Development of 640 GHz SIS Mixer for Space Application

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Abstract — We describe our development of 640 GHz SIS mixers for use in a space experiment. The screening method of the SIS mixer is investigating to achieve both excellent noise performance and high reliability. Based on our experiment, the SIS device whose resonance-induced Josephson step appears around 1.2 mV shows a good noise performance at 640 GHz band. From the environment tests, SIS mixer shows adequate tolerances to cosmic ray particle and launch vibration. The increase of normal resistance was observed after holding 80°C for a week.

I. INTRODUCTION

The development of low-noise SIS mixers at 640 GHz band is a key issue of Superconducting Submillimeter-wave Limb-emission Sounder (SMILES) mission (e. g. [1]), which is an atmospheric observatory to be on-boarded on the Japanese Experimental Module at the International Space Station in 2005.

Through our early development phase, an excellent noise performance less than 200 K (DSB) has already achieved for a receiver with Nb-based Parallel-connected Twin-junction (PCTJ) SIS mixer as a breadboard model [2]. In further phase, both experimental and analytical studies should be done to assure not only good noise performance but also high reliability, with the aim of space application. For this purpose, technical establishment of screening method is particularly important to select reliable SIS devices.

In this presentation, we report the result of RF noise measurements to investigate the relation between RF performances and DC characteristics of SIS, such as resonance-induced Josephson step. The fact that the RF performance of the SIS mixer is able to be predicted from the DC characteristics allows us quite convenient screening process. We also present the result of various environment tests to SIS devices, such as ion irradiation and thermal cycle, to confirm their tolerance in space.

II. NOISE PERFORMANCE

Fig. 1 shows a schematic view of the SIS mixer device for SMILES. Typical junction area is about $1.25 \times 1.25 \mu m^2$, and current density is $5 - 8 \, kA/cm^2$. Considering the space application, we adopted the PCTJ type device which enables to achieve a broad RF impedance matching without troublesome mechanical tuning.

To investigate the most suitable tuning length for 640 GHz application, we fabricated PSCJs with three different tuning lengths in a wafer. The resonance-induced Josephson step voltage ($V_{res}$) is predicted to change with the tuning length ($L$) as $V_{res} \propto L^{-0.5}$. Fig. 2 shows mea-

![Schematic view of the SIS device.](image-url)
Figure 2: Resonance step voltage ($V_{\text{res}}$) normalized by the $V_{\text{res}}$ of A-series ($L = 7.5 \mu m$) device for each wafer. Symbols indicate different wafers. The inset represents an example of the obtained $I - V$ characteristics to determine $V_{\text{res}}$.

measured $V_{\text{res}}$ as a function of $L$. Since the resonance step is also a function of another parameters, such as junction area, the indicated $V_{\text{res}}$ is normalized for comparison between different wafers. The result represents that the prediction is roughly correct.

We also measured the DSB receiver noise temperature ($T_{\text{ns}}$) for the fabricated SIS mixers. The detail of the measurement system is described in elsewhere [2]. Fig. 3 shows an interpolated contour plot of the noise temperature, based on the measurement of seven mixers, as a function of $V_{\text{res}}$ and local oscillator (LO) frequency. Although the minimum $T_{\text{ns}}$ is not so excellent in this experiment, we could find that $V_{\text{res}}$ should around 1.2 mV for our purpose.

III. ENVIRONMENT TESTS

The space environment is a hostile one in which to operate a sensitive measurement system in many ways. We were carrying out various environmental tests to SIS mixers to confirm their tolerance and estimate its effect. Here we briefly introduce some topics.

A. Cosmic Ray Particles

The SIS mixer is shielded from the cosmic ray particles by some “walls” (e.g. cryostat), so that total dose in one year is estimated only less than 750 rads. We performed proton irradiation test with cooling the SIS device below 4 K. The DC characteristics was monitored during the test. Although some changes in DC characteristics was observed after extremely high fluence irradiation, we confirmed that the cosmic ray tolerance of the SIS device was far higher than the total dose expected in the orbit.

B. Thermal Cycle

Figure 3: Contour plot of the noise temperature as a function of $V_{\text{res}}$ and local oscillator (LO) frequency.

It is expected that the SIS mixer will experience some $-40^\circ C$ to $+60^\circ C$ thermal cycles in orbit when mechanical cooler is not operating. Moreover, baking of cryostat system will be done to reduce outgassing before launch. To investigate the influence of the thermal environment, we measured the change of DC characteristics after keeping the SIS device at high temperature. As the result, an increase of normal resistance by $\sim 10 \%$ ($\approx 1 \Omega$) was observed by 80$^\circ C$, one week test. It is probably due to increase of tunnel barrier at SIS junction by reaction of unbound oxygen with Al atoms (e.g. [3]).

C. Launch Vibration

The launch vibration will not affect the SIS device itself, but possibly damage an electric circuit integrated in the mixer mount, or move the SIS device to undesirable position. The maximum level of the vibration load at 4 K stage in cryostat, where the SIS mixers will be installed, is estimated to 37 G$_{\text{rms}}$ for our launcher. We have performed preliminary vibration test to the SIS mixer with the same level. As the result, no change in DC and RF performance was found.

REFERENCES