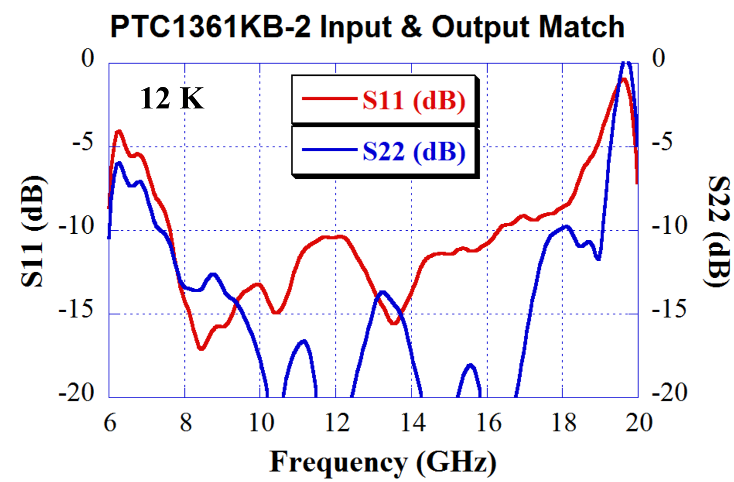


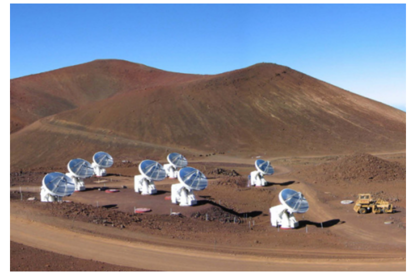
New 8 – 18 GHz Cryogenic Isolator

- Initially designed by PAMTECH as a 12 – 18 GHz unit for NASA's deep space network
- compact: 2 x 1 x 1 cm (*Vs* 6.5 x 3.5 x 1.5 cm for the 4-14 GHz isolator)
- Insertion Loss: 1.2 dB over 8.5 – 18.5 GHz
- Reverse Isolation better than 14 dB
- Measured Input match is relatively poor --- only -9 dB return loss
- Reasonable Output match

- Currently working with Quinstar to reproduce and improve the performance

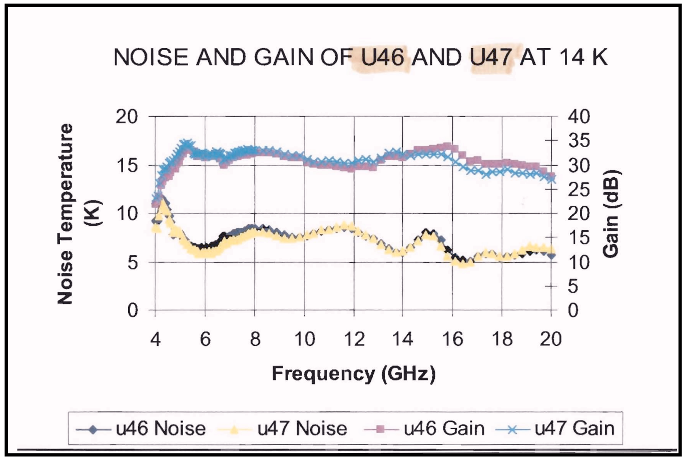






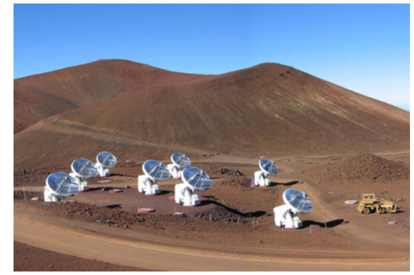
High Frequency Cryogenic Low Noise Amplifiers to 18 GHz

- Best fit model is the ones developed for EVLA by Marion Popieszalski
- Requires isolator to use
- Balanced amplifier configuration is possible but requires good wideband quadrature hybrids. Also more amplifier modules have to be built
- Realistic to expect them to work between 8 and 18 GHz
- Other sources (?)

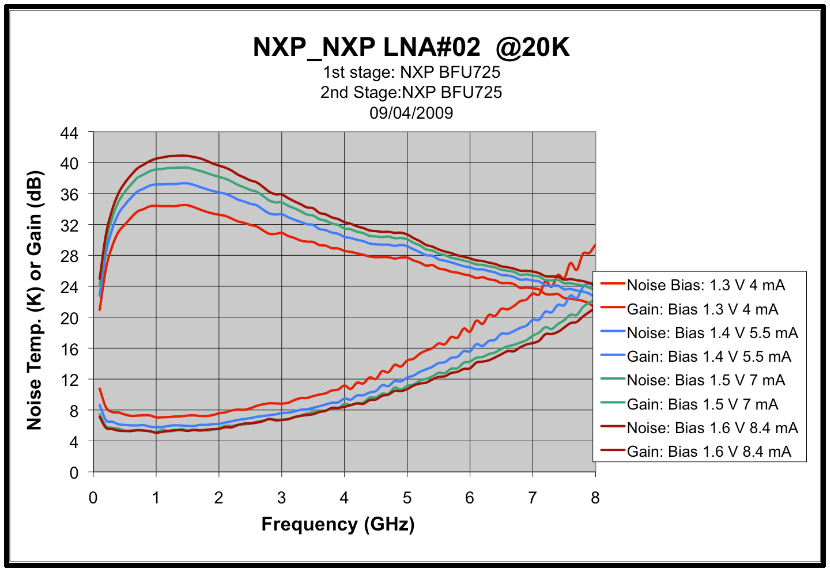


Measured data of two NRAO amplifiers on loan to SAO (courtesy of Marion Popieszalski).

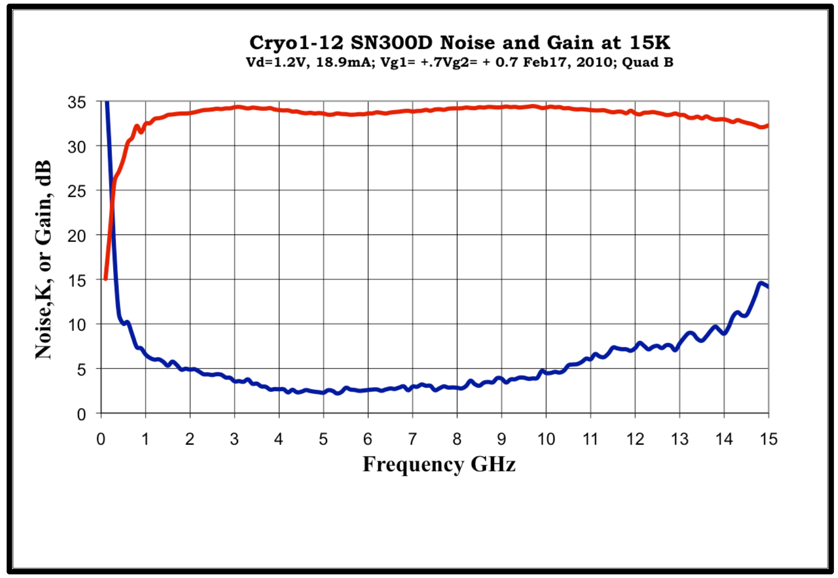
Tamp<8 K between 5 and 20 GHz



Cryogenic LNA developed for SKA (Sandy Weinreb)



- Good input match, no need of isolator
- Relative easy to reproduce
- Usable up to 4 GHz with commercial transistors
- High potential for further development



- MMIC developed for SKA
- Use for ALMA receivers built by Japan
- Poor input match: require isolator for operation.

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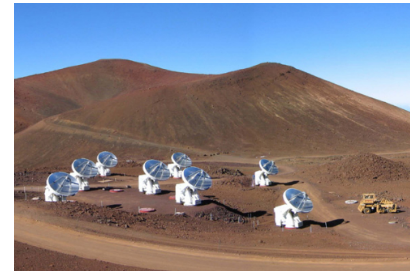
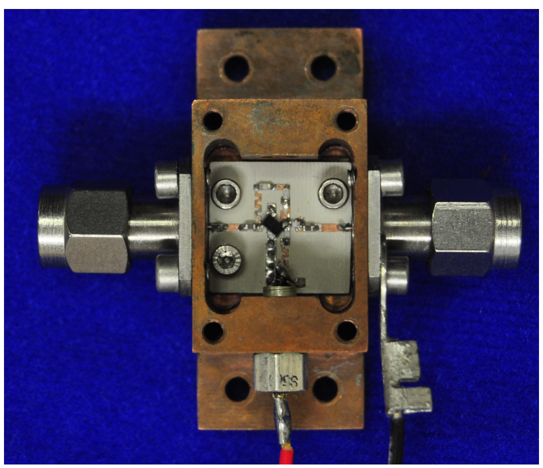


In-House Cryogenic LNA Development

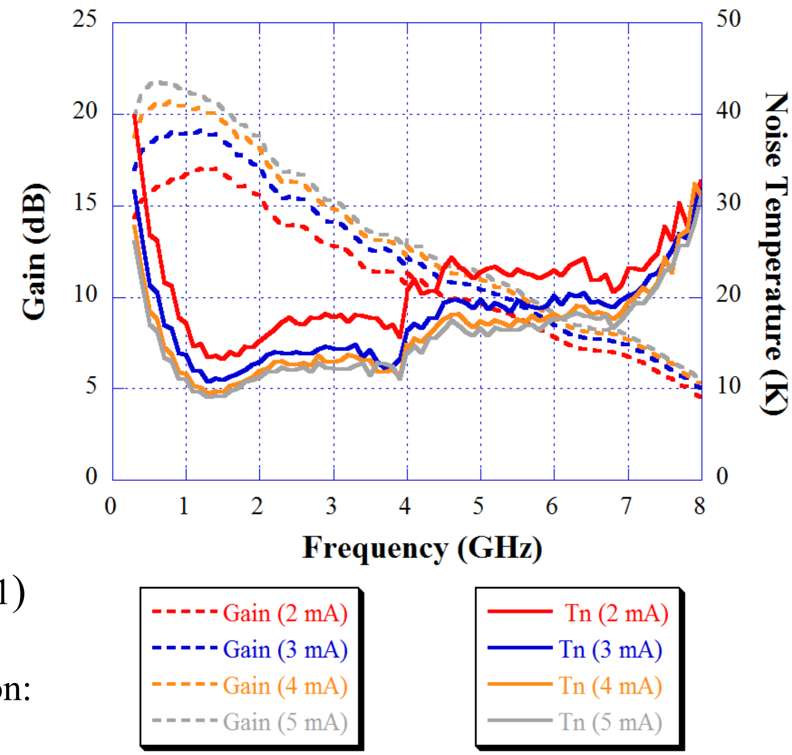
- **Based on Sandy Weinreb design**
- **Employ newer generation of SiGe transistor**
- **Work started in July 2010**
- **Preliminary results obtained recently**
- **Target operating frequency: 0.1 – 8 GHz**



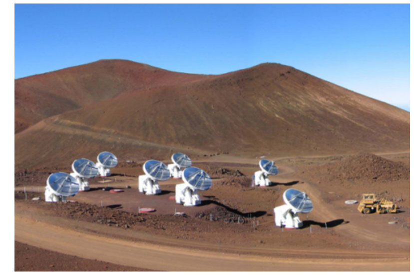
Single stage BUF transistor (cost ~$1)

Power consumption: ~6 mW per stage

Performance @ 15 K measured Oct 6, 2010



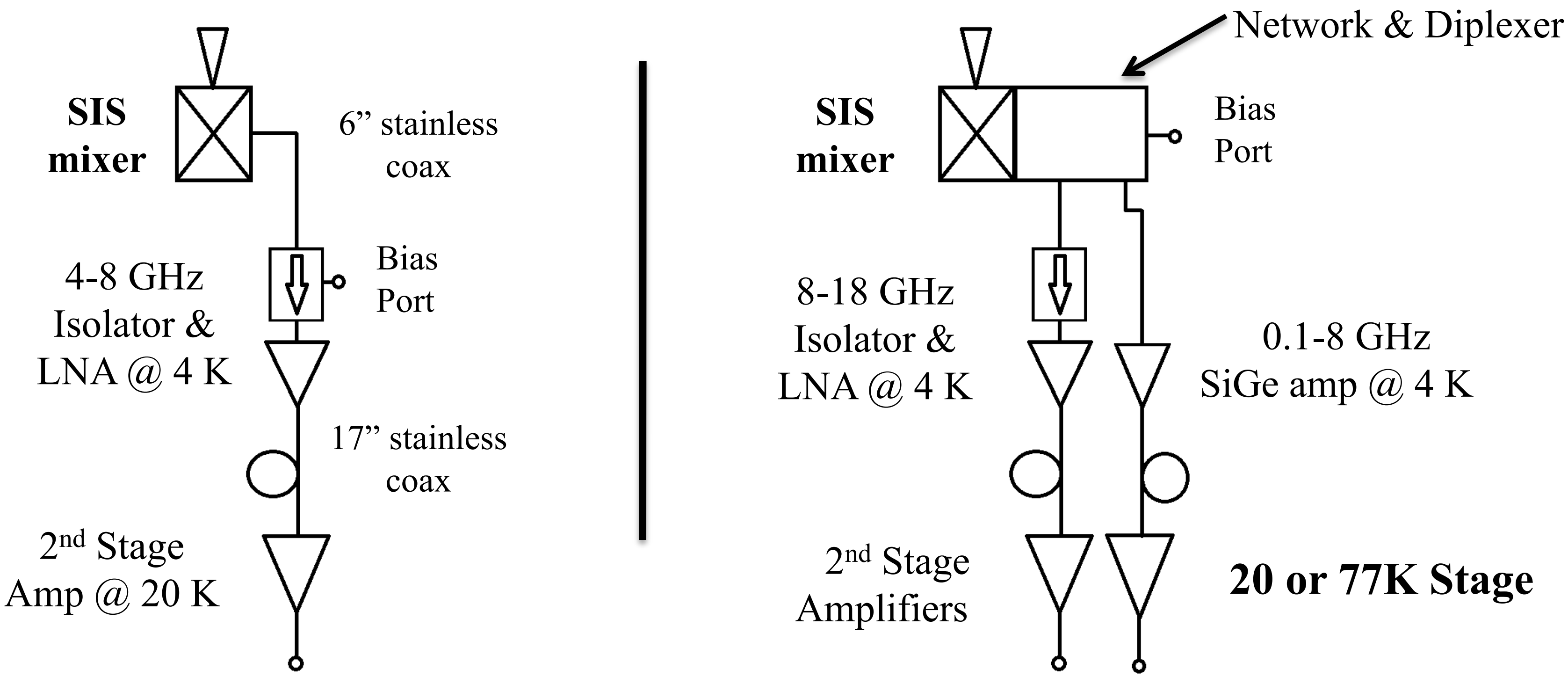
Credit: Kyle DeGhetto, Robert Kimberk and Steve Leiker



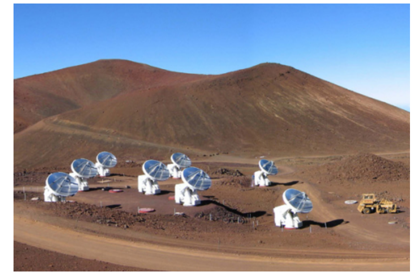
Plan for Wide IF Receiver Implementation

Current Configuration

Proposed Configuration

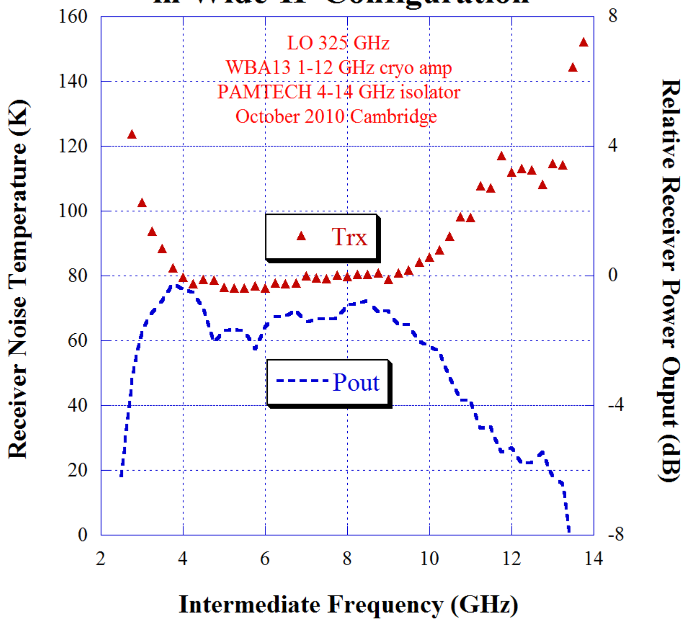


Cryostat Outputs: 8-18 GHz & 0.1-8 GHz

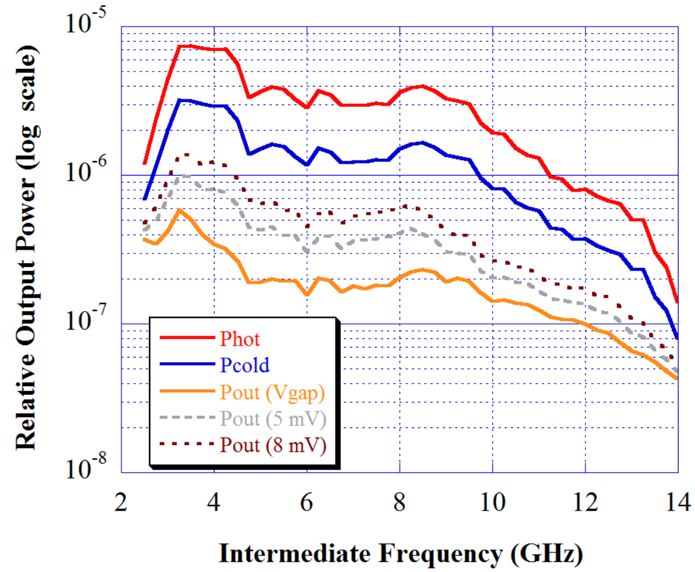


What is our current performance with existing components?

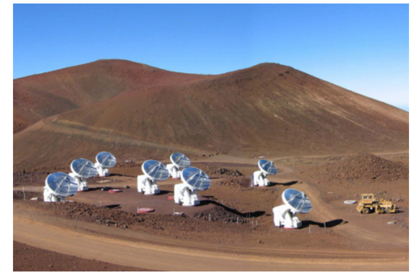
**Performance of SMA-300
in Wide-IF Configuration**



Receiver Output Power Spectrum

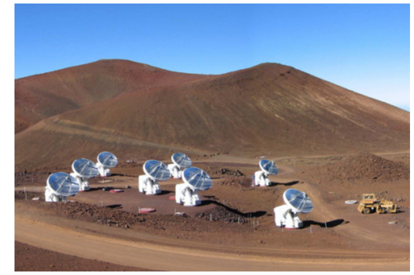


- Roll-off above 10 GHz IF is due to an increase in noise temp. of both mixer and amplifier
- LO set to 325 GHz to right on top of water line
- This experiment is set up in the receiver lab



Plan for New wide-IF band SIS mixers

- UVa --- New 200 GHz mixer with staggered tuned 2-junction array is currently being worked on (contact person: Arthur Lichtenberger).
- NAOJ --- Exploration of a joint collaboration to make a 4-junction series array mixer for 200 GHz (contact person: T. Noguchi)
- Koln --- Talking about developing beam lead mixer with novel tuning design targeting 300 GHz band (contact person: Karl Jacob)
- IRAM --- has discussed about the possibility of a 300 GHz run (contact person: Karl Schuster)



Summary

- Extension of IF bandwidth to cover 0.1 – 18 GHz range promises to increase sensitivity of SMA and extend spectral coverage.
- To achieve wide IF bandwidth, SIS junction capacitance has to be reduced.
- Novel SIS designs exist to extend the available IF bandwidth.
- Amplifier technology is moving along the direction of wider band operation.
- Wide-band cryogenic isolator exists and is being developed.
- Plans are in place for using diplexer to cover 18 GHz band with 2 LNA.
- Intermediate target to cover 3-13 GHz IF is in progress.
- Working with various institutes to make new SIS mixers with very wide IF coverage.

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