Upgrade of EMIR's Band 3 and Band 4 Mixers

D. Maier, J. Reverdy, D. Billon-Pierron, and A. Barbier

Abstract— **The Eight MIxer Receiver (EMIR) is a multi-band millimeter wave receiver installed since 2009 at the 30m telescope of the Institut de RadioAstronomie Millimétrique (IRAM) at Pico Veleta in Spain. In autumn 2011, Band 3 and Band 4 will be equipped with state-of-the-art sideband-separating mixers with 8 GHz IF bandwidth.**

For Band 3 a sideband-separating mixer has been developed within the European project AMSTAR+ in order to replace the currently employed single-sideband mixer. The new mixer has a twice as large IF bandwidth than the current one thus doubling the continuum sensitivity of the receiver.

The mixer currently installed in Band 4 will simply be upgraded to 8 GHz IF bandwidth by changing its IF components.

***Index Terms*—millimeter wave receiver, sideband-separating mixers, SIS mixers, wide IF band**

I. Introduction

In spring 2009 IRAM installed its **E**ight **MI**xer **R**eceiver (EMIR) at the 30m telescope at Pico Veleta in Spain [1]. Since then EMIR observes successfully in four frequency bands centered around 100, 150, 230, and 305 GHz, respectively. The characteristics of its mixers are summarized in **Table 1**.

Table 1: Characteristics of EMIR mixers.

Band	Frequency	Mixer Type	IF Band
1	83–116 GHz	2SB	4–12 GHz
2	129–174 GHz	SSB	4–8 GHz
3	200–268 GHz	SSB	4–8 GHz
4	260–354 GHz	2SB	4–8 GHz

Bands 2 and 3 still employ single-sideband mixers using a movable backshort in the waveguide behind the mixer chip to tune out the image sideband and delivering one IF output of 4–8 GHz [2], [3], whereas current state-of-the-art receivers employ sideband-separating (2SB) mixers with two IF outputs and twice as large IF bands [4], [5]. EMIR's Band 1 is already equipped with such a sideband-separating mixer, which has been developed within the European project AMSTAR [6], [7]. Band 4 finally, is equipped with a sideband-separating mixer with 4–8 GHz IF bandwidth, which has been originally developed for the ALMA Band 7 cartridge [8] and tuned down in frequency to join the Band 3 frequency range.

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II. Band 3 upgrade

A. 2SB Mixer Assembly

Within the European project AMSTAR+, follow-up project of AMSTAR, we designed a 230 GHz sideband-separating mixer to be employed in focal plane array receivers [9]. For this mixer RF quadrature coupler, two LO couplers, LO splitter as well as two DSB mixers have been combined into one unit and realized as one E-plane split-block (see Figure 1). Since this mixer has been designed having in view its future use for a focal plane array receiver, the IF outputs have been placed at the back of the mixer block, allowing the signal path to go straight through the block, so that the mixers can be plugged onto a feedhorn array and be followed in-line by the IF chain. The LO input has been moved to the top of the mixer block by adding an H-bend into the LO injection path [10]. For a detailed description of the design of the waveguide components see [9].

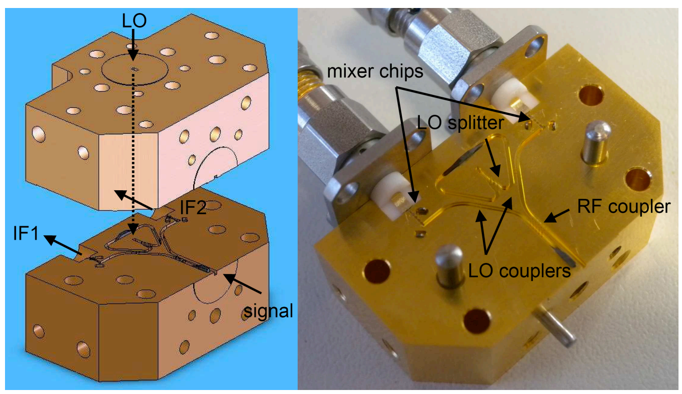

Figure 1: Left: Schematic view of the E-plane split-block combining waveguide couplers, LO splitter, and DSB mixers. Right: Photograph of one half of the split-block with mounted loads, mixer chips, and IF connectors.

The distance of the IF outputs has been adjusted to the inputs of the employed IF coupler [11], so that the hybrid can be mounted directly onto the mixer block.

B. DSB Mixer

A detailed description of the DSB mixer design is given in [9]. The mixing element is a superconductor-insulator-superconductor (SIS) tunnel junction, which is deposited together with a superconducting circuit onto a quartz substrate. The role of this circuit is to compensate the junction's capacitance and to provide a match to the RF input and the IF output. Figure 2 shows a photograph of the mixer chip mounted into the RF coupler/mixer block. The dimensions of such a chip are 2.4x0.26x0.08 mm^3. These devices are fabricated by IRAM's SIS group [12].

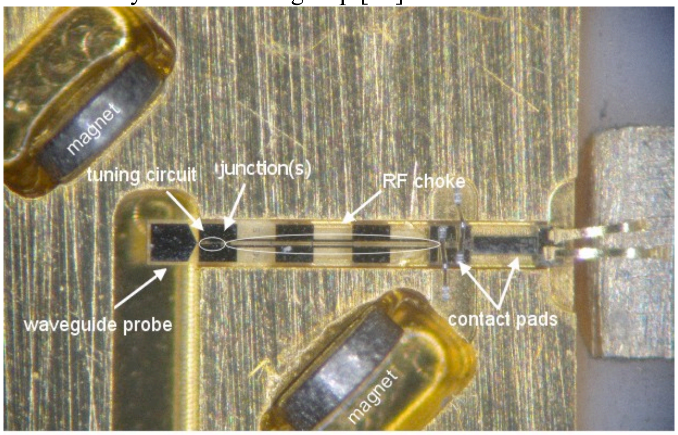

Figure 2: Mixer chip mounted into the RF coupler/mixer block.

A close-up of the tuning structure is shown in Figure 3. A parallel inductance consisting of a coplanar waveguide compensates the capacitance of the $1\,\mu m^2$ junction and the following capacitance provides the virtual ground. The impedance of this structure is matched to the probe impedance by a quarter-wavelength transformer.

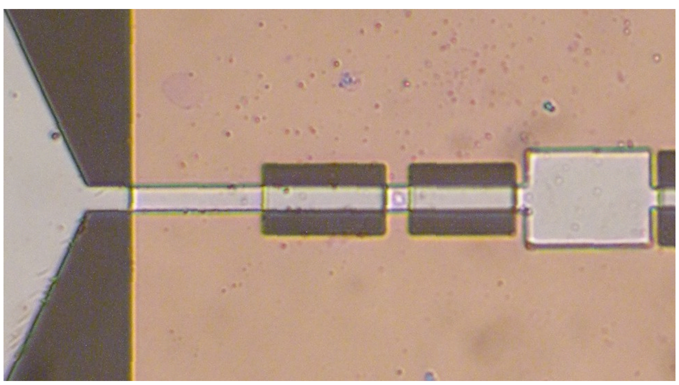

Figure 3: Close-up of the tuning structure.

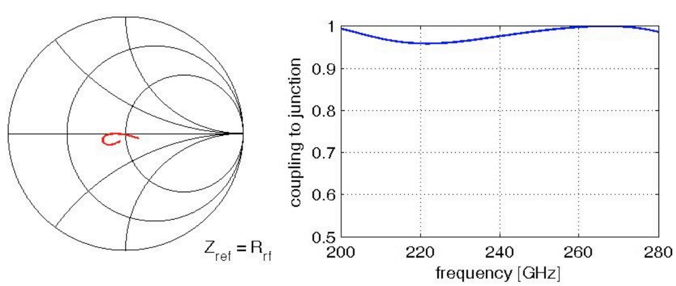

Figure 4: Left: Embedding impedance of the junction for frequencies between 200 and 280 GHz. Right: Fraction of power coupled to the junction.

The achieved matching to the junction is quite homogenous over the whole frequency range as can be seen by the junction's embedding impedance plotted in the Smith chart in Figure 4 (left). The power coupled to the junction lies above 96% (see Figure 4, right).

C. Mixer Performances

Two mixers for the installation on-site as well as spare mixers have been fabricated and fully characterized by measuring noise temperatures and image rejections in the 4–12 GHz IF band for LO frequencies between 210 and 270. The results of one mixer are shown in Figure 5. As can be seen, the achieved noise temperatures are very good over the whole frequency range. The obtained image rejection is almost always better than –10 dB.

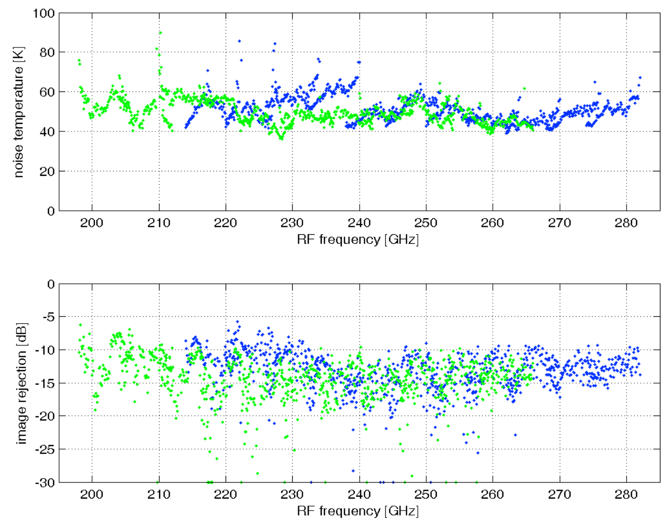

Figure 5: Noise (above) and image rejection (below) of one Band 3 sideband-separating mixer measured in the IF band for LO frequencies between 210 and 270 GHz. LSB measurements are plotted in green, USB results are shown in blue.

III. Band 4 Upgrade

A. Current Mixer

The mixer currently installed in Band 4 of EMIR is a modification of a mixer initially designed for the ALMA Band 7 cartridge [8], [13]. Since this mixer has been designed having in view a small series production, a modular approach has been chosen, which allows testing of the different parts prior to integration. Only the waveguide couplers have been realized as one E-plane split-block, so that the block as a whole can be characterized using a vector network analyzer. The DSB mixers are separate units, which can be tested individually and which are then selected according to their performances for integration into a 2SB mixer. The employed IF hybrid coupler is commercially available [14]. A photograph of a Band 4 2SB mixer assembly is shown in Figure 6.

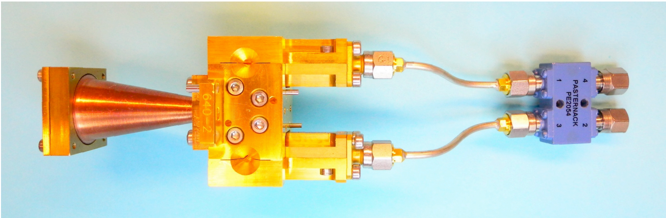

Figure 6: Photograph of the EMIR Band 4 Mixer.

The ALMA mixer has been adapted to the lower frequency range of Band 4 by changing the RF coupler and increasing the size, and thus the capacitance, of the junctions.

B. Upgrade to 4-12 GHz IF Band

As 8 GHz IF bandwidth is more and more attractive, we tested this mixer for the larger IF band. These tests have been carried out with a mixer of the ALMA Band 7 production by replacing the commercial IF coupler [14] with the same coupler used for the Band 3 mixer and developed for frequencies from 4–12 GHz [11].

The conclusion of these mixer tests was that the existing Band 4 receivers could be easily upgraded to the twice as large IF band by simply changing its IF components.

And since the new Band 3 mixers work up to at least 280 GHz, there is no need anymore for the use of the frequency shifted Band 4 mixers. The new Band 4 mixers will therefore work for the initially designed frequency range of 275–373 GHz with a 4–12 GHz IF band.

C. Mixer Performances

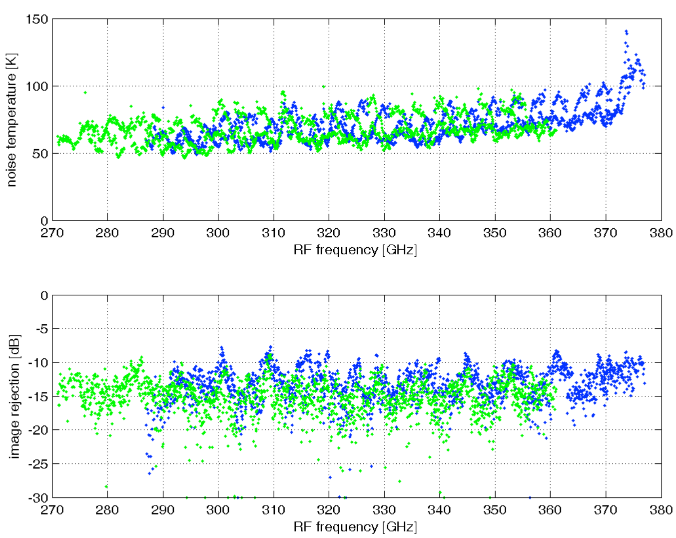

Figure 7: Noise (above) and image rejection (below) of one Band 4 sideband-separating mixer measured in the IF band for LO frequencies between 283 and 365 GHz. LSB measurements are plotted in green, USB results are shown in blue.

Mixers have been fabricated and characterized. Just as for Band 3, noise temperatures and image rejections have been measured in the 4–12 GHz IF band for LO frequencies between 283 and 365 GHz. The achieved noise temperatures over the RF band are very good as can be seen in the plot in Figure 7, above. The obtained image rejections are quite below –10 dB (see Figure 7, below).

IV. Conclusion

A sideband-separating mixer with wide IF band has been successfully developed for EMIR Band 3. It covers an RF frequency range of 200–280 GHz and shows very good noise temperatures over the whole RF band. Achieved image rejections are better than –10 dB. This mixer increases the Band 3 frequency range and replacing the old SSB mixer with 4 GHz IF band by this mixer will double the continuum sensitivity of the receiver and increase the flexibility of line observations.

The current Band 4 mixer has been upgraded to larger IF bandwidths and its RF frequency range has been shifted to higher frequencies. The new mixers will cover RF frequencies from 275 to 365 GHz with an IF band of 4–12 GHz.

The upgrade of both bands will take place in autumn 2011 allowing observations with the improved system in winter 2011/2012.

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