2SB and Balanced Receiver Architectures using Hole Couplers

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Abstract

The ALMA telescope has now entered cycle 4 operations [1] and as part of a research study proposal [2], we are exploring possible improvements to the ALMA Band 3 receiver cartridge. The Band 3 receiver is capable of detecting both linear polarisations which are discriminated using a waveguide orthomode transducer (OMT). Within each polarisation, both the upper and lower sidebands are separated out using a sideband-separating (2SB) layout.

We report on the progress of two new prototype designs that use an integrated OMT with hole couplers to give: (1) a dual-linear sideband-separating architecture, and, (2) a balanced, sideband-separating architecture.

1. Introduction

Over the past several years, we have developed OMTs using a stacked, 3-piece assembly [3], [4]. Using a stacked layout allows for the use of small aperture hole couplers [5] in place of the branch-line couplers commonly used in split-block designs. In particular, the weak coupling required by the local oscillator (LO) signal is difficult to realise with branch-line couplers because the slots are very narrow for the given aspect ratio. Furthermore, only a few slots are used which, in turn, provides narrowband directivity.

Hole couplers can be designed for extremely weak coupling (i.e. ~-30 dB) using multiple stages for broadband directivity and still result in machinable features [6]. Here, we show the hole couplers, combined with a turnstile for an integrated OMT, and applied to two architectures: (1) dual-linear sideband-separating (DL-2SB), and, (2) balanced sideband-separating (BAL-2SB). Motivation for exploring the balanced receiver architecture is shown in [7].

Assuming that there is enough LO power to pump the mixer, weaker coupling of the LO is desirable since the RF signal path is likewise less affected. We have estimated that in the ALMA Band 3 receiver, there is enough LO power to use approximately -30 dB coupling; this is interesting since the "through" path of the LO coupler only reduces by ~0.01 dB and may be used to pump the other polarisation, or possibly several more pixels in an array [8].

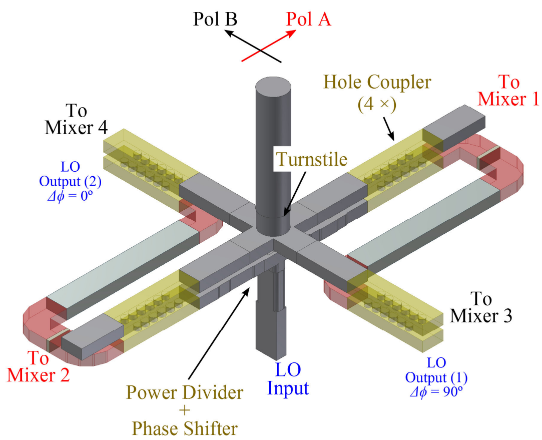

Figure 1. Waveguide layout for a dual-linear sideband-separating (DL-2SB) front-end.

2. Dual-Linear Sideband-Separating (DL-2SB)

Figure 1 shows the proposed configuration to be used with the front end of a dual-linear sideband separating waveguide assembly. Two linear polarisations (Pol A and Pol B) are supported along the input circular waveguide and separated using a turnstile. The turnstile essentially acts like a Y-splitter power divider for each polarisation. For 2SB, the LO and RF signal need to be combined in-quadrature before the mixer, so a phase shifter has been added to the LO input. Figure 1 shows that the LO is first coupled into the Pol A branches (for mixers 1 and 2) and then is routed to couple into the Pol B branches (for mixers 3 and 4); in this manner, a single LO is used for both polarisations and, in future work, could be reused further for adjacent dual-linear 2SB pixels.

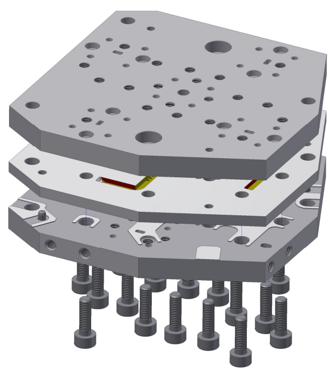

Figure 2. Mechanical assembly of the 3-piece DL-2SB block.

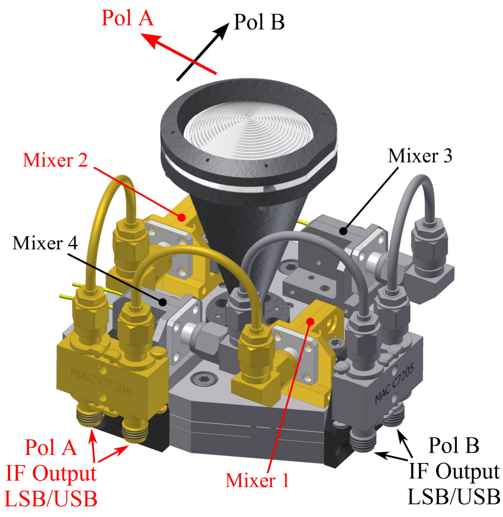

Figure 3. DL-2SB block shown with the feed horn, mixer blocks, IF cables, and IF hybrids connected.

Figure 2 illustrates the 3-piece mechanical design of the block. Since we are experimenting with pre-built mixer blocks, the waveguide outputs have been routed upwards to accommodate the mixers, as shown in Figure 3. For example, Figure 3 shows the Pol A mixer blocks, phase-matched IF cables, and 90º IF hybrid highlighted in yellow. The assembly has been carefully designed to fit within the existing ALMA Band 3 cartridge so that the same mixer blocks may be used in measurements that compare the as-built cartridge assembly against the new DL-2SB prototype.

3. Balanced Sideband Separating (BAL-2SB)

A drawback of using the turnstile as the initial power splitter is its inherent lack of isolation. In contrast, 2SB assemblies that use branch-line couplers have superior isolation and any balanced reflections from the mixer pairs will be terminated into the 4th isolated port of the branch-line coupler [7].

For the balanced receiver, an input 3-dB 90º hybrid may be used to combine the LO and RF signal [7]. Given the lack of isolation of the turnstile, it is interesting to explore the effect of increased isolation due to the added 90º hybrids, as shown in Figure 5 (see [7] for detailed attributes of a balanced receiver).

To keep the hole couplers machinable, the membrane thickness should not be too thin. Above, a thickness of 0.5 mm was used for the LO coupler; however, for a 3-dB coupler design, this membrane thickness would necessitate approximately 50 hole pairs and the coupler would be prohibitively large for the receiver cartridge volume allowance.

A more compact 3-dB coupler can be constructed [9], as shown in Figure 4, but it requires significantly reduced height waveguides to prevent unwanted higher order modes in the coupler.

Figure 5 shows an initial design for a balanced receiver front-end using reduced height 3-dB couplers. Here, it is envisioned that the machined block will be fabricated into 3 pieces, similar to Figure 2 above. Note that Figure 5 shows one polarisation (Pol B) terminated with a waveguide load. The extra complexity of balanced, sideband-separating layout requires 4 mixers per polarisation and for the prototype we have limited ourselves to just one polarisation.

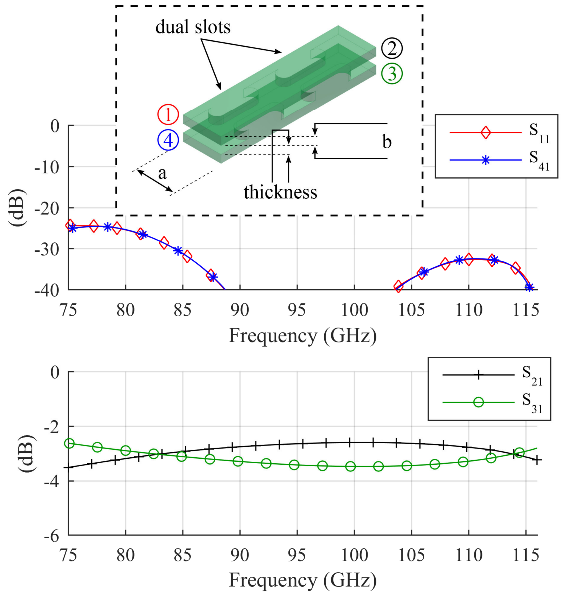

Figure 4. Compact dual-slot 3-dB coupler using reduced height waveguides. Port numbers correspond to the encircled numbers shown in the inset. Dimensions are: a = 2.44 mm, b = thickness = 0.5 mm, and slots are 0.8 mm × 2.9 mm.

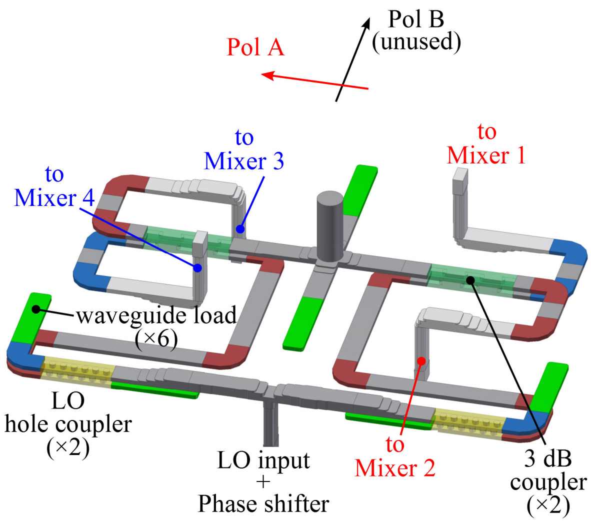

Figure 5. Waveguide layout for a balanced sideband-separating (BAL-2SB) front-end. The IF outputs of mixers 1&2 and 3&4 comprise balanced pairs that would each combine through a 180º IF hybrid. The sum port of each 180º hybrid would then connect to a 90º IF hybrid for the 2SB.

As a possible alternative, we are currently working on a compact, full-height waveguide assembly for the BAL-2SB but it requires 5 stacked layers, where two of the layers are much thinner membranes that include the coupled hole definitions.

4. Acknowledgements

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5. References

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