ORAL SESSION n°4

« SIS 2 »

Thursday 11 May 10:30-12:00

Chaired by :

Dr. Anthony Kerr & Dr. Karl Schuster

A 211-275 GHz Sideband Separating SIS Mixer for APEX

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Abstract— **We present the results of the development and characterization of the sideband separating (2SB) SIS mixer for the APEX band 1, 211-275 GHz.**

All mixer components, except the IF hybrid, are integrated into a single mixer block. The sideband separation is achieved by using a quadrature scheme where a local oscillator (LO) pumps two identical SIS mixers. The RF power is divided using a waveguide branch line coupler and directed with 90° phase difference to the ends of the substrate, where each path is coupled to the mixer chip through a waveguide to microstrip transition.

Preliminary tests of this 2SB mixer show a sideband suppression ratio of about 12 dB and a typical SSB noise temperature of 80K.

Index Terms—**SIS mixer, sideband separating mixers, quadrature hybrid**

I. INTRODUCTION

APEX, the Atacama Pathfinder Experiment [1], is a collaboration between the Max Planck Institute for Radio astronomy, Onsala Space Observatory, and the European Southern Observatory. APEX is a 12 m single dish telescope with a surface accuracy of 17 um (rms) allowing observations in the sub-mm region.

The Onsala Space Observatory is committed to providing single pixel heterodyne receivers covering the following bands:

Band	RF range, GHz	Mixer type
APEX 1	211-275	sideband separating
APEX 2	275-370	sideband separating
APEX 3	375-500	sideband separating
APEX T2	1250-1390	balanced

This paper concentrates on the development of the band 1 sideband separating (2SB) mixer. The motivation for using 2SB mixers for radio astronomical applications at mm-wavelengths is that the noise performance of a double-side band (DSB) heterodyne receiver is often limited by the atmospheric noise fed into the system via the image band. Thus, to increase the system sensitivity, 2SB or single sideband (SSB) operation is preferred.

Sideband separation is achieved by using a quadrature scheme where the RF power is divided and applied with 90° phase difference to two identical mixer junctions. The mixer junctions are pumped by a local oscillator (LO) with either 0^0 or 180° phase difference.

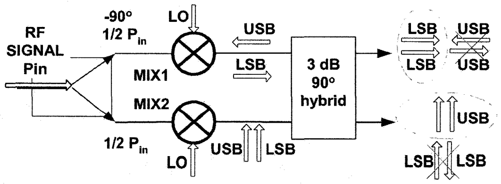

Figure 1 Block diagram of the sideband separating mixer. To illustrate the sideband cancellation, the relative phases of the sideband signals are shown at different points of the mixer. USB and LSB stand for Upper and Lower Side Band respectively.

Sideband separation, using the quadrature scheme illustrated above, does not use any tunable RF filter components and has been demonstrated at mm-wavelengths [2]-[6]. The degree of sideband suppression is directly related to the magnitude and phase balance of the RF and LO power applied to the mixers and the symmetry of the circuitry.

II. MIXER DESIGN

A. *Mixer Configuration*

The mixer block layout is shown in Figure 2 where the corrugated horn is followed by a RF quadrature hybrid. The divided RF power is coupled to the mixer substrate by two RF radial probes at the ends of the chip.

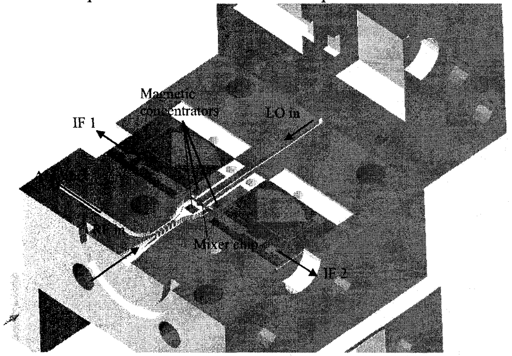

Figure 2 The bottom part of the mixer block accommodates the mixer chip, two bias-Ts and an absorber to terminate the idle port of the RF waveguide hybrid.

The LO power is applied to the middle of the substrate

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and is divided by double probes which extend into the LO waveguide.

Individual magnetic fields are applied to the SIS junctions using two external coils. Magnetic concentrators bring the magnetic field in close vicinity to the junctions, thus a very little current (about 1 mA per coil) is needed to suppress the super current.

A closer look at the mixer chip is shown in Figure 3. The RF is coupled from a full-height waveguide to a microstrip line by a pair of radial probes. A high impedance line is attached to the radial end of the probe. This line together with a RF choke provides RF/DC isolation and is used to inject DC for mixer biasing and to extract the IF [7].

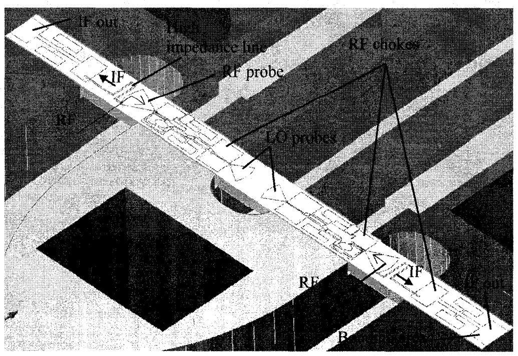

Figure 3 The 2SB mixer chip coupled to the RF/LO waveguides. The two central RF chokes provide ground for the SIS and their tuning circuitry while the chokes at the ends of the substrate provide RF/IF isolation. The relatively large area of the last choke section facilitates bonding to the Bias-T.

A second pair of radial probes divides the LO power and provides the transition from waveguide to microstrip line [8]. The two central RF chokes provide a ground for the SIS and its tuning circuitry.

The IF is extracted through the RF probe, a high impedance line, and a second choke. The high impedance line and the choke prevent RF leakage to the IF port, while at IF they represent a small inductance.

B. *Tuning Circuitry*

The mixer tuning circuitry, illustrated in Figure 4, uses a $\lambda/4$ transformer section to match the RF probe to the SIS junction. The same transformer section is used as a part of a directional coupler providing -17 dB LO coupling to RF. To provide the required coupling ratio and to avoid small gap between the lines of the coupler, two perforations in the ground plane are introduced. In order to terminate the idle port of the LO coupler, we use an elliptical planar termination [9], [10], which is made of a resistive normal-metal film. The termination is designed such that it occupies a minimum area on the substrate and provides return loss S11<-10 dB over the whole LO band. The required sheet resistance of the film forming the dot is obtained by sputtering Ti in N_2 atmosphere, resulting in a Ti/N_2 mixture with the desired resistivity.

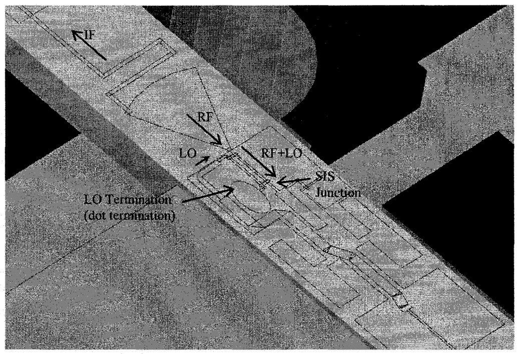

Figure 4 The mixer tuning circuitry uses a directional coupler to couple LO to RF. To provide the required coupling ratio of -17 dB and to keep the RF and LO lines well separated, two perforations in the ground plane are introduced. The RF line of the coupler is also used to match the real part of the SIS RF impedance to the signal source (the RF probe).

C. *Nb Superconducting IF hybrid*

To achieve as compact as possible 2SB mixer assembly, and to minimize losses, we use a superconducting IF hybrid. The hybrid is a traditional Lange coupler made of Nb thin film lines on a 300um quartz substrate using the same process as for the mixer fabrication. To simplify the circuitry we use an additional SiO_2 layer as an insulator and a second layer of Nb film to connect bridges instead of bond wires. The covered bandwidth exceeds the 4-8 GHz band.

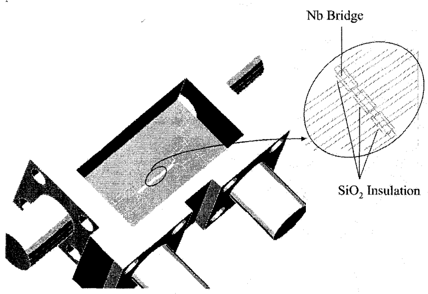

Figure 5 A picture of the superconducting IF hybrid. To achieve as compact design as possible, the width of the hybrid matches the width of the mixer block and thus can be connected without using only SMA adapters.

III. MIXER MEASUREMENTS

A. *Measurements in DSB mode*

To evaluate the symmetry of the branches of the 2SB mixer and to calculate the gain and the noise of each mixer, initial tests were performed in a DSB configuration as shown below.

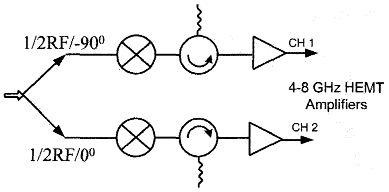

Figure 6 A DSB mixer configuration for the initial tests.

The DSB measurements were performed at different LO frequencies and for different LO powers. These measurements were used to choose optimum LO pumping power and pairs of bias points where both mixers have similar gains and minimum noise for each LO frequency.

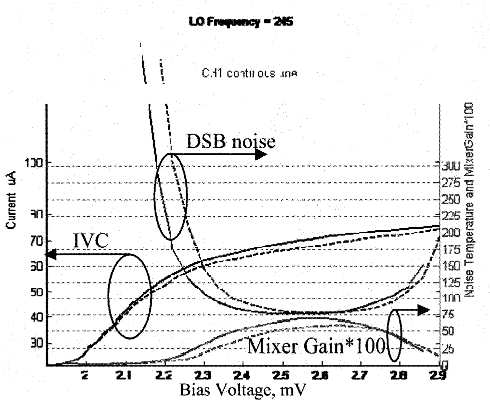

Figure 7 An example of mixer measurements in DSB mode. SIS mixer gains can be extracted by measurements of the linear region of the unpumped IVC's, thus the IF gains can be subtracted from the total gain.

Since the RF hybrid is present in the DSB tests, the measured DSB noise closely predicts the SSB noise when the IF hybrid is connected and the mixer is operated in sideband separating mode.

B. Sideband separating measurements

When operated in 2SB mode the IF hybrid is connected to the mixer as shown in the figure below.

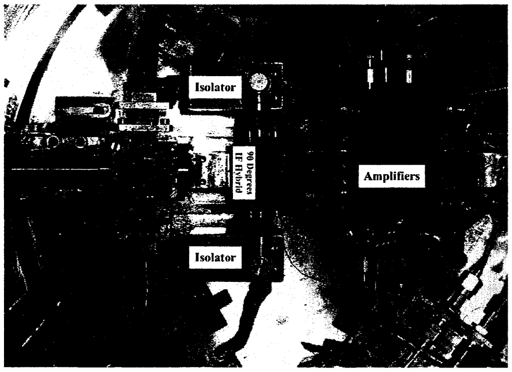

Figure 8 A picture of the setup used in the mixer measurement in 2SB mode. The mixer IF outputs are connected to isolators followed by the IF quadrature hybrid and amplifiers. The IF band is 4-8 GHz.

The sideband rejection is measured by injecting a pilot signal generated by a harmonic mixer pumped with frequency around 12 GHz. The frequency of the pilot signal is changed a few times at RF for each of the sidebands, the IF spectrum is taken each time at both IF outputs of the mixer. This results in couple of values for the LSB/USB and USB/LSB rejection ratios per single LO frequency. The sideband rejection is the difference between the peak values at IF for both sidebands (the system IF gain is nearly the same for both channels). This measurement is illustrated in Figure 9.

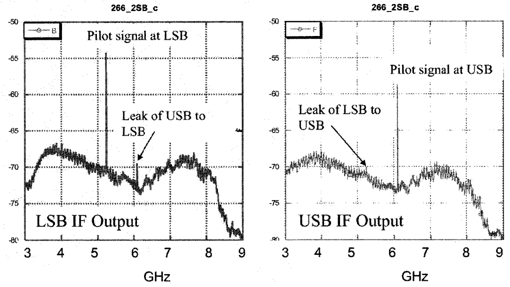

Figure 9 Illustration of the sideband rejection ratio measurement for LO frequency 266 GHz. Two pilot signals are generated (one in the LSB, one in the USB), the rejection ratios are calculated by taking the difference in the peak value at LSB/USB IF outputs of the mixer.

The measured rejection ratios and SSB noise temperatures are shown in Figure 10.

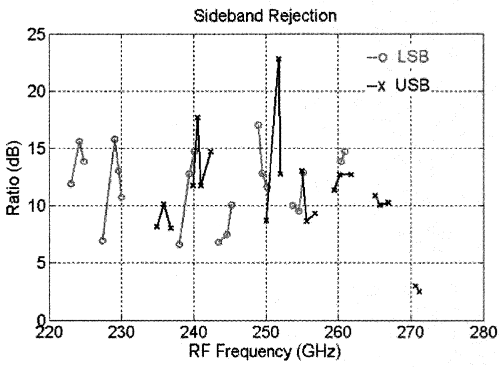

Figure 10 The measured sideband rejection ratios.

For each LO frequency the Y-factor is measured with a spectrum analyzer at both sidebands. The measured noise temperature is shown in Figure 11.

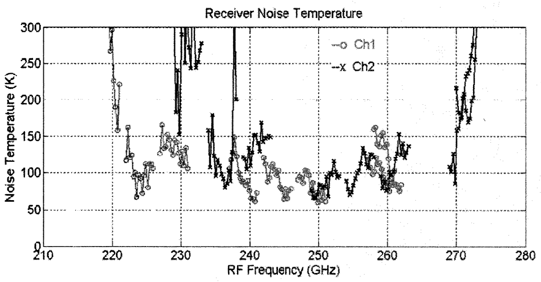

Figure 11 The measured receiver noise temperature. This noise is uncorrected for the image band contribution, if it is assumed that typical rejection ratio is 12 dB, the SSB noise temperature would be 6% higher than the temperature shown in the plot.

IV. CONCLUSION

We present the design and initial results of a 2SB mixer for Band 1 of the APEX telescope. The results presented here are preliminary and further mixer characterization is required to verify the limit of the mixer performance. The mixer setup is still not optimized e.g. the phase difference between the isolators was recently measured to be 20^0 limiting the obtainable rejection ratios. Different configurations will be also tested, e.g. rearranging the order of the IF components.

ACKNOWLEDGMENT

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