ALMA Band 2+3 MMIC Down-converter Design

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If the HEMT-based receiver configuration is adopted for ALMA Band 2+3 system, it is plausible to have a down-converter operating at room temperature as in Band 1. Here, in-house designed MMIC amplifier and mixer covering ALMA Band 2+3 are presented. They are key components in our proposed room temperature down-converter. This mixer with wide RF/IF bandwidth and flat conversion response followed exactly the same design concept to the mixer covering ALMA Band 1 frequency. Due to the high gain (> 50 dB) and wide bandwidth (~ 50 GHz), power handling capability of the amplifier and the mixer are important.

Room Temperature Down-converter for Band 1

In the current Band 1 receiver system, the down-converter is located at RT for better reliability. It consists of RF amplifier, filter for SSB operation, mixer and IF amplifier. More than 50 dB gain is required before the mixer to surpress the mixer noise contribution to less than 0.1 K. The high gain is provided by cold LNA and RT amplifier in the system (Fig. 1).

A successful mixer should meet the following requirements:

Conversion gain	> -10 dB
Gain flatness @ fixed LO frequency	1 dB (full band) 0.6 dB (any 2 GHz band)
LO driving power	< 13 dBm
RF frequency	35~50 GHz
LO frequency	31~38 GHz
IF frequency	4~12 GHz
RF port return loss	> 8 dB
IF port return loss	> 10 dB
LO-RF isolation	> 25 dB
LO-IF isolation	> 25 dB
1-dB gain compression point	> 0 dBm
Noise figure	< 10 dB

At the end of the Band 1 R&D phase, only one commercial mixer by Marki (MM1-2567LS, available from Dec. 2015) and our own in-house designed mixer meet the specifications. Though not selected in baseline design due to more complex biasing scheme, Band 1 system with our own mixer has almost identical performance in terms of receiver noise temperature and IF output power flatness to the Marki mixer. Furthermore, our mixer requires less LO power (7 dBm vs. 13 dBm) in the system.

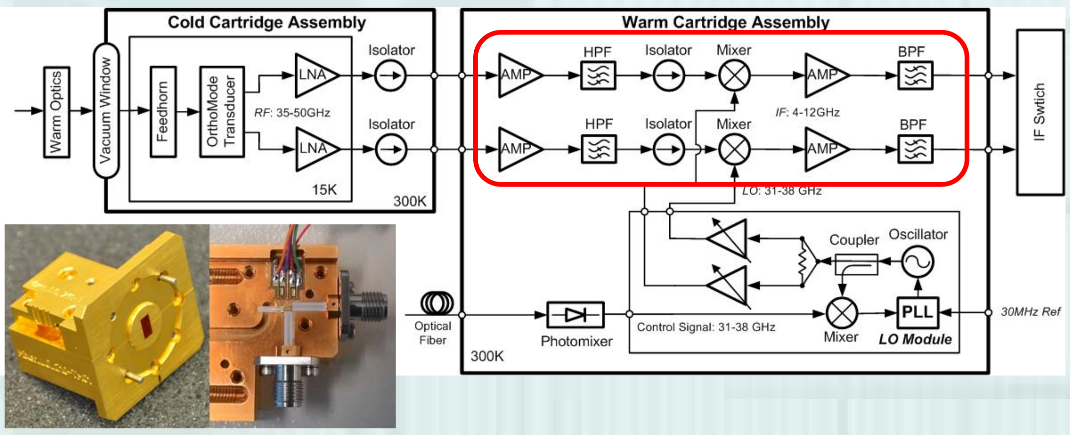
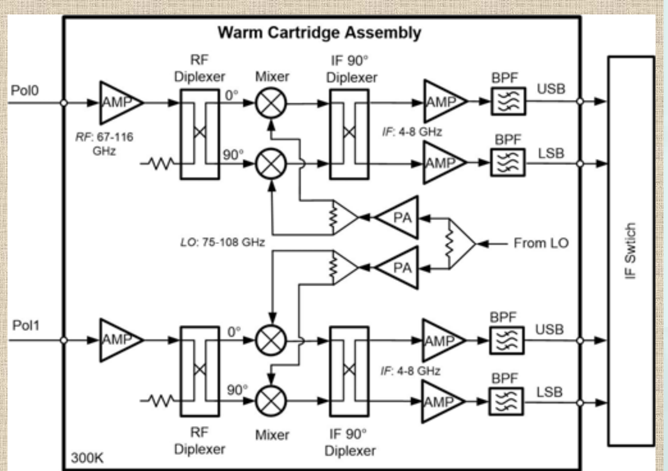


Fig. 1: Block diagram of ALMA Band 1 receiver front-end. Down-converter is circled in red. (Lower-left) Photo of the in-house designed MMIC mixer module.

ALMA Band 2+3 Down-converter Key Requirements and Proposed Configuration

	Specification
RF frequency	67~116 GHz
LO frequency	75~108 GHz
IF frequency	4~8 GHz in 2SB scheme
Conversion gain	+3 to +12 dB
Conversion gain flatness (peak-to-peak)	< 2 dB (any 2 GHz window) < 3 dB (full band)
Noise Figure	< 8 dB
Gain compression	< 5 %
Sideband rejection	> 10 dB



To cover extremely wide RF bandwidth, 2SB down-converting scheme is proposed to obtain reasonable LO fractional bandwidth (75-108 GHz, 36%) with 4-8 GHz IF frequency band. IF amplifier is optional to provide flexible IF output power control.

Applying Band 1 mixer to Band 2+3

With the experience from Band 1, this mixer design is a good candidate for Band 2+3 application for the following reasons:

- No commercial mixer covers such wide bandwidth with excellent flatness response under fixed LO frequency
- More than 300 pieces are required. MMIC approach has better reliability
- Good LO-RF isolation (> 40 dB) to minimize LO power leakage to the RF path
- Pumping power is lower than passive device

Together with the Band 1 R&D, our first try on the mixer for Band 2+3 frequency is published in 2014 [1]. The mixer show promising performance across wide RF bandwidth. Key features are summarized here:

Conversion gain	-11 to -13 dB
LO driving power	< 7 dBm
RF frequency	> 75~120 GHz
LO frequency	Only 86 and 96 GHz have been measured
IF frequency	DC to 26 GHz
IF-RF isolation	> 45 dB
LO-RF isolation	> 41 dB
LO-IF isolation	> 29 dB
DC power consumption	24 mW
Noise figure	< 17 dB

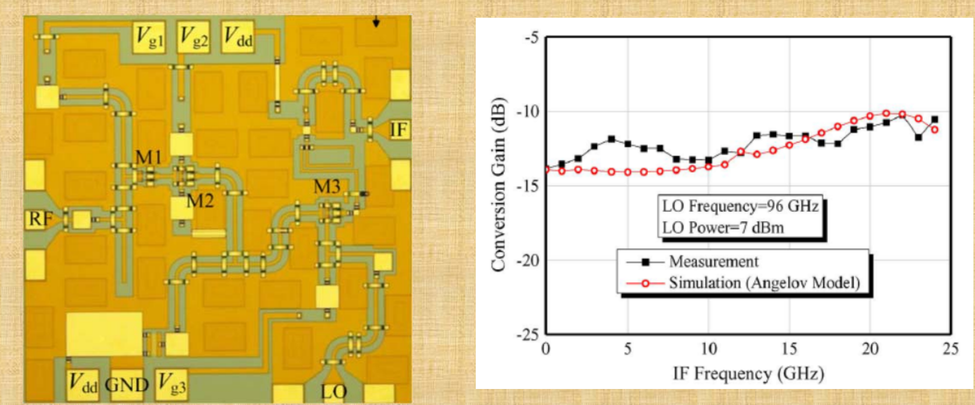


Fig. 2: Mixer operating at Band 2+3 frequency: (left) chip photo. The chip area is 1mm x 1mm; (right) simulated versus measured conversion gain of the mixer.

Band 2+3 Room Temperature Amplifier

The amplifier covering Band 2+3 frequency range is also designed and fabricated in-house. The main design goal is to have good power handling capability (P_{1dB} > 15 dBm) and moderate gain (25-30 dB).

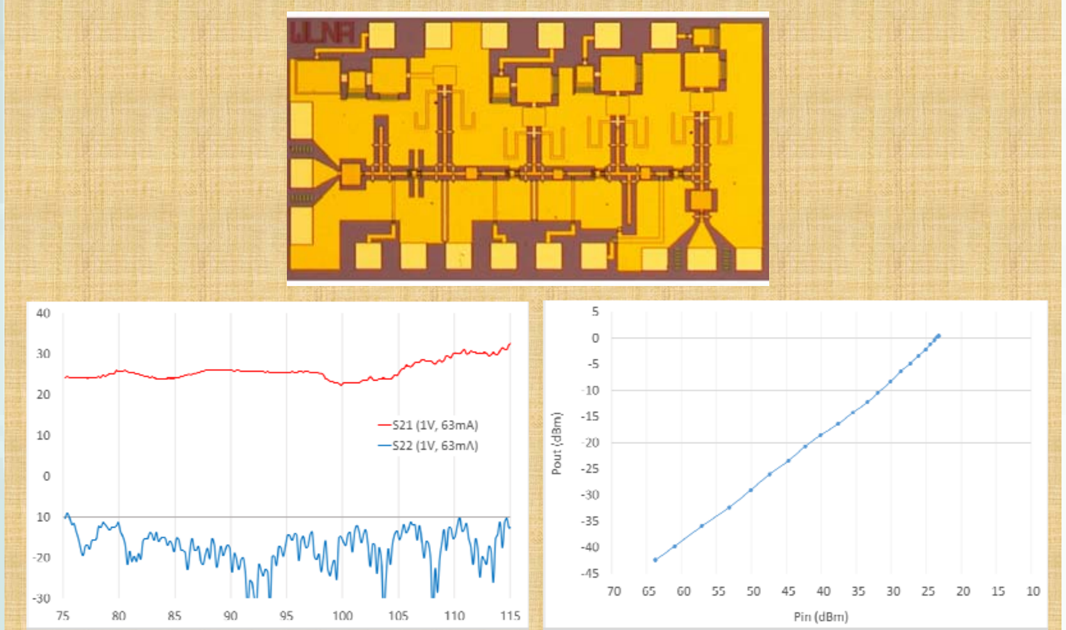


Fig. 3: RT Amplifier operating at Band 2+3 frequency: (upper) chip photo. The chip area is 1.25mm x 0.66mm; (lower left) Measured gain and output return loss of the amplifier and (lower right) Measured input power versus output power at 100 GHz. P1dB > 0dBm.

[1] J.-C. Kao, K.-Y. Lin, C.-C. Chiong, C. Y. Peng and H. Wang, "A W-band High LO-to-RF Isolation Triple Cascode Mixer with Wide IF Bandwidth," *IEEE Transactions on Microwave Theory and Techniques (MTT),* vol. 62, no. 7, Jul. 2014, pp. 1506-1514.