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The Superconducting Receivers of the Sub-mm Array of Taiwan

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Abstract. The Institute of Astronomy and Astrophysics (IAA) has reached an agreement, with Havard-Smithsonian Center for Astrophysics to extend the Sub-mm array by two telescopes. IAA will deliver the low noise superconducting receivers for the two telescopes, and integrate the receivers to the telescope. This paper is to report the current, development of the superconducting receivers at IAA.

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I. Introduction

Sub-mm astronomy is regarded as the last frontier of radio astronomy in the 21st century. It has led to a better understanding of the giant molecular clouds and interstellar chemistry. The sub-mm array, utilizing superconducting receivers will provide high sensitivity and resolution. Havard-Smithsonian Center of Astrophysics (CFA) is building a sub-mm array with six telescopes. The power and the speed of the array are proportional to the permutation of the number of the telescopes. The Institute of Astronomy and Astrophysics (IAA) of Academia Sinica had reached an agreement with CFA to add 2 telescopes to the array such that the power of the array will be nearly double. The design of the telescopes and superconducting receivers of the two telescopes added are the same as the other six telescopes for system compatibility. IAA will build the superconducting receivers and telescopes in Taiwan. The purpose of doing this is to extend the instrumentation capacity at IAA, and to build up a good solid foundation for future development of high technology instrumentation. The know-how of the mm and sub-mm technology can be spun off to the local industry.

This project was started from scratch two years ago. Firstly, we have had to equip the receiver laboratory. Our first goal is to deliver the low noise 200 GHz receiver. In this paper, we will discuss the structure of the superconducting mixer. A low noise temperature of 45 K and wide band width of 50 GHz superconducting mixer was achieved.

II. Corrugated feed horn and mixer

We have followed the design from Blundell et al. [1]. The 200 GHz mixer is composed of a corrugated feed horn, a mixer back section block and a superconducting-insulating-superconducting (SIS) junction. Fig. 1 shows the drawing of the corrugated feed horn

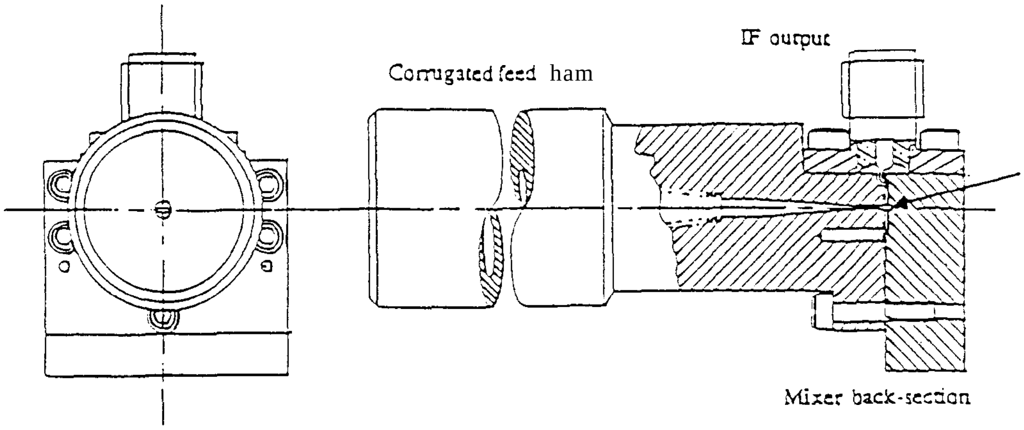


FIG.1. shows the structure of the corrugated feed horn and the mixer block. The arrow indicate the backshort.

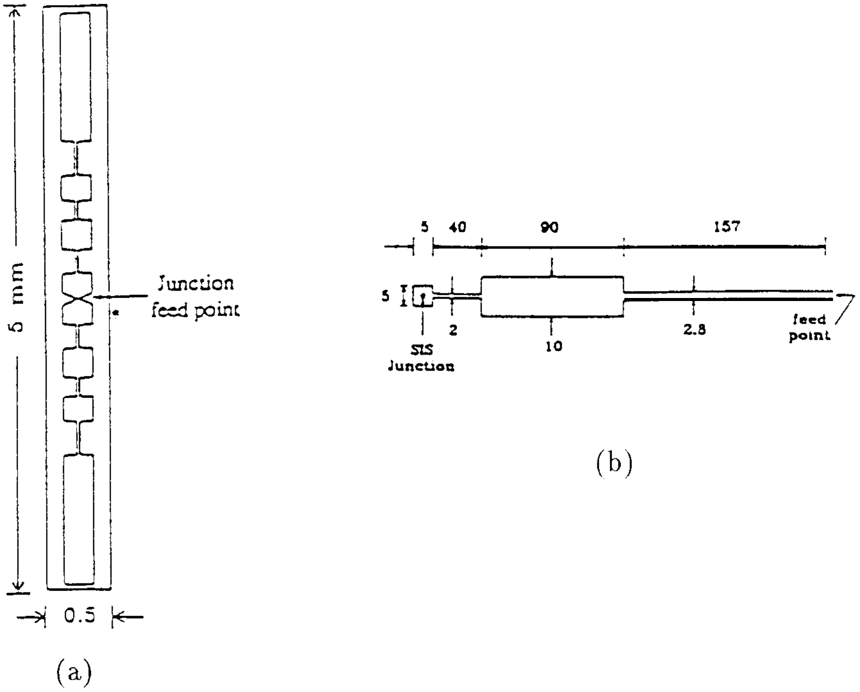
and the mixer block. The design of the wide band and low return loss corrugated feed horn followed that of Xiaolei Zhang [2]. Our mixer block and corrugated feed horn were fabricated by electroforming and machining. A fixed-tuned design was employed at the back short of the mixer block. The depth of the back short was chosen to be 343 μm in order to get the real impedance at the feed point of the junction according to Blundell *et al.* [1].

Figures 2 (a) and (b) show the schematic of the mixer junction. The structure shown in Fig. 2 (a) is a band pass filter for the IF output signal at the center frequency of 5 GHz (The IF frequency). The junction with its tuning stubs is fed at the junction feed point. Figure 2(b) shows the details of the SIS junction with the tuning stubs. The 40 μm long microstrip is used to tune out the imaginary part of the impedance due to the capacitance of the SIS junction such that a real impedance can be obtained. The combination of the 90 μm and 157 μm long microstrips act as the impedance transformer which matches the 35 Ω input impedance of the horn with the real impedance of the combination of the tuning stub and the junction.

The junction was mounted on the slot of the mixer back-section in our lab at IAA. We obtained the junction fabricated at JPL from Dr. Ray Blundell. The signal from the sky coupled with that from the local oscillator is input at the front end of the horn. The signal is then guided to the SIS junction which acts as the mixer to down convert the signals. The IF signal is conducted from the junction to the connector by a small Be-Cu spring wire which contacts the junction. The down converted IF signal is then output from the connector.

III. Noise measurement system

The noise measurement system is composed of an Infrared Laboratory dewar in which the corrugated feed horn with SIS mixer junction mounted, HEMT IF amplifier and isolator are mounted. The Infrared Laboratory dewar provided a 4.2 K environment for the components mounted inside. The down converted IF signal from the mixer is connected



(a) (b)

FIG. 2. shows the structure of the junction mixer. (a) shows the details of the filter for the IF output signal. The dimensions are in mm. (b) shows the details of the SIS junction with the tuning stubs. The dimensions are in μm. (b) is the enlarged view of the region around the junction feed powt of (a).

to the HEMT IF amplifier through the isolator by a cryogenic microwave cable. The IF signal is further amplified by a post amplifier system which is located outside the dewar. The amplitude of the IF signal is then measured by a power meter.

The 200 GHz LO signals are generated by a 100 GHz Gunn oscillator with frequency doubling. The noise signals from the hot/cold back body loads, coupled with the signal from the local oscillator are fed into the horn through a Teflon lens. The amplitude of the IF signals are measured under both hot and cold loads. Here we have chosen the temperature of the hot and cold load to be room temperature (297 K) and liquid nitrogen temperature (77 K) respectively. The noise temperature T of the receiver is calculated by the Y - factor method given by $Tc = \frac{T_{hot}-YT_{cold}}{Y-1}$ where Y is the ratio between the IF output powers of the receiver when looking at a black body at room temperature (T_{hot}) and at 77 K (T_{cold}).

Fig. 3 shows the frequency response of the measured noise temperature of the receiver. A low noise temperature of roughly 45 K is measured across the whole bandwidth of the mixer designed. The quantum limit of noise temperature at 200 GHz is approximately 15 K [3]. This low noise temperature is only three times the quantum limit and is competitive with other observatories.

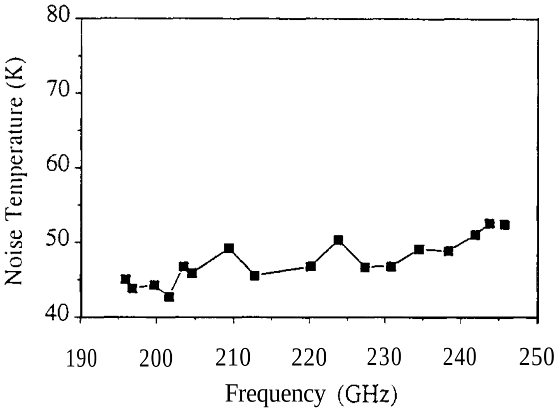


FIG. 3. shows the noise temperature of the receiver as a function of frequency.

IV. Conclusion

We are building the super conducting receivers for the sub-mm array. A receiver laboratory has been set up at IAA. A wide band and low noise **200 GHz** receiver has been fabricated. This demonstrates that we have managed the technology to build those low noise receiver at IAA. We are going to build the 300 and 600 Ghz receivers in the near future. Those receivers will be integrated into the telescopes for the Sub-mm array.

Acknowledgment

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