## A-1.1.2 Development of Millimeter-Wave instruments of ClO and Ozone

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**Total Budget for FY1994-FY1996** 74,727,000Yen

### Abstract

We are developing low-noise superconducting receivers of the 200 GHz band in oder to observe rare constituents of the earth's atmosphere, particularly ClO. This development includes 200 GHz mixer mounts, Superconductor-insulator-superconductor (SIS) junctions, backshort tuners, Gunn oscillators at 70-80 GHz as LO, and frequency triplers. The measurements in the laboratory indicate the best noise temperature of 60K in DSB in a frequency range of 210 to 230 GHz, an encouraging result for realization of a ClO monitoring system.

**Key Word** ClO, Ozone, Millimeter receiver, Superconductivity

### 1. Introduction

In recent years, various atmospheric constituents have been measured by microwave techniques. The method has a distinctive advantage for measurements of diurnal and short term variation over other techniques. The microwave observations measure thermal emission of molecules and then the measurement does not require a background radiation source like the sun as is the case in absorption measurements.

It is becoming more and more of urgent need to precisely measure the abundance and time variation of atmospheric ozone. We have developed very low noise Superconductive radio meters for ozone measurement. Table 1 summarized the main characteristic of ozone instruments for each institute. At the same time, the simultaneous measurement of ClO molecule, one of the most effective destructors of ozone, has been paid a keen attention to.

It is pointed out that the measurements of ClO molecules can be most accurately made at frequency above 200 GHz because of less contamination due to other molecular spectra at such higher frequency. The most suitable ClO rotational transition is located at 278 GHz, and by observing this transition we are able to make a direct assessment of the ozone destructing scheme due to ClO. We are developing new very sensitive radio meter for ClO monitoring by extrapolating the SIS receiver technique already in use for the ozone monitoring system [1] in work at Tsukuba since 1995. Other molecular spectra of interest include $N_2O$ (276 GHz), $HO_2$ (266GHz), etc.

So far, observations of ClO molecules were made at Maunakea in Hawaii (NASA) and in Jungfrau of Alps (University of Blemen). Both of them employed semiconductor receivers having rather low sensitivity, and the quality of the data were not very suitable to be compared with ozone variation in detail. Most recently, a new radio meter started its operation in the antarctica. A summary of these efforts to monitor ClO is given in table 2. The aim of this research is to develope a superconducting receiver more sensitive than those listed in table, and to use it to monitor ClO behaviour in a higher time resolution, revealing thereby how ozone behaviour is correlated with ClO's.

## 2. Developments

Figure 1 shows a block diagram of the ClO receiver front end. In the following we shall describe in detail the major parts of this front end.

### 2.1 Mixer mount

The mixer mount in which the SIS junctions are installed should be made accurately as much as possible. For a lower frequency 100 GHz mixer [2], we made a high precision waveguide of 150-micron high through machining. This method is convenient since it is a very versatile way to change the waveguide impedance easily, to adjust itself for any change or improvements of the shape or dimension of the SIS junction. For 200 GHz mixer, we need waveguide impedance smaller than 100 ohms, corresponding to a waveguide of 120-micron height. 100 GHz mixer mounts are machined by using a phospherbronze plate of 30-micron thickness with a special jig, and a backshort tuner of 170-micron diameter is manufactured. An ideal impedance matching was achieved by squeezing this backshort into the 150-micron height waveguide. According to the change of the wavelength from 2.7 mm to 1.2 mm, the size of the waveguide needs to be scaled down by about 50 %. We developed jigs etc. which matches this scaling down and succeeded in manufactured a 200 GHz mixer mount as shown in Figure 2.

### 2.2 SIS junction

It is important to reduce the capacitance of the SIS junction for higher frequency. It is however seriously limited to reduce the diameter of a single SIS junction; a practical limit in the diameter is around 0.2 microns in case of the present method, photolisography. In addition, the actual limitation comes from the accuracy of the junction, and for a diameter less than 1 micron, reproducibility becomes worse to an unacceptable level. We therefore chose the diameter of a single junction to be 1.5 micron (the diameter for a 100 GHz junction is 2.5 microns), and use 8 of them in series in order to reduce the synthesized capacitance. The junctions so designed are now being fabricated in Fujitsu Laboratories, and the results so far obtained indicate that SIS junctions having single capacitance of 30fF and normal resistance of 50 ohms can be produced at a high rate more than 60%. Figure 3 shows a voltage-current diagram of one of these junctions, demonstrating its nice characteristics.

### 2.3 Noise performance of the SIS mixer at 200 GHz

The mixer mount described above was used to measure the noise temperature in the laboratory, cryogenically cooled at 4K. The local oscillator consisted of a 70 GHz Gunn oscillator combined with a frequency tripler, and the LO power was coupled to the receiver input port via a beam splitter made of a flat teflon plate as shown in Figure 1. The intermediate frequency amplifier is a L band HEMT amplifier. Figure 4 indicates the IF power responses measured for input loads equivalent to 300K and 77 K, respectively. Theses data were used to evaluated the receiver noise temperature as shown in Figure 5 [3),4)]. The best data obtained so far is 60 K in DSB at 220 GHz, corresponding to about 5 times the quantum limit at the frequency.

### 2.4 Development of LO

The LO power is obtained via a tripler from the Gunn oscillator. The mixer requires an output power level of 1 mW. The tripler has an efficiency of around 5% at 270 GHz. This means the input power at 70-80 GHz should be more than 20mW. The current Gunn oscillator provides output power of 30mW at 71-78 GHz, and this frequency range should be at 90 GHz for the ClO receiver.

## 3. Summary

The developments of a ClO SIS mixer receiver is reported. The best data in noise temperature, 60 K in DSB at 230 GHz, encouraging us to use the technique for the actual ClO monitoring system.

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Table 1 Ozone radio meter in the world

| Institute / Location | Freq. GHz | Mixer | Cooled K | Band | T sys K | Spectrometer MHz | |
|---|---|---|---|---|---|---|---|
| NASA / T.M.O. | 110.8<br>109.5 | SD | 15 | SSB | 340 | 630 | FB |
| Bordeaux | 110.8 | SD | 20 | SSB | 480 | 128 | FB |
| Onsala | 110.8 | SD | 15 | SSB | 300 | 512 | FB & AOS |
| Helsinki | 110.8 | SD | 20 | SSB | 530 | 1000 | AOS |
| Nagoya | 110.8<br>110.8 | SIS<br>SIS | 4<br>4 | DSB<br>SSB | 23<br>34 | 51<br>51 | AOS |
| Bremen / Ny-Alesund | 110.8<br>142.2 | SD<br>SD | 12.5<br>12.5 | SSB<br>SSB | 690<br>590 | 950<br>950 | AOS |
| Bern | 142.2 | SD | no<br>25 | DSB<br>DSB | 1300<br>700 | 1200<br>1200 | FB |
| Moscow / Puschino | 142.2 | SD | 20 | SSB | 1000 | 64 | FB |
| SUNY / South Pole | 276.9 | SD | 20 | | 650 | 512 | FB |
| NIES / Tsukuba | 110.8 | SIS | 4 | SSB | 34 | 60 | AOS |

( reference 5) except for Tsukuba )

SD : Schottky Diode mixer

SIS : Superconductor-Insulator-Superconductor mixer

FB : Filter Bank Spectrometer

AOS : Acousto-Optical Spectrometer

Table 2 ClO radio meter in the world

| Location | Frequency GHz | Mixer | Cooled K | Band | Tsys K | Spectrometer MHz | | Reference |
|---|---|---|---|---|---|---|---|---|
| Mauna Kea (4200m) | 278.631 | SD | (20) | (SSB) | (850) | (128) | FB | 6) |
| Plateau de Bure (2550m) | 278.631 | SD | 20 | SSB | 850 | 128 | FB | 6) |
| Ny-Alesund (~10m) | 204.352 | SD | 15 | SSB | 1100 | 945 | AOS | 7) |
| Jungfraujoch (3580m) | 204.352 | SD | 20-40 | SSB | 1200 | 400 | FB | 8) |
| McMurdo Sta. South Pole | 278.631 | SIS | 4.5 | | 350 | 600 | AOS | 9) |

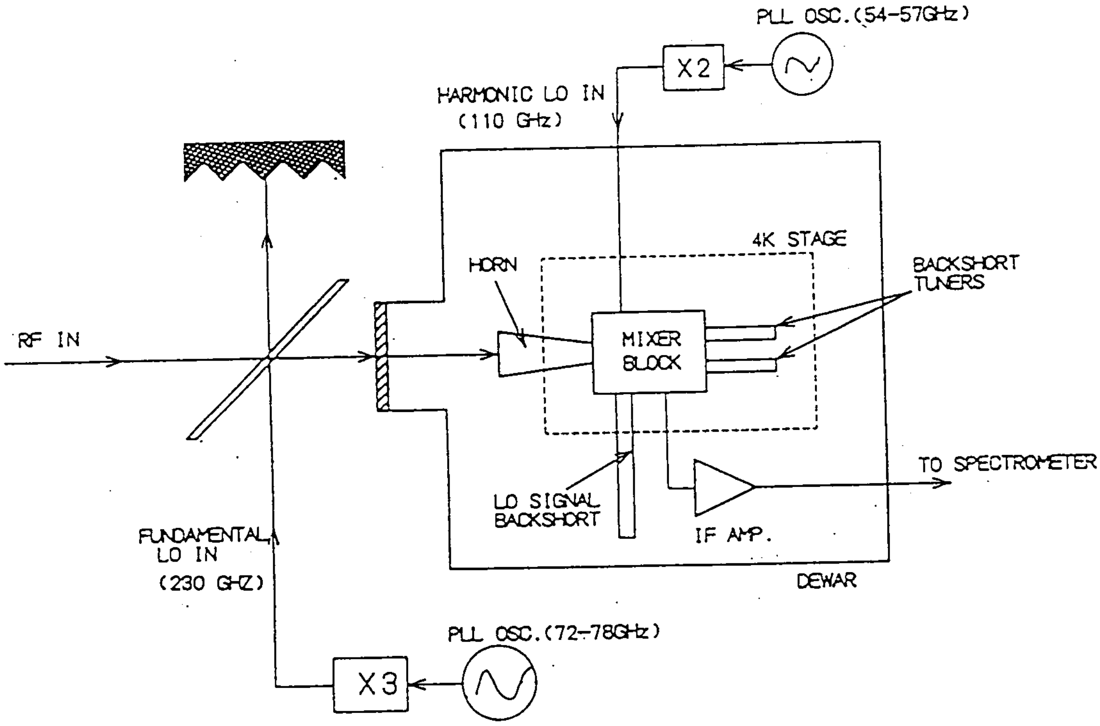


Figure 1 Block diagram of the front end of a 200 GHz receiver

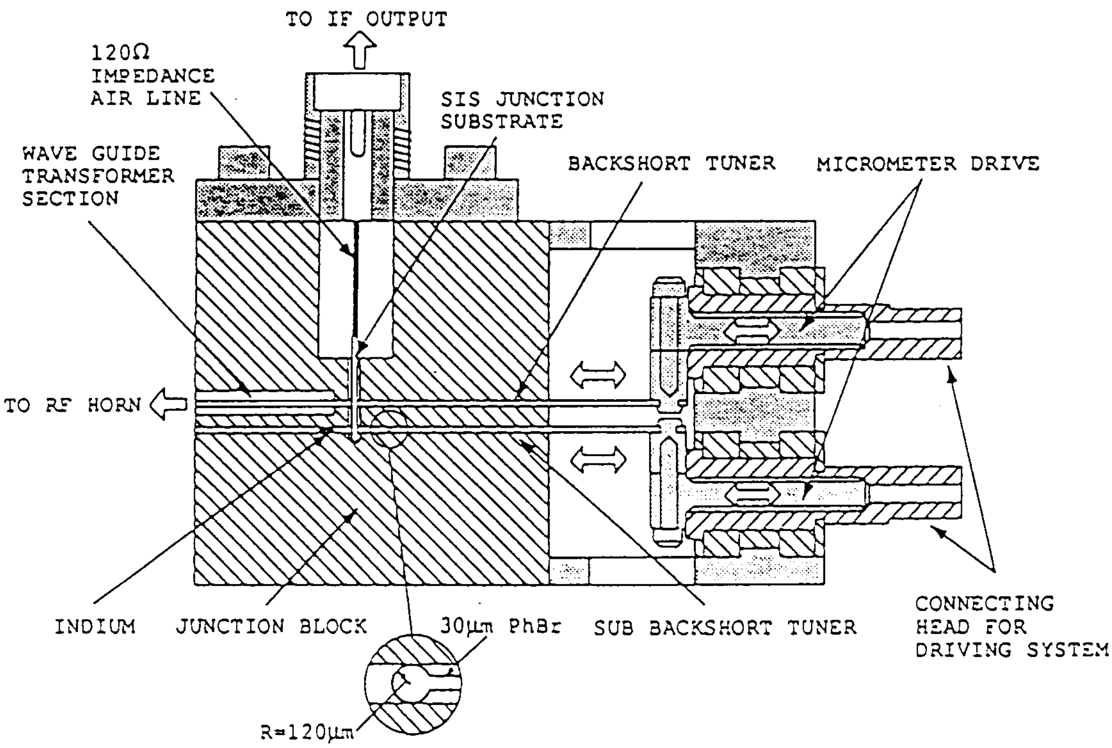


Figure 2 Cross section of the 200 GHz mixer block (size of the block is 2cm x 2 cm)

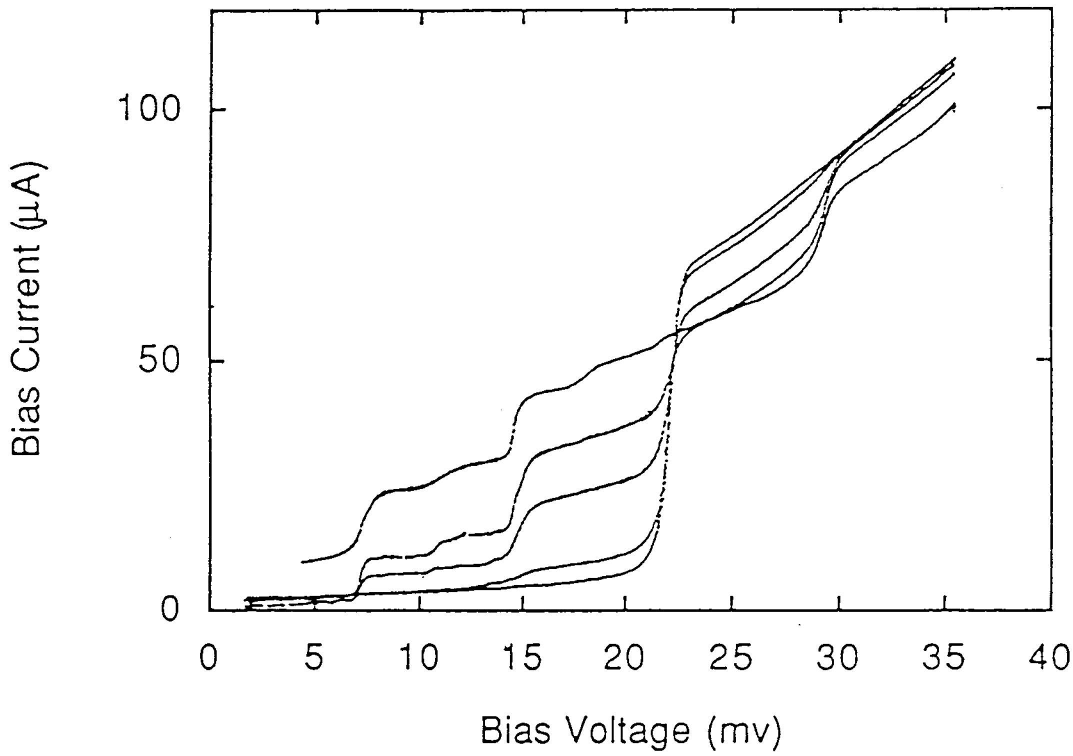


Figure 3 Voltage-current diagram of the 200 GHz mixer. The steps corresponds to the voltage of a 200 GHz photon.

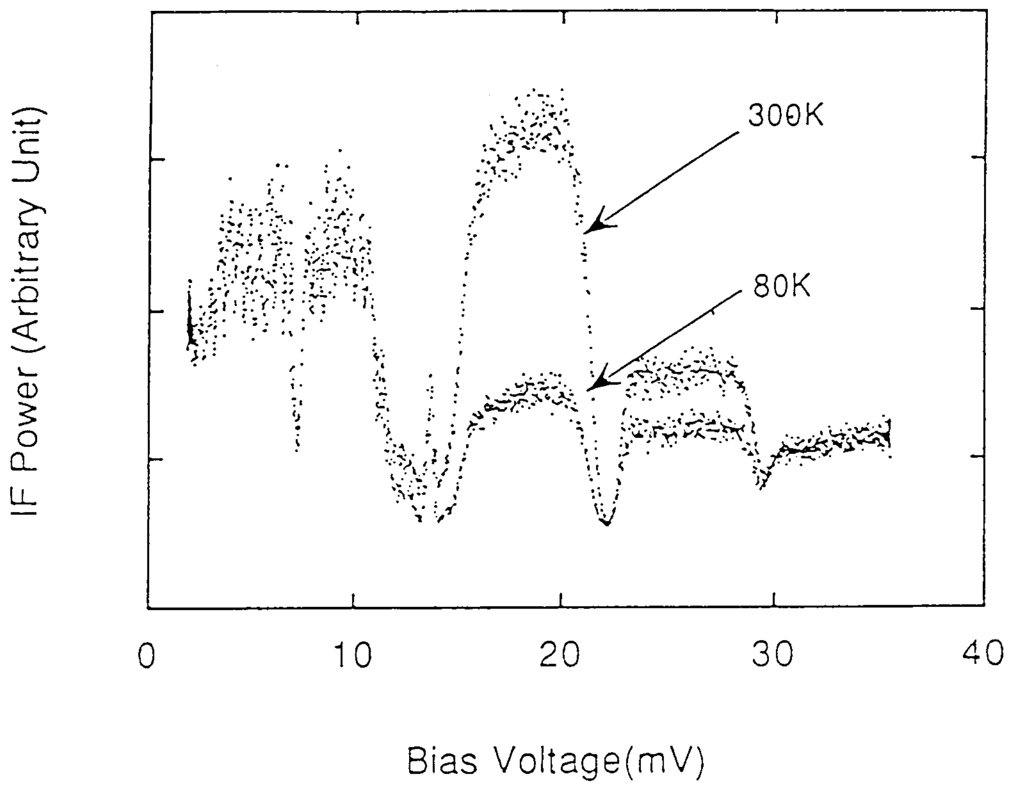


Figure 4 Power at the intermediate frequency output. The physical temperatures of the loads are shown for each data set.

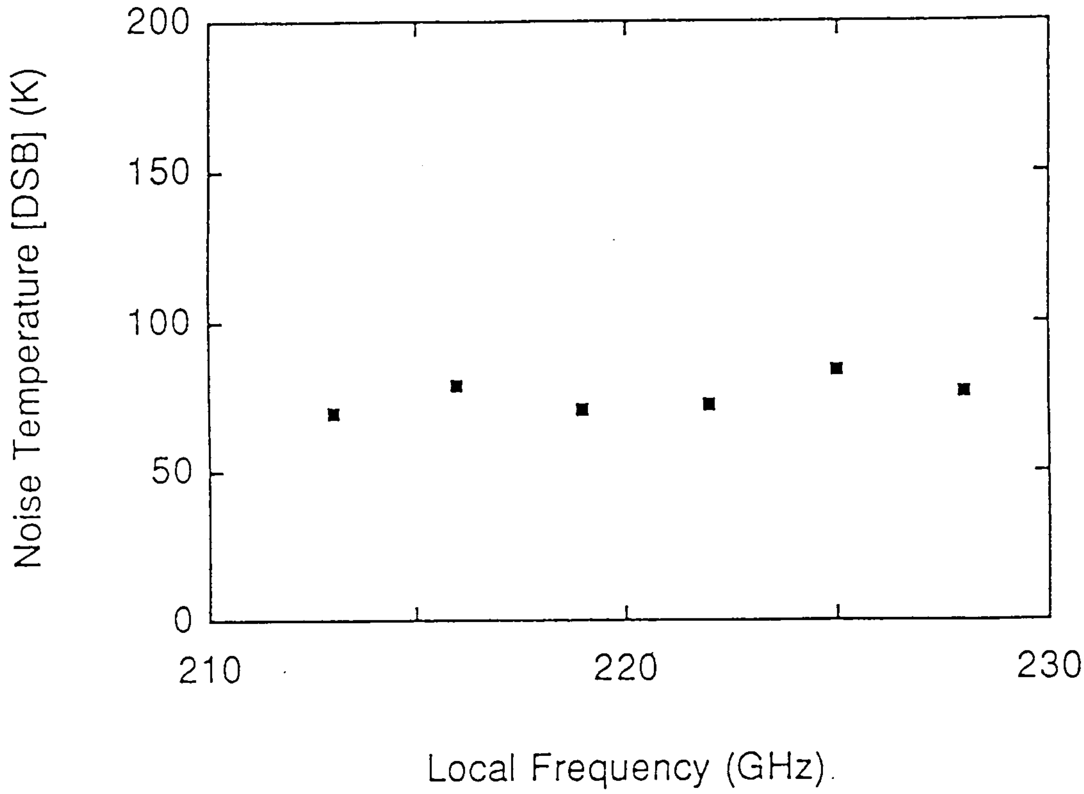


Figure 5 Noise temperature of the 200 GHz receiver.