Upgrading of the 40 GHz 6-beam SIS receiver for Snuyaev-Zel'dovich observations

Takashi Kasuga [1] and Masato Tsuboi [2]

1 *Department of System and Control Engineering, Faculty of Engineering, Hosei University, Kajino-cho 3-7-2, Koganei, Tokyo 184-8588, Japan.* kasuga_t@k.hosei.ac.jp

2 *Nobeyama Radio Observatory, National Astronomical Observatory, Minamisaku, Nagano 384-1305, Japan.* tsuboi@nro.nao.ac.jp

ABSTRACT

We conducted Sunyaev-Zeldovich observation over 7 years using the Nobeyama 45m telescope and the 40 GHz 6-beam SIS receiver. In 1998 the receiver dedicated to the high-sensitivity continuum observation was constructed and boarded on the 45 m telescope. The multi beams and sensitive SIS receiver made it possible for us to observe distant sources. In 2003 we started to reconstruct and upgrade the receiver for deeper and more rapid observations and for mapping high-z sources. The points of this up-grade are the use of the cooled HEMT IF amplifier with more wider bandwidth and stable SIS bias supplies that resist noise environments.

INTRODUCTION

Observations of the Sunyaev-Zeldovich（SZ） effect［1］ are very important probes for the studies of the early universe. The SZ effect signal at millimeter wavelength appears as a very shallow dip at the center of galaxy cluster because of the inverse-Compton scattering between the cosmic background radiation photons and hot electrons in the cluster. The detection is very difficult because the temperature decrement of the SZ signal is less than 100 μK and extended over several arc-minute size. Highly sensitive detection and rapid imaging techniques including interferometers were waited for the detection［2］. In 1995 we started the SZ observation at 43 GHz（7 mm） using a fairly sharp beam and a large focusing power of the of Nobeyama 45m telescope［3］ and a high sensitive single receiver with the SIS mixer. In 1998 we introduced a 6-beam 43 GHz SIS receiver camera dedicated for the SZ and continuum observations［4］. And in 2003 we started to reconstruct and improve the receiver for deeper and more rapid observations and for mapping high-z sources. In this letter, details of the up-grades of the 6 beam SIS receiver system are shown.

RECEIVER SYSTEM

The outline of the 6 beam 40 GHz SIS receiver system［5］ is shown in Figure 1. The receiver is placed at one of the Coude focus in the receiver room of the 45m telescope. The signal beam comes down and is divided to 6 beams by roof top mirrors. The beam separation is 80 arc-seconds corresponding to two beam-width of the telescope. Each beam comes in the receiver vessel through an input lens port. In the vessel there are 3 × 2 receivers which are aligned along two rows. Each receiver consists of a SIS mixer and a cooled IF amplifier. Local power is generated in a phase-locked Gunn oscillator located outside of the vessel and divided to two branch waveguides by a 3 dB divider. Each waveguide is followed by an attenuator and is fed into the vessel. At 4 K stage in the vessel LO power of each branch is divided and supplied to three SIS mixers by cross guide couplers. Six IF signals of SIS mixers are amplified by cooled HEMT amplifiers at 4 K stage and room temperature amplifiers outside of the vessel, and detected as total power continuum signals, which are DC amplified and transmitted to the telescope data acquisition system through long cables. The whole receiver is on the rotation table which can be PC-controlled to rotate the image angle according to the earth rotation.

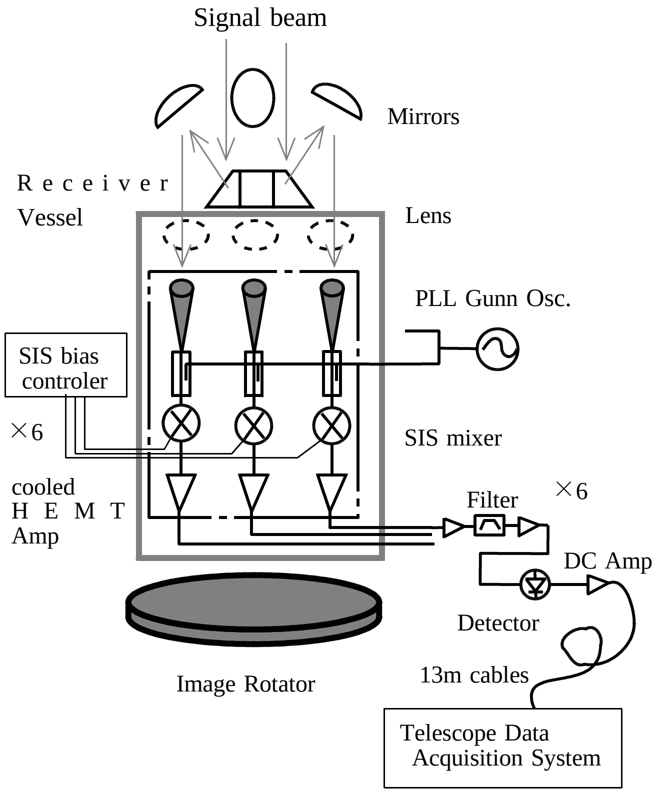


Fig. 1 Schematic display of the 6 beam receiver system. Beams are alligned in two rows. One row of three beams are shown.

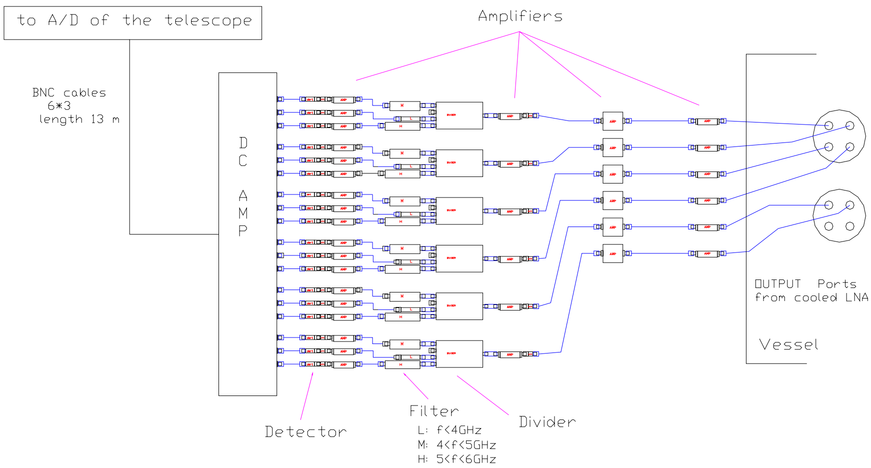
In the first generation receiver system, there were two problems.

(1) L-band amplifier of the center frequency 1.5 GHz and the bandwidth 500 MHz with an input isolator was used as IF amplifier. The noise is sufficiently low, but the observation sensitivity was limited by the bandwidth.

(2) SIS bias voltage around millivolts was supplied from the bias controller outside of the vessel, and bias and monitor lines were directly connected to SIS mixer junction. This bias system was very weak to noises and fluctuations of the electric ground environment. In January, 2003 one of three DC power supply lines (+15, -15, and 0) to the bias controller was disconnected by an accident and the controller outputted maximum voltage +15V, which was directly supplied to SIS junction. Four SIS junctions were shorted. And the observations of this season using this receiver stopped.

NEW SYSTEM

We started to repair and upgrade the receiver in 2003. SIS mixer junctions were remade. Cooled IF amplifiers were replaced from 1.2-1.7 GHz to wider 3-7 GHz band ones. Flatness of output power level of IF amplifiers with



Fog. 2 IF amplifiers and filter banks out of the vessel. Three frequeucy bads, L: f<4GHz, M:4<f<5GHz, and 5<f<6 GHz are used..

SIS mixer were not so good, so dividers and three filters at the frequency of lower than 4, 4-5, and 5-6 GHz followed by detectors were used, as shown in Figure 2. Three band signals are separately amplified, square-law detected, DC amplified, and transmitted to the A/D data acquisition system of the telescope through 18 （=3*6） cables of 13 m length. Outputs of three frequency bands are mapping separately and three maps are combined after some calibrations.

The SIS bias control electronics and wiring were replaced to newly designed ones for increments of resistance to external fluctuating noise at low frequency. The main point is using resistances between output of bias controller and SIS mixer. Series and parallel resistances are placed near the mixer at 4 K. Figure 3 shows electronics and wiring. Wires between the outer electronics and the mixer is not replaced, and four lines wiring methods can not be used for I and V measurement of the SIS mixer.

Fluctuations of output voltage levels at low frequency decreased and sensitivity was improved about three times and observation speed is ten times higher. The review of the results of the SZ observations including some maps will be presented in Session-J of this URSI GA ［6］.

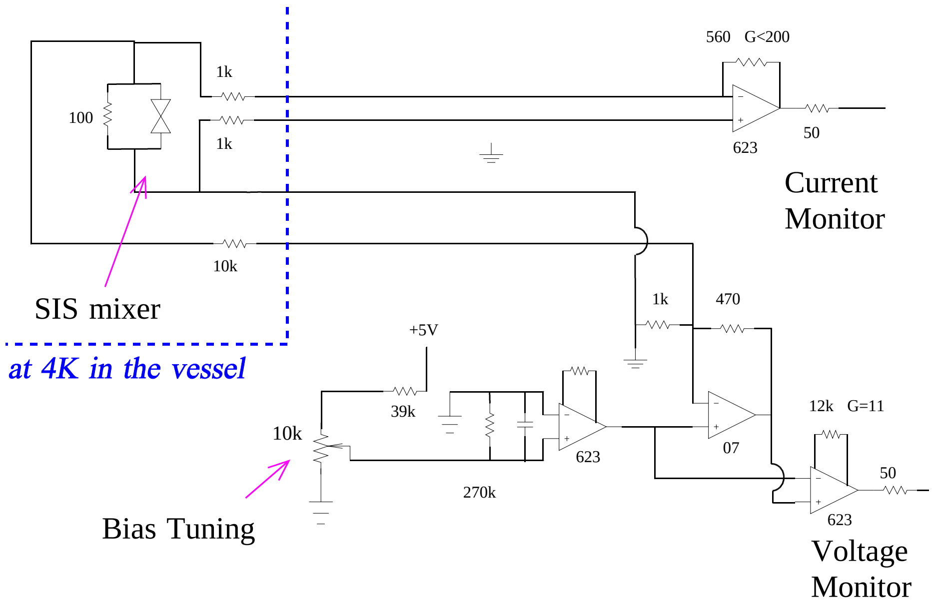


Fig. 3 SIS mixer bias circiut with series and parallel resistors.

We plan to replace 4 wires to 5 wires for the bias controller, and introduce coaxial capacitor feed-through. And now we are doing design and fabrication of InP HEMT chips in cooperation with National Institute of Information and Communication Technology ［7］, and cooled amplifiers with this chips will be used.

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