Configuring the ALMA Band 3 Cartridge into a Balanced 2SB Receiver

Doug Henke, Pat Niranjanan, and Lewis Knee

***Abstract*—Using a balanced mixer has the advantages of a reduced LO power requirement and cancellation of LO amplitude noise. A new power divider block was designed to rearrange all four mixers of an existing ALMA Band 3 test cartridge into a single-polarization, balanced and sideband-separating receiver.**

***Index Terms*—ALMA Band 3, ALMA instrumentation, balanced mixer, balanced sideband-separating receiver.**

I. Introduction

Many low-noise receivers for radio astronomy are configured using either sideband-separating or balanced mixers, but few have been implemented that take on both aspects within the same receiver [1]–[4]. A test ALMA Band 3 cartridge was arranged so that all four mixers were used within one polarisation to configure it into a balanced and sideband-separating architecture (BAL-2SB). We wanted to test the configuration to see its impact within Band 3 and for consideration if the design could be scaled to other frequency bands.

In [5], a table of noise contributions is shown in Table 1 where the terms "LO coupled noise" and "image termination contribute ~3 K and ~5 K, respectively, towards an overall receiver noise of ~30 K. Adding a balanced architecture has the advantage of requiring less LO power, cancelling LO amplitude noise, and cancelling "image termination" noise [1],[6]—the latter being the most pertinent to the Band 3 cartridge.

II. Implementation

Fig. 1 shows the arrangement used for the BAL-2SB receiver. The LO is fed through the front of the power divider block where it is coupled into the RF signal path. There is clear symmetry dividing the left and right sides which shows how each balanced mixer pair is combined through a 180° IF coupler. The delta port of each balanced output is then connected to the final 90° IF hybrid for image-rejection.

In the ALMA Band 3 receiver cartridge, the SIS mixers are biased through a bias-T within each LNA such that the DC bias is carried through the coaxial port of the SIS mixer block.

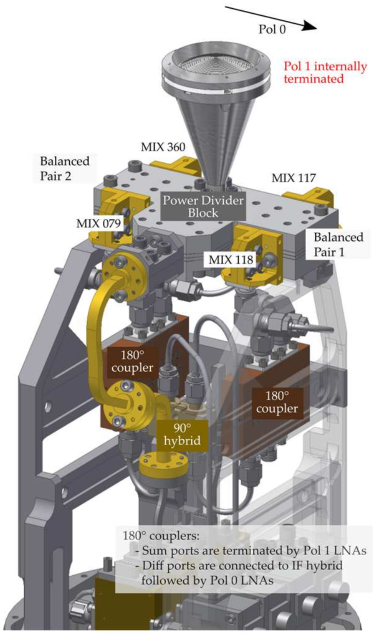

Fig. 1. Prototype cartridge for ALMA Band 3 arranged into a balanced and sideband-separating (BAL-2SB) receiver. Details of the power divider block are shown in Fig. 2.

Normally, the sum port of the 180° IF coupler would be terminated by a 50-Ohm termination, but here each sum port was instead connected to an LNA to provide the DC bias.

The power division and LO coupling was accomplished through the power divider block, as shown in Fig. 2. A turnstile has been used for both polarisation discrimination and the first power division required for sideband-separation. The LO and RF for each balanced pair are combined in-quadrature using 3 dB 90° hole couplers.

Fig. 2 (b) shows the 4-piece power divider block that used a platelet approach, instead of split-block, which enabled broad-wall hole couplers. Only one polarization was used from the turnstile and the other was internally terminated with waveguide loads. The LO was divided in-phase using a 6-port hole coupler, followed by a pair of phase shifters acting on the upper and lower LO paths to pump each balanced mixer pair.

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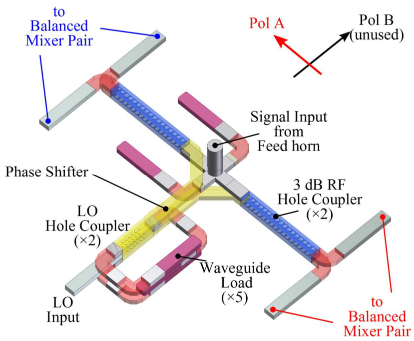
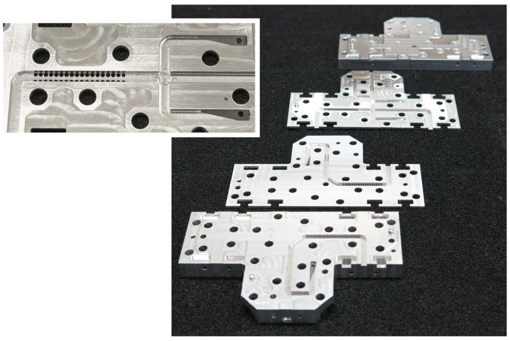


(a)

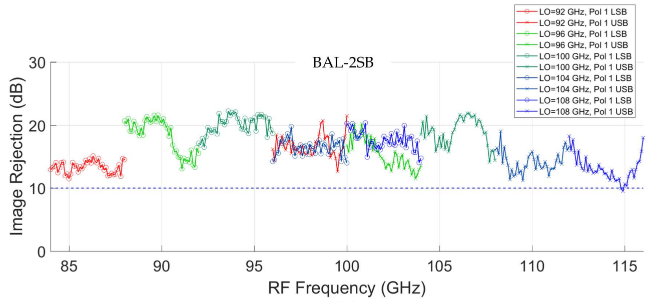


(b)

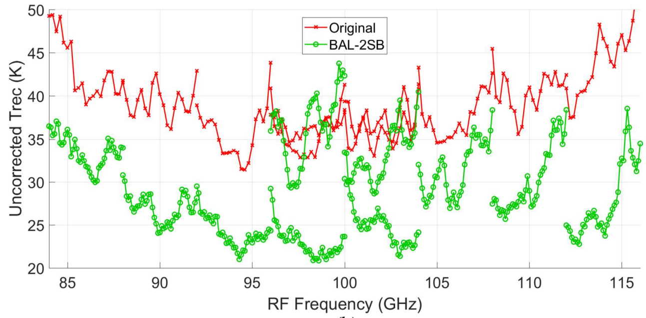
Fig. 2. Power divider block used within the balanced sideband-separating receiver (BAL-2SB). A CAD model of the waveguide channels is shown in (a) and the 4-layer machined block is shown in (b). A close-up of the turnstile and one of the 3 dB 90° hole couplers is shown inset.

Measurements of the image rejection and noise are shown in Fig. 3. Of first note, the image rejection is acceptable (i.e., better than 10 dB) and indicates that overall RF signal and LO balance has been attained. In the measured noise, there is a significant drop due to reductions in the LO coupled noise (-30 dB coupling is used within the 6-port coupler shown in Fig. 2) and image termination noise mentioned above. However, there is noticeable ripple in the middle of the band. Upon closer inspection, the noise profiles in the LSB and USB track each other indicating more of a double-sideband response rather than sideband-separated.

The apparent contradiction may be explained by considering the testing condition for sideband-separation versus that for noise. The sideband interferer was injected towards the cartridge window using an open-ended rectangular waveguide that induced a TE11 mode into the circular guide. Because of the symmetry of the power division block, higher-order modes within the circular waveguide and turnstile were not excited. However, when the noise temperature was measured using black-body calibration loads, we can assume that the polarization from each black-body load was random and energy could be transduced within the circular guide in any of the supported higher-order modes. If higher-modes are transduced they will corrupt the phase balance. This can give rise to the situation where the image-rejection appears fine from measurement, yet receiver noise measurements have degraded. We plan to test this hypothesis by implementing a linear polarization filter to see if the measured noise will change.



(a)



(b)

Fig. 3. Cartridge measurements of (a) image-rejection and (b) narrow-band receiver noise. In (b), the noise is compared against the original Band 3 configuration.

Integrating the turnstile as an OMT and power divider for sideband-separation was shown to be problematic and it would have been better to keep the OMT separate. Note that the same optics, mixer blocks, IF chains, and operating conditions were used throughout to allow for comparison with the original configuration.

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