Design of RF waveguide structure for 2SB SIS mixer at 210-280 GHz

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***Abstract*— We discuss the latest results on the design of a new receiver based on modular sideband separating SIS mixers working in the frequency range 210-280 GHz (approximately corresponding to ALMA Band 6). In particular, we present the design of the components that make up the RF waveguide block, which provides the input to the mixers. We optimized the design taking into account spurious reflections, which have a significant impact on the Image Rejection Ratio. Given the simulated performance of each component, it is also possible to develop a full model of the 2SB SIS receiver, which allows us to verify the influence of each component on the total IRR performance in terms of spurious reflections.**

***Keywords*— sideband-separating mixers, waveguide hybrids, submillimeter receivers**

I. INTRODUCTION

Sideband separating (2SB) receivers based on SIS (superconductor-insulator-superconductor) mixers are widely used in ground-based observatories such as ALMA, NOEMA and SMA to perform frequency down-conversion and separate the image signal from the signal channel. The use of sideband-separating receivers is highly desirable because it allows the reduction of the atmospheric noise contribution when observing spectral lines.

The receiver we present is based on a modular configuration, which is convenient to characterize all the components separately before assembling. As shown schematically in Fig. 1, the RF input signal is split in two branches by a quadrature hybrid. The local oscillator (LO) power is also divided by a power splitter and coupled to the mixers. The IF outputs of the two mixers are amplified and then combined in the IF quadrature hybrid with the required phase delay. The final outputs are the separated down-converted upper (USB) and lower (LSB) sideband signals.

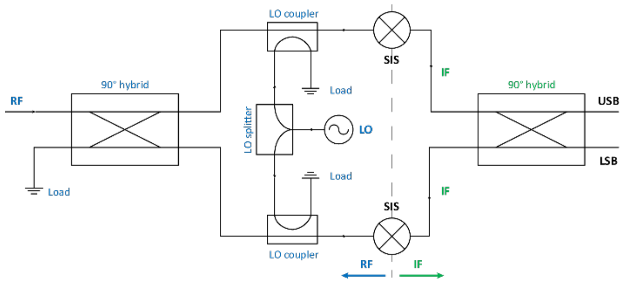

Fig. 1. Schematic design of the modular 2SB SIS receiver.

This parameter should be better than 10 dB, and preferably better than 20 dB, in order to optimize the sensitivity of the receiver and avoid line confusion during observations.

II. RF WAVEGUIDE STRUCTURE

The waveguide structure is based on a six-branch quadrature hybrid coupler designed to operate in the frequency range 210-280 GHz. The LO signal is equally divided by an E-plane T-splitter and coupled to the SIS mixers with a pair of two-branch directional couplers. The modular design concept is similar to the one presented in [1].

The RF imbalance is one of the key parameter limiting the IRR and its design requires to pay attention to the phase and amplitude balance of the entire RF structure. However, as shown in [2-3], the total RF balance is strongly influenced by reflections within the RF structure. Therefore, we designed the RF hybrid by optimizing the RF matching and isolation by varying slot widths and positions while keeping the phase and amplitude balance within about 0.3° and 0.6 dB, respectively. Due to these imbalances, we predict a contribution to the overall IRR below –25 dB, as shown in Fig. 2.

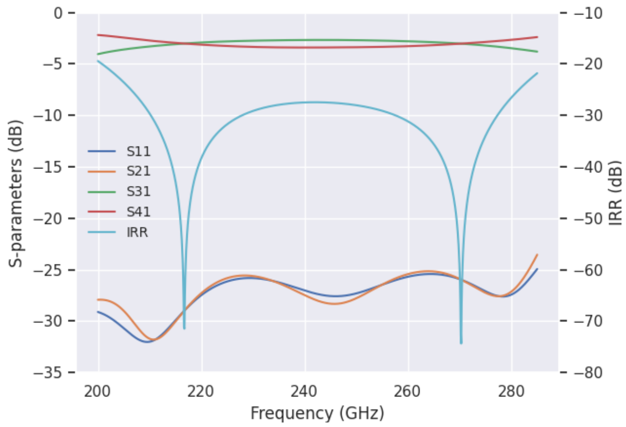

Fig. 2. Simulation of S-parameters of the RF hybrid and its contribution to the IRR.

The LO power is coupled with a two branch directional coupler, which has been optimized to have a low reflection (<–25 dB) and a coupling factor of ≈–16 dB.

The LO is divided by a T splitter with matching sections in the three legs. Since the splitter is a non-dissipative device, it has highly reflective output ports (S_{22}, S_{33}) and/or low isolation between them (S_{23}, S_{32}). Because both affect the standing wave issues, we chose a similar level of -6 dB. The input reflection was minimized to be <-25 dB to avoid further problems with standing waves between the mixer block and the LO itself.

W we performed also a tolerance analysis to understand which parameters affect the most the performance, the accuracy required in the machining process and the effect of possible asymmetries in the arms. Assuming a possible deviation of ±5% around the nominal value, the results of the simulations show that the T-shaped splitter gives a good performance within the tolerance guaranteed by the manufacturing process.

The main loads (hybrid termination and LO dump) are made by terminating the waveguide with an oblique angle into a large block of absorbing material. Simulations show that the transition into the cavity filled with the absorber has

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a reflection of less than -30 dB. Since the simulations are performed assuming room temperature there are still some uncertainties about the expected behavior at 4 K, which will be addressed in the future with experimental tests.

III. Results

Given the results of the electromagnetic design and simulation of each component, we will be able to set up a full circuit simulation of the entire RF structure in order to model the effect of standing waves in the integrated system. A full model of the 2SB SIS receiver allows us to study carefully the influence of each component on the total IRR performance in terms of spurious reflections. The results of electromagnetic simulations are also fundamental to get a comparison with measurements.

The technology developed within this study will be useful for future ground-based telescopes like LLAMA and the Africa Millimetre Telescope (AMT).

References

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