

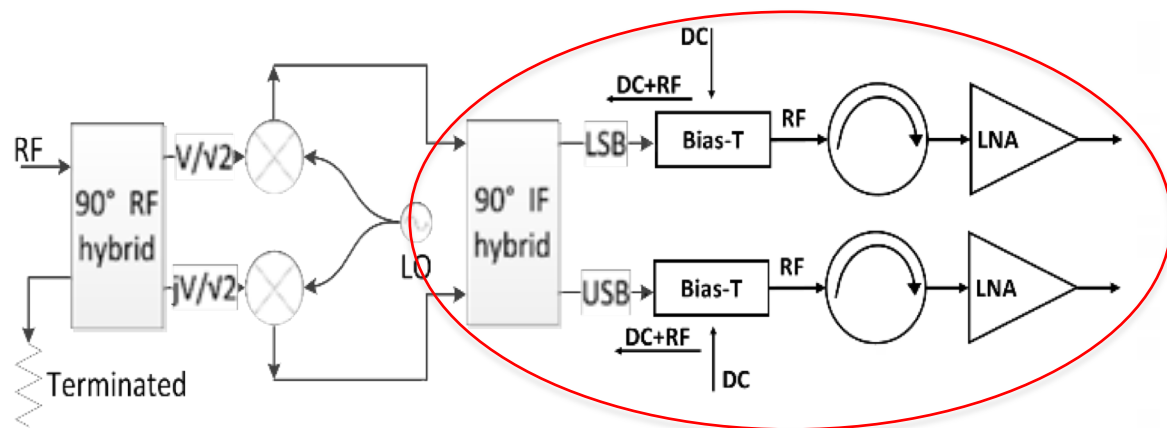
Balanced Amplifiers for Future ALMA Wideband Receivers

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Wideband IF receivers – Limits and solutions

The **ALMA 2030 Roadmap**:
**doubled RF and IF bands for
2SB receivers** compared to
today's receivers

The ***whole IF chain*** needs to be
broadband

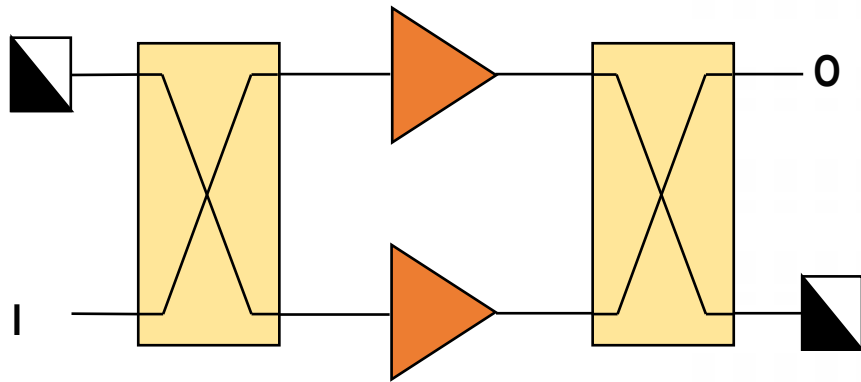


The whole IF chain needs to be wideband:

- ✓ **SIS mixers:** Not IF limited at intrinsically
- ✓ **IF Hybrids:** 4-12GHz exists, 4-16GHz and 4-20GHz under development
- ✓ **Bias-T:** 4-20 GHz already in place:
- !! **Isolators:** 4-12GHz maximum and with some loss
- !! **Amplifiers:** 4-12 GHz / 4-16 GHz noise performance limited by Noise / match trade-off: require isolators

Balanced amplifiers can make the whole IF chain wideband and possibly compact !!

Balanced Amplifier Technology



$$F = \frac{F_1 + F_2}{2}$$

$$G = \frac{G_1 + G_2}{2}$$

$$\Gamma = \frac{\Gamma_1 - \Gamma_2}{2}$$

Provide **at the same time** :

- Same Gain and Noise performance as single-ended amplifiers
- Superior input matching

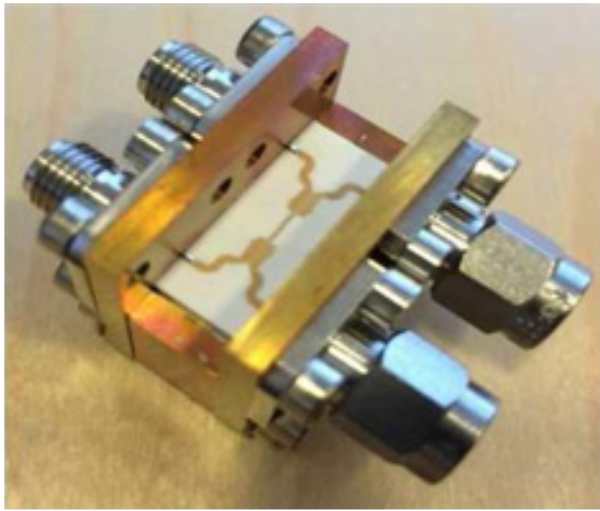
Requires co-design of:

- ✓ Compact “lossless” wideband hybrids
- !! low power , low noise, wideband amplifiers

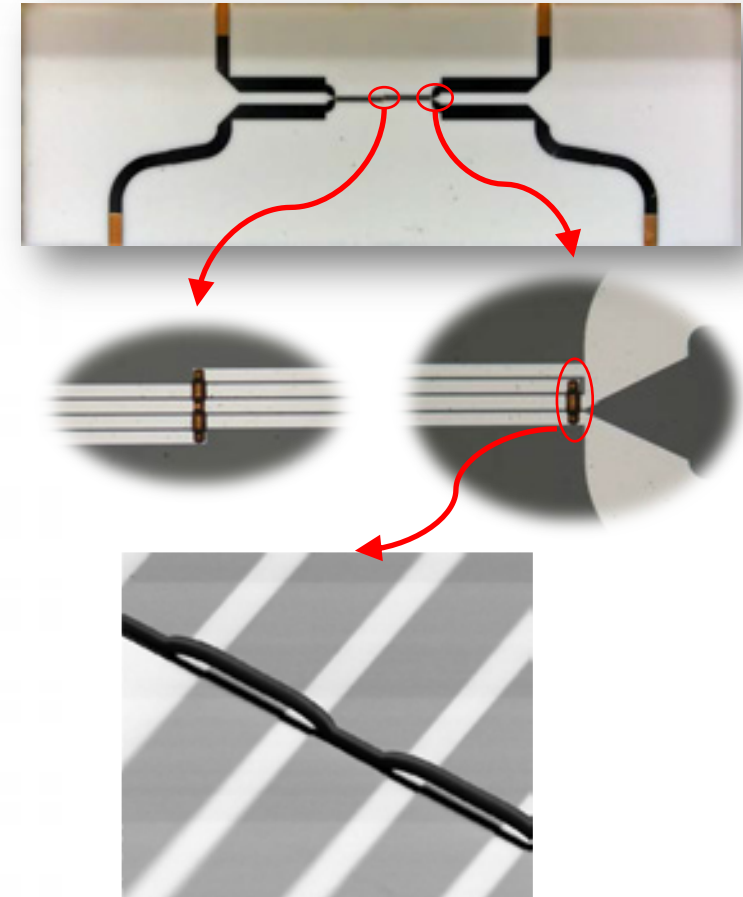
Low Loss compact wideband hybrids

✓ Compact design

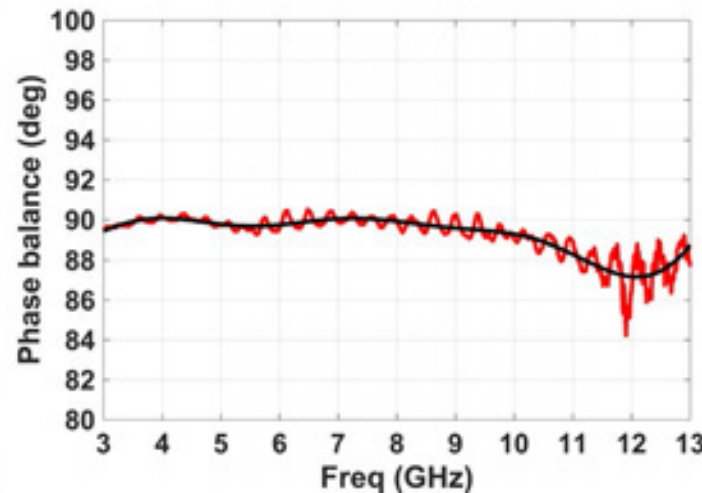
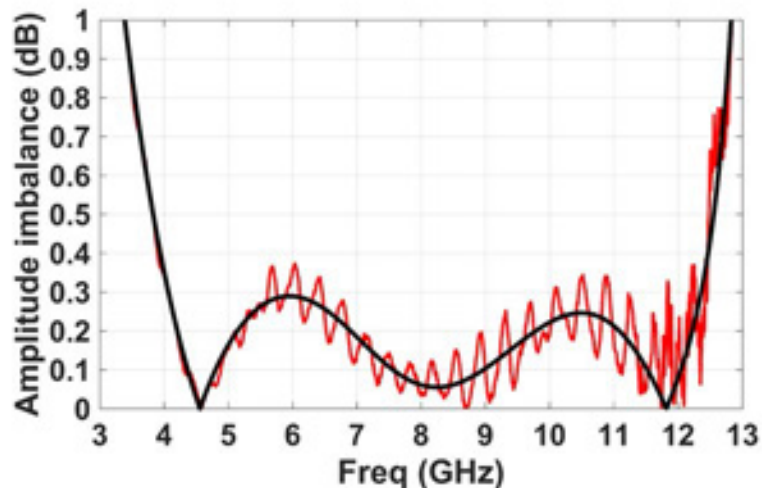
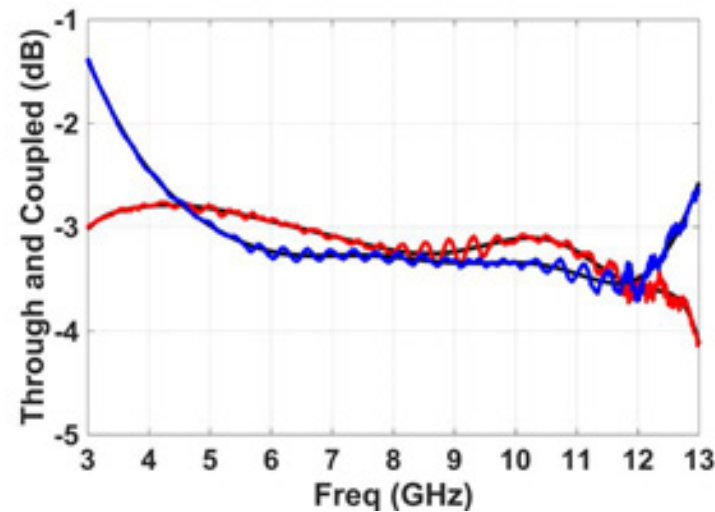
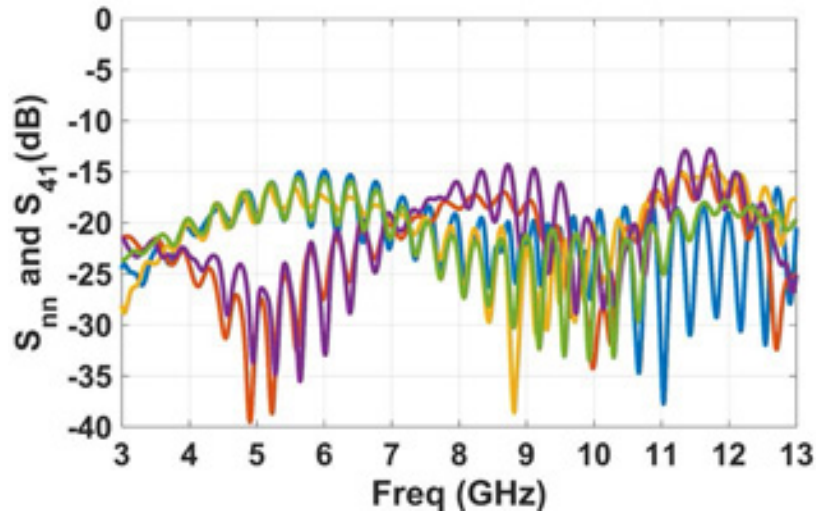
- *In-house fabrication*
- Planar design
- Superconducting Nb transmission lines to minimize losses
- Can include built-in Bias-T
- Microstrip lines ease the integration with LNA



Superconducting hybrid for balanced LNA



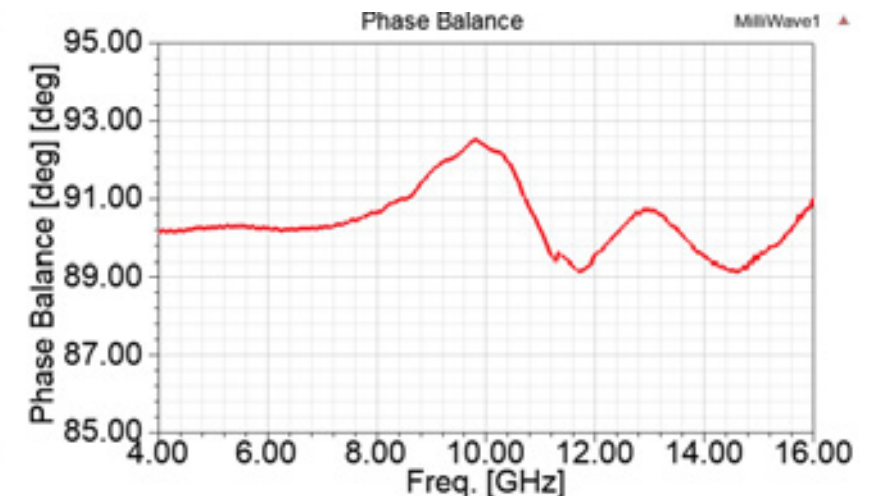
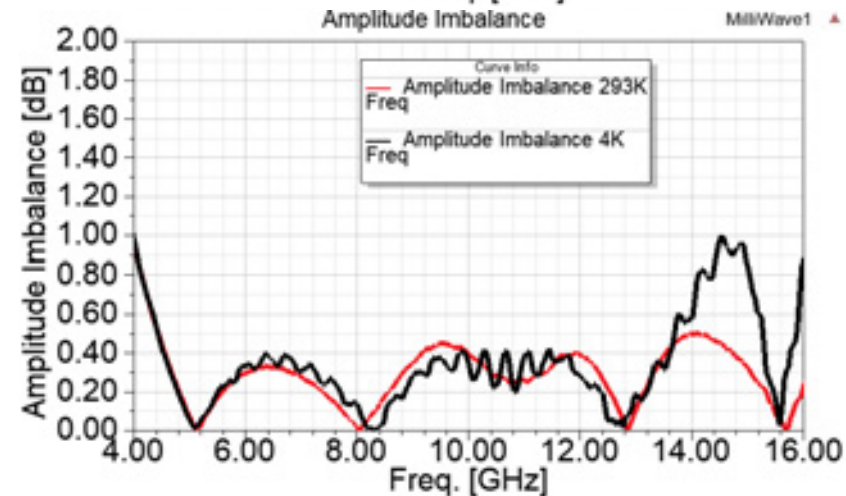
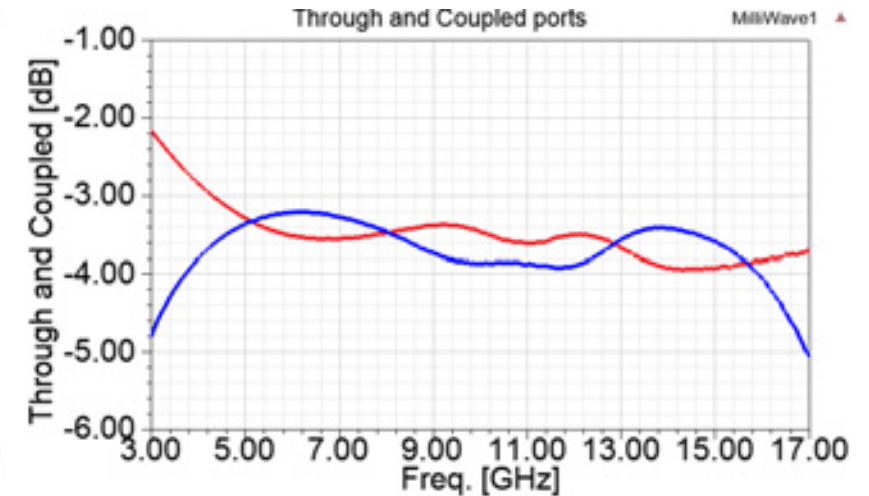
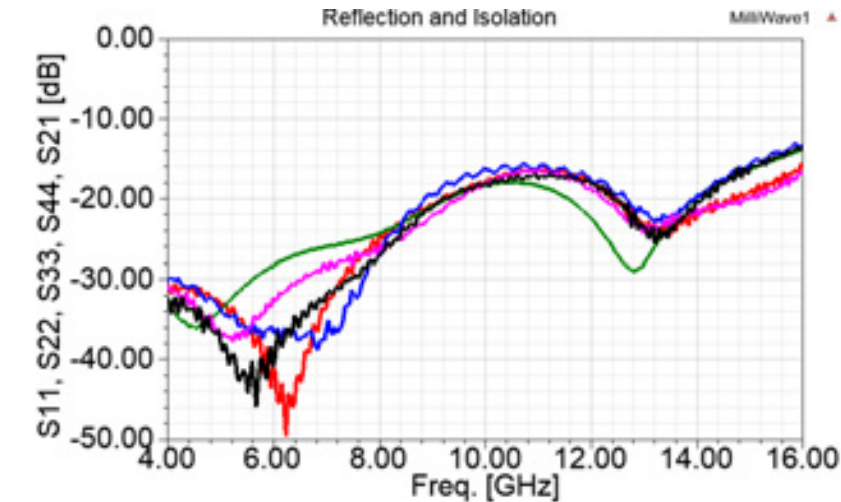
Low Loss compact wideband hybrids



- ✓ Low loss
- ✓ Excellent amplitude and phase imbalance
- ✓ Adequate return loss
- ✓ 4-12 GHz

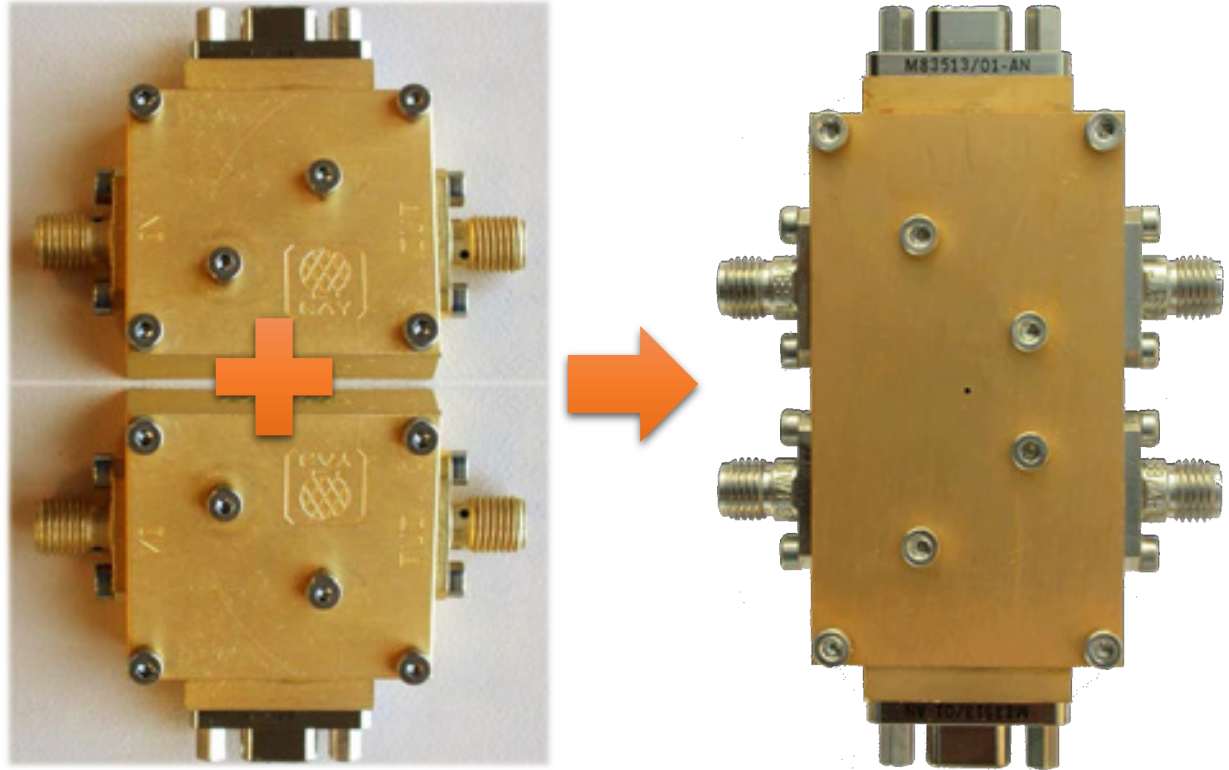
Compact prototype hybrid chips with even wider bandwidth?

- ✓ **Yes** , 4-16 GHz /4-20 GHz is possible...
- ✓ ... with proper support of the activity



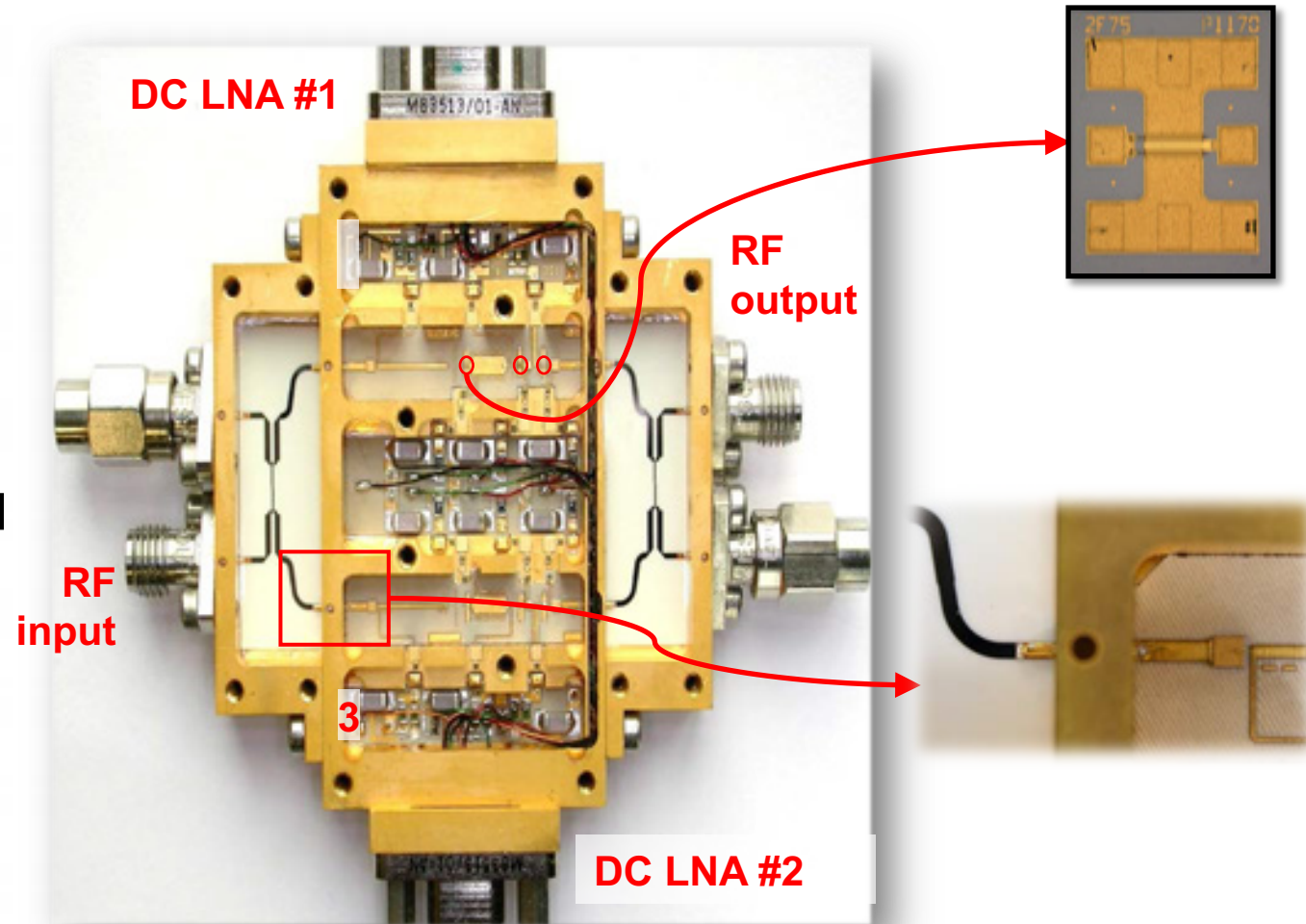
Low Noise Amplifiers

- Design in hybrid technology with microstrip substrates based on **ALMA 4-12 GHz IF LNAs** for Bands 9
- High performance **InP transistors** from **Diramics** (former ETH) with $150 \times 0.1 \text{ } \mu\text{m}$ gates used in the first stage to improve noise temperature.
- Designed with **poor input reflection** to optimize noise, as it was conceived to be used with a cryogenic isolator.
- In house fabrication and assembly of the modules and DUROID substrates.

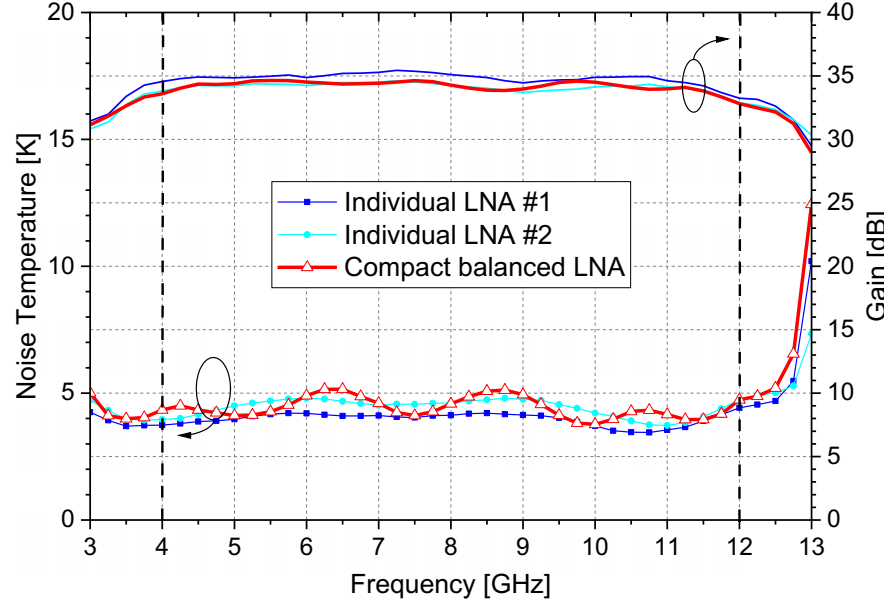
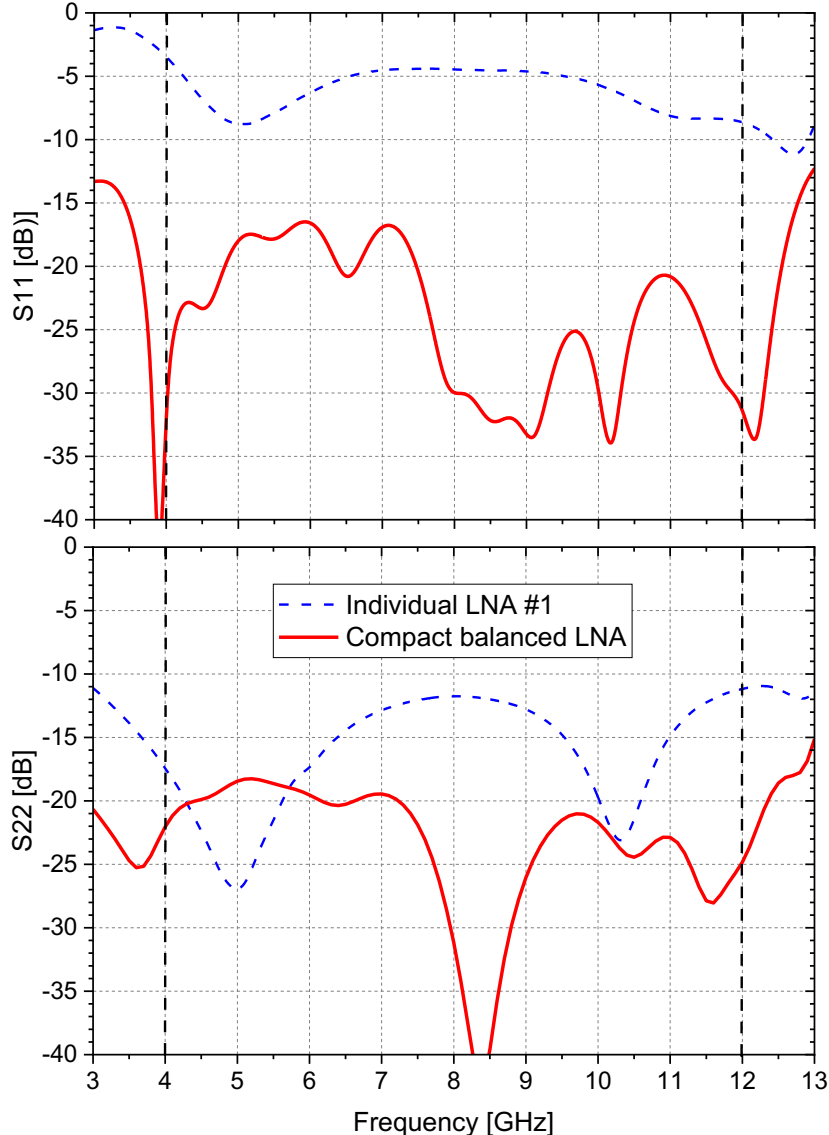


Compact Balanced Amplifiers

- **Modular design** enables verifying and tuning the LNAs prior to hybrid integration
- Interface between hybrid and LNA through connector bead and tab contact
- All blocks machined in CuTe and gold plated
- Proof of concept design trying to reproduce single ended LNAs
 - ***Not optimized size-wise***
 - Separate bias connector for each amplifier

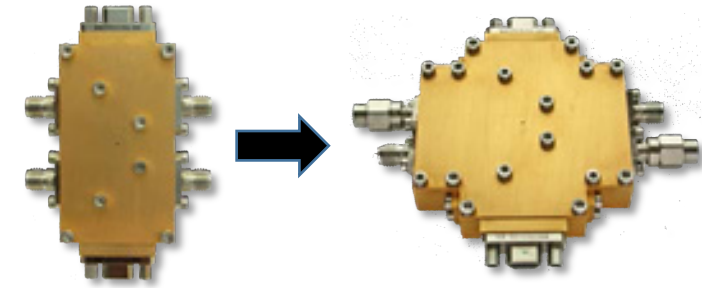


Compact Balanced Amplifiers vs its individual LNAs



Compact Balanced LNA performance 4-12 GHz @ 5 K

Average Noise (ripple)	4.4 K (1.4 K)
Average Gain (ripple)	34.1 dB (1.7 dB)
IRL max.	-15.8 dB
ORL max.	-18.3 dB
Power dissipation	12-15 mW

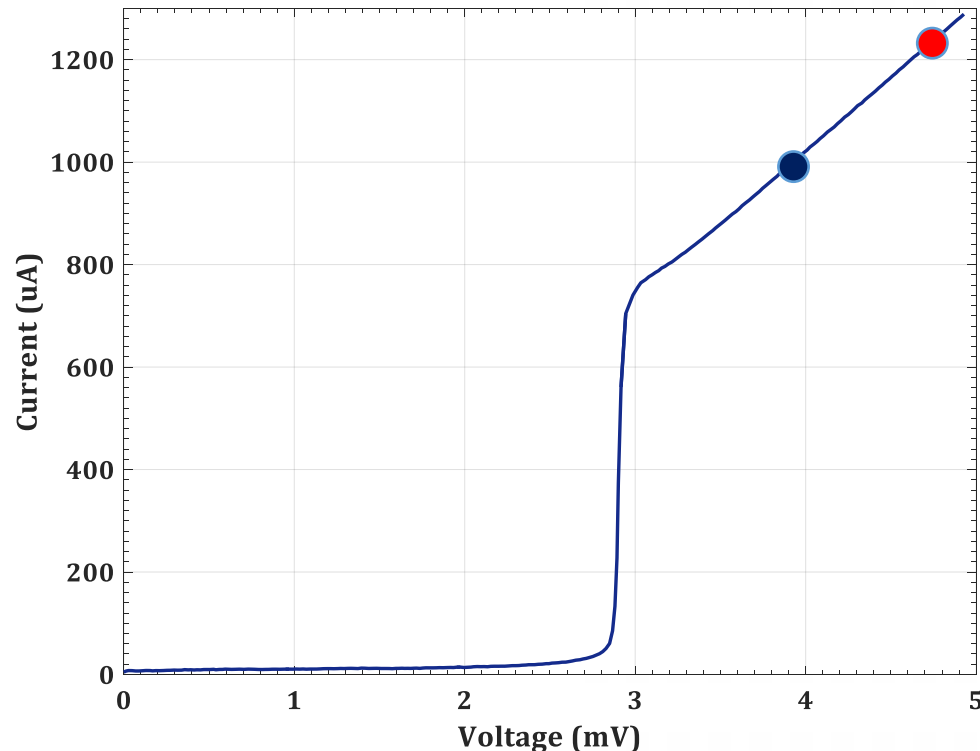


Noise degradation due
to input hybrid
below 0.2 K !

**But Improvement in
input reflection by
more than 10 dB !**

LNA's influence on IF chains performance

SIS is used as a calibrated shot noise source while biasing above V_g to measure the Noise temperature of the Mixer's IF chain

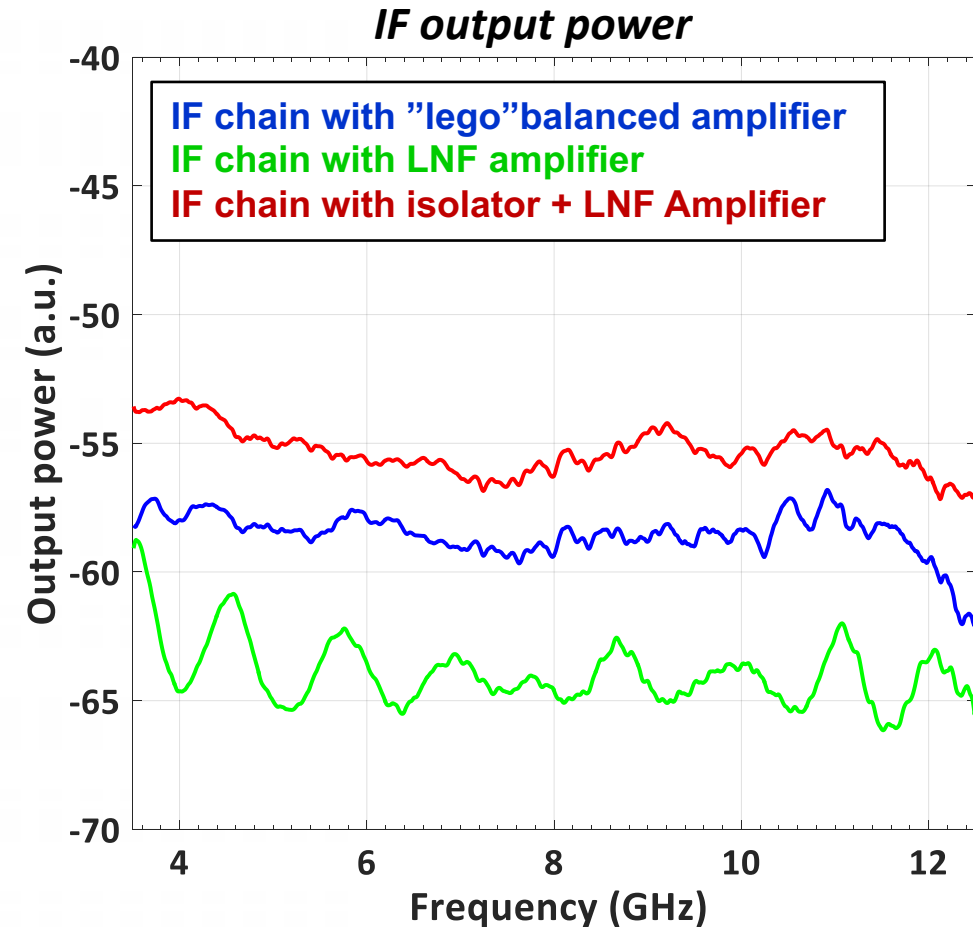
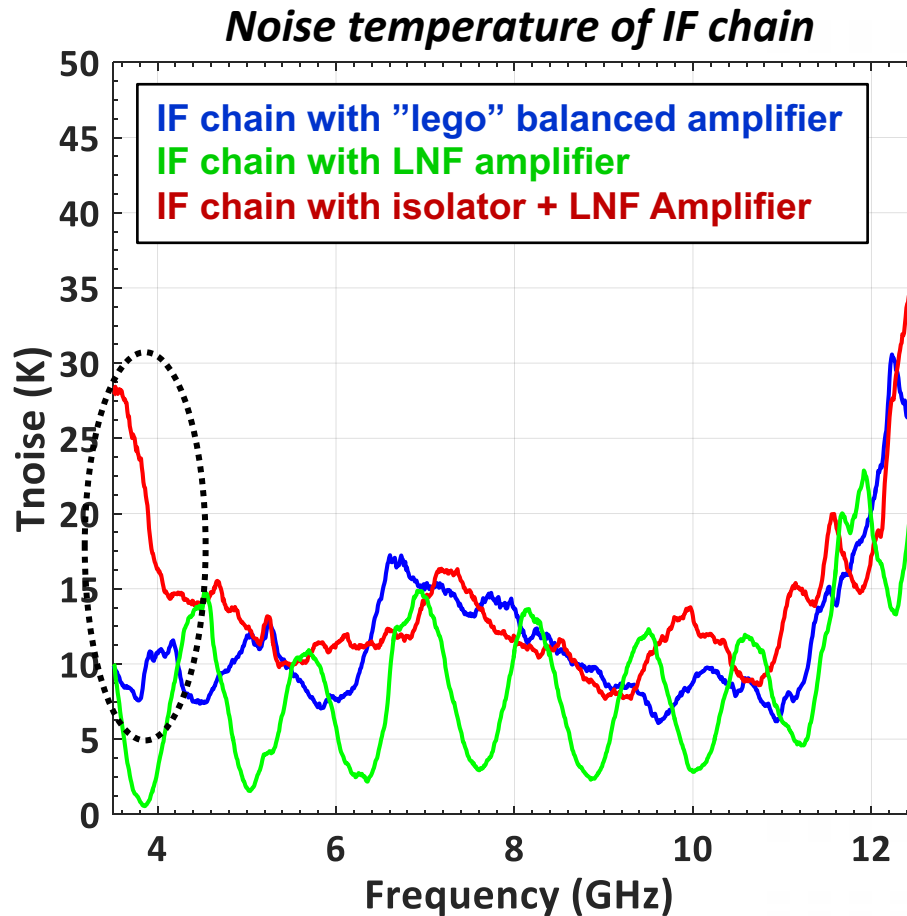


$$T_{eq} = \frac{eI_b}{2k} \frac{dV}{dI} \left(\frac{eV_b}{2kT} \right) \approx \frac{eV_b}{2k}$$

$$Y = \frac{P_{IF_HV}}{P_{IF_LV}}$$

$$T_{IF} = \frac{T_{eq_HV} - YT_{eq_LV}}{Y - 1}$$

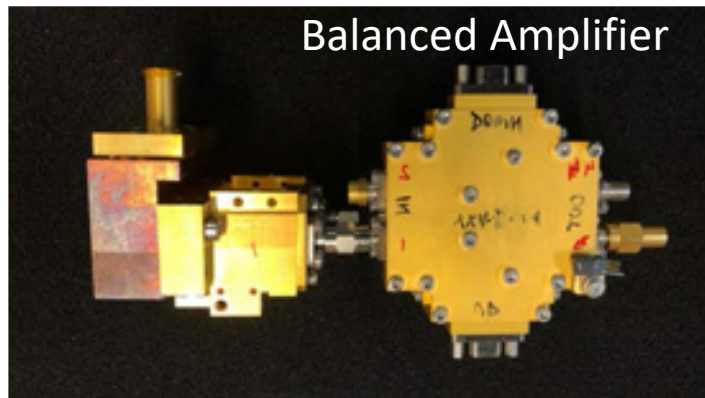
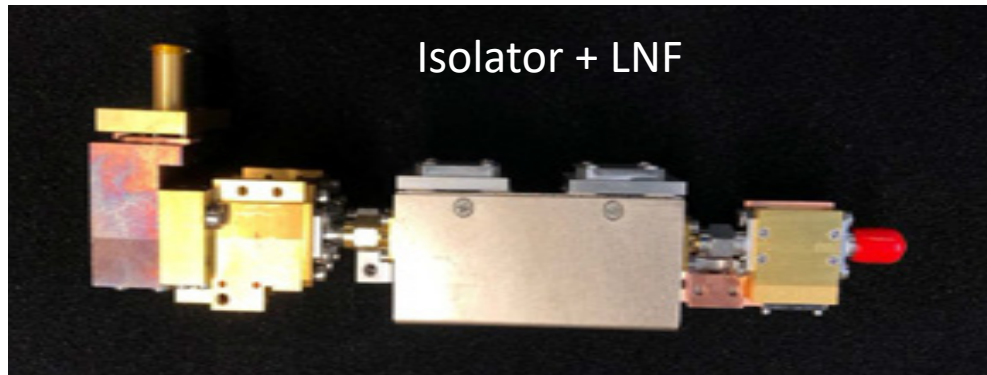
Performance of 3 IF chains with the same 300GHz DSB mixer



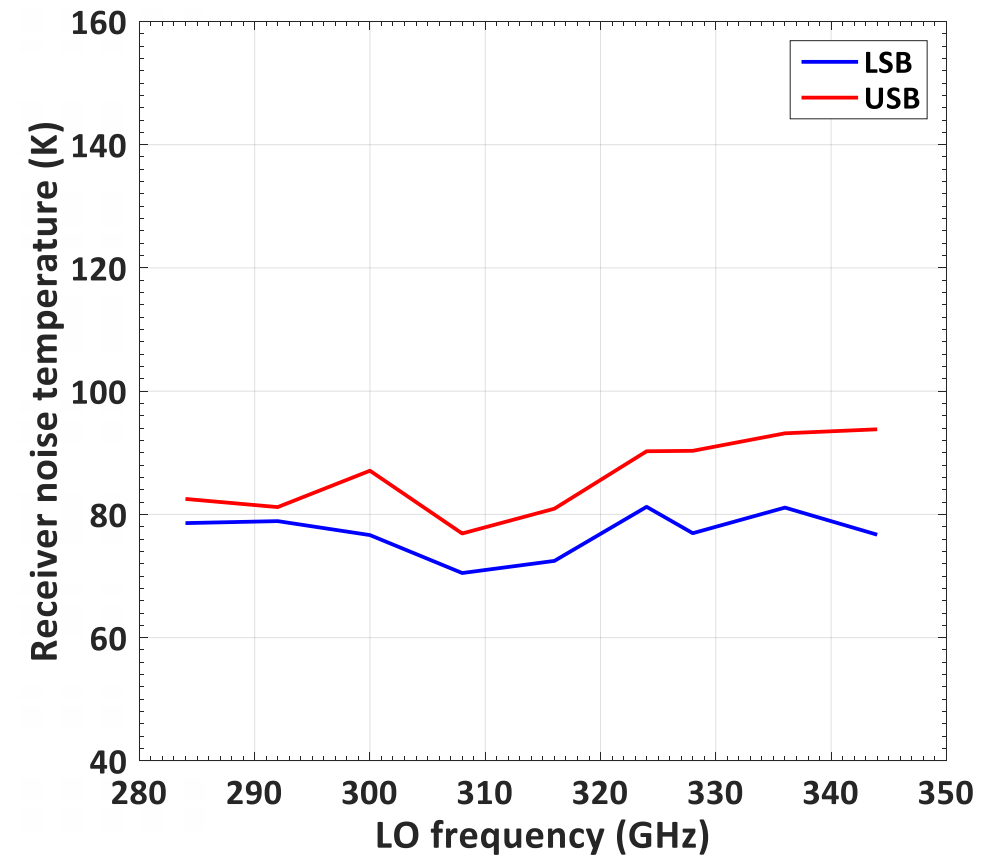
- ✓ Isolator puts limitation to noise performance at low frequency
- ✓ Even state-of-the-art LNAs cannot be used without isolators

Performance of 3 IF chains with the same 300GHz 2SB mixer

SEPIA Band7 prototype mixer test bed

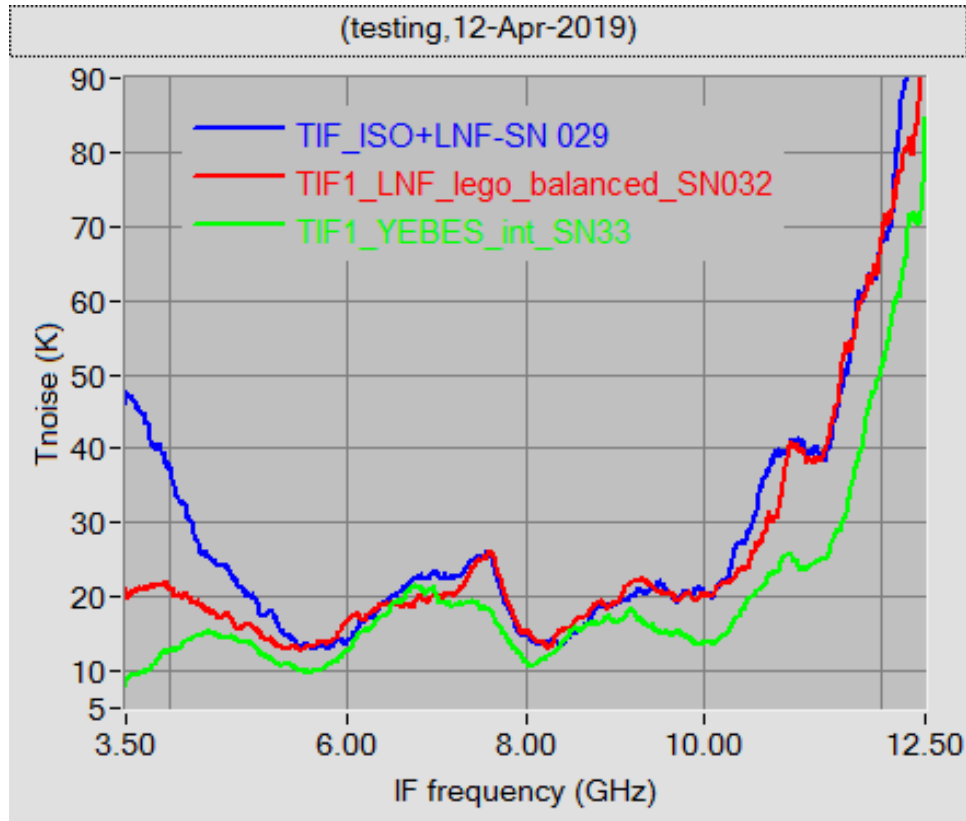


Typical 2SB mixer performance including optics losses

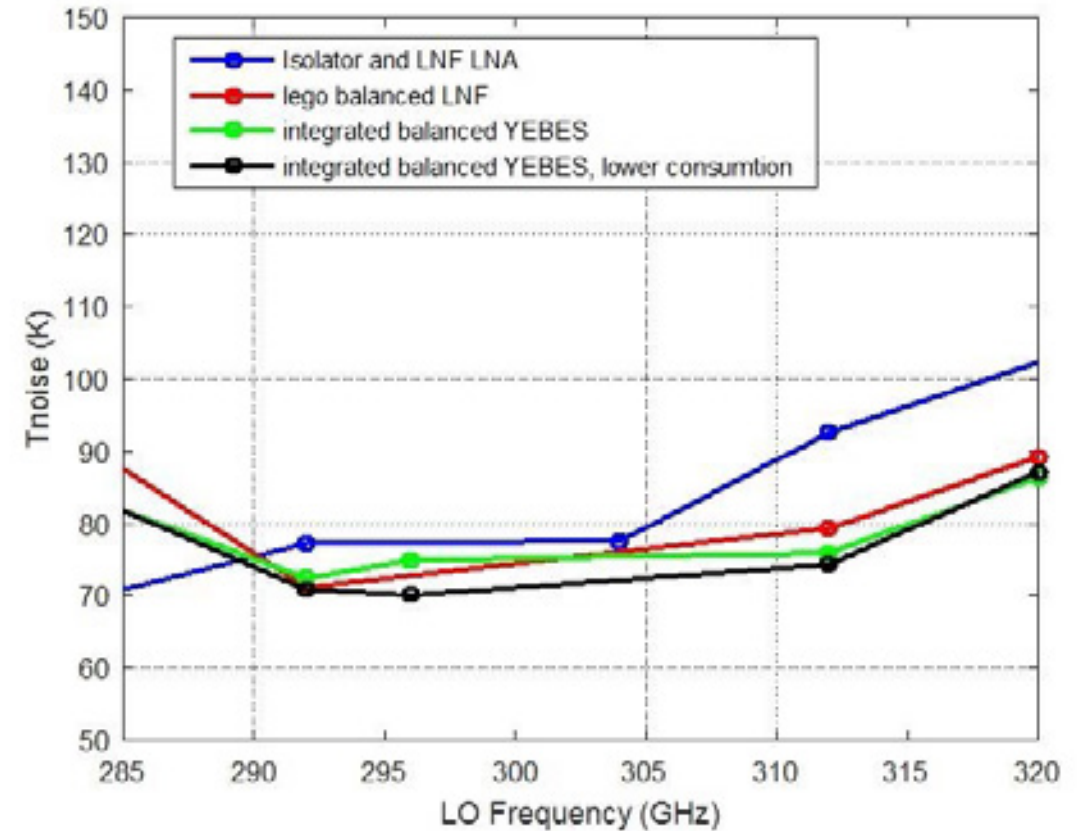


Performance of 3 IF chains with the same 300GHz 2SB mixer

Noise temperature of IF chain



IF output power



- ✓ Isolator limits performance at low frequency
- ✓ The compact balanced LNAs performs similar or slightly better than commercial LNAs balanced “lego-style” or isolators + commercial LNA

Wideband Balanced IF LNAs - Summary

- State-of-the-art noise performance obtained for 4-12 GHz together with return loss > 15 dB, in a collaborative effort driven by own interest
- Extension of the technology to 4-16 GHz or 4-20 GHz:
 - ✓ technically possible
 - !! but need support