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THE DEVELOPMENT OF A LOW NOISE 230 GHZ SIS RECEIVER IN NAGOYA UNIVERSITY

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ABSTRACT

A 230 GHz SIS tunnel junction receiver has been being developed for radio astronomy in Nagoya University. In this heterodyne receiver, we use a $\sim 1/3$ reduced hight rectangular waveguide SIS mixer with two tuning elements as front end. The mixer block with SIS junction was cooled to 4K with a closed cycle He-gas refrigerator. So far, a double sideband receiver noise temperature lower than 100K in 222-237 GHz is obtained. The receiver exhibits a best DSB noise temperature of 69K at 236 GHz as well as 228 GHz.

Key Words : SIS junction, DSB noise temperature

I. INTRODUCTION

Due to their excellent sensitivity performance, SIS receivers have become the most effective and powerful radio astronomical observing instruments in frequency of 80-800 GHz. Based on the successful development of 110 GHz band SIS receiver (Ogawa et al. 1990) and focusing the further observation to the second rotational transition of carbon monoxide (230 GHz for ^{12}CO and 220 GHz for ^{13}CO) using the 4m millimeter telescope at Nagoya University, we have been developing a 230 GHz band SIS mixer receiver. Although nowaday fixed-tuned mixer is well used by many other reserch groups, the mixer with two mechanical tuning elements is still used by us as optimum performance could be obtained in some relatively narrow specific frequency bands. In this paper, we introduce the receiver design and preliminary results.

II. JUNCTION AND MIXER DESIGN

To obtain good impedance match between the high impedance waveguide source and the low impedance SIS junction, eight Nb/AlO$_x$/Nb SIS junctions in series is used for our mixing device. The junction was designed to satisfy $\omega RC \simeq 3$ for the center frequency $\omega/2\pi=230$ GHz in order to get wide instantaneous bandwidth. The normal state resistance Rn of a junction is usually $\sim 20\Omega$ and the specific capacitance $C_j \sim 60$ fF/μm^2. So the area of each junction was set to be $\sim 1.7\mu m^2$ to satisfy $\omega RC \simeq 3$. As device have eight junctions in series, Rn$\cong$ 160Ω is rather close to the embedding impedance of the reduced hight waveguide mount seen from the junction and it is expected to make impedance match easy. The junction substrate is a 200μm thick crystal quartz with a size of 3000μm length and 300μm width, on which has a RF choke filter of a seven elements quarter-wave design. This RF choke is used to! pass the IF signal and dc bias to the junction while preventing RF power leakage. In the mixer block, the RF input waveguide is rectangular(WR-4) and has a channel transformer section which smoothly change the characteristic impedance,leading to a $\sim$1/3 reduced hight section where the SIS junction substrate is installed. The mixer block has two backshort tuners (Pan et al. 1989) providing a large range of embedding admittances to the junctions. The sub waveguide for the second backshort is blocked by a fixed indium short circuit a quarter wavelength away from the substrate channel and coupled to the SIS junction in the main waveguide through the stripline,thereby providing a tunable reactance in series with the junction.

III. MEASUREMENTS

Detailed measurements of receiver noise temperature were made from 222 GHz to 236.5 GHz. The RF signal and LO power were injected via a 50μm Teflon beam splitter mounted at 45° to the LO path with about 97% RF signal together with about 3% LO radiation coupled into the cryostat and then received by a diagonal horn mounted together with mixer block at 4K. The IF output is centered at 1.5 GHz with 500 MHz bandwidth and fed directly into a cooled GaAs FET amplifier at 15K stage with 10K noise tempersture. LO is a solid state Gunn-multiplier combination with a continuously tuning band of about 15 GHz around 230 GHz, and the LO source can generate sufficient power to saturate the junctions. During the tests the junction was kept to be biased approximately at the middle of the first photon step and the mixer was tuned for maximum noise output power, which was achieved when the junction is best matched to waveguide.

IV. RESULTS AND DISCUSSION

The typical bias voltage of SIS mixer is Vgap minus half the photon step, $\cong$18mV. The sub-gap leakage at this bias point is about 6μA. It is suggested by Kooi et al.(1995) that typical operating condition to achieve maximum sensitivity is about 3 times the subgap leakage current at the proper bias point. In our measurement the LO power on the junction was adjusted to register ~25μA at 18mV bias, a bit higher than what is suggested. We found that the noise response over IF band was not very flat. We attribute it to the poor IF coupling efficiency caused by the mismatch between the high IF output impedance of our EJCS (Eight Junctions Connected in Series) device and 50Ω IF load impedance, as well as probably influence of the unexpressed Josephson current. The 230 GHz band receiver noise temperature in DSB versus LO-frequency has been measured. All noise temperature presented are refered to the input of the beam splitter and no corrections have been m! ade for beam splitter or other losses. Over frequency band 222-237 GHz, we obtained a DSB receiver noise temperature lower than 100K. In particular, a best noise temperature of 69K is achieved at 236.5 GHz and 228 GHz. From analyzing our experimental data, we believe that if our Gunn/multiplier LO chain can work upto the frequency higher than 236.5 GHz, much lower noise results should be obtained.

V. CONCLUSION

We have designed and fabricated a connected in series eight junction device and a twin-backshorts tunable mixer mount. The receiver system has been tested in 230 GHz band and shows a good noise response of lower than 100K at a RF input frequency range from 222GHz to 236.5 GHz. We believe that the noise temperature presented is closed to the best result yet reported for 230 GHz receiver using untuned junction. We expect that by applying IF matching network to raise IF coupling efficiency and magnet to suppress Josephson current, as well as making use of good performance backshorts, the receiver performance would be improved. Experiments are in progress to verify this prediction.

REFERENCES

H.Ogawa et al., Int.J.Infrared and Millimeter Waves, vol.11, no.6, pp.66-74,1990

S.-K.Pan et al., IEEE Trans.,MTT-37, pp.580-592, March 1989

J.W.Kooi et al., CSO Astrophysics Preprint