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Double Dipole Antenna SIS Receivers at 100 and 400 GHz

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Abstract

Antenna patterns were measured between 95 and 120 GHz for a double dipole antenna / ellipsoidal lens combination. The structure produces a non-astigmatic beam with low side lobe levels over that whole band. A heterodyne SIS receiver based on this concept gave a best noise temperature of 145K DSB at 98 GHz. Measurements were also made with a 400 GHz heterodyne SIS receiver, using a double dipole antenna in conjunction with a hyperhemispherical lens. The best noise temperature was 220 K DSB at 402 GHz. On-chip stubs were used to tune out the SIS junction capacitance.

Introduction

We here describe two SIS heterodyne receivers, both using double dipole antennas [1,2,3,4] placed on the back plane of a thick dielectric lens. In both cases, the antenna consisted of two half wave dipoles, connected by a stripline with the SIS mixer at the mid point, Fig.1 . The quartz chip with the antenna was mounted on the back plane of a thick quartz lens, and was backed by a quarter wave thick quartz slab and a reflector, Fig.2 . Some early low frequency scale model measurements of this structure can be found in [4].

Both receivers were designed in similar but not identical ways, and will be described separately.

100 GHz Receiver Design

The size of the dipole antenna was chosen to give a center frequency of 100 GHz. The 11mm diameter quartz lens was polished to an ellipsoidal shape, designed to produce a diffraction limited main lobe. The polishing tool was a brass rod with an ellipsoidal hole at one end, machined with a numerically controlled milling machine.

As shown in Fig.3 the mixer fixture pinched the lens between a copper back plate and two flanges, which fitted into two grooves in the quartz. With the help of a small amount of vacuum grease, this provided excellent 4K cooling of the lens and the mixer chip.

The mixer itself was a series array of two Nb-Al/AlOx-Nb SIS junctions with a normal state resistance of 34 ohms. The size of each junction was 2 square microns. No attempts were made to tune out the parasitic capacitance of the junctions.

The mixer chip was contacted by a flexible strip transmission line, Fig.4 , which was soldered to a 85 mil output co-ax. The strip was cut to high accuracy from a Kapton/copper laminated sheet, to give a characteristic impedance close to 50 ohms. As shown in Fig.5 , the strip line would work well even for intermediate frequencies of up to 8 GHz, where resonances in the lens fixture begin to appear.

100 GHz Measurements

The antenna pattern of the dipole/lens fixture was measured at room temperature with a bismuth bolometer in place of the SIS junctions, Fig.6 . Both the E- and H-plane beam profiles were of high quality over the whole 95-120 GHz band, in good agreement with earlier scale model measurements [4].

Y-factor measurements with the SIS mixer in a 4.2K helium cryostat gave a best receiver noise temperature of 145K DSB at 98 GHz, Fig.7 . The intermediate frequency amplifier was a 1.5 GHz cooled Berkshire HEMT, with a noise temperature of 4K (from the manufacturers data sheets). We believe that the noise performance can be improved considerably by the use of on-chip tuning structures, but have not yet implemented this in the 100 GHz receiver.

400 GHz Receiver Design

The 400 GHz receiver differed from the 100 GHz one in a few ways, namely :

1. We chose to use a hyperhemisperical lens, mainly because it can be manufactured to higher tolerances than an ellipsoidal one.

2. The antenna was a scaled down version of the 100 GHz structure. The center frequency was chosen to 310 GHz, which puts the upper frequency limit of the antenna itself somewhere around 430 GHz (one octave bandwidth).

3. The SIS parasitic capacitances were tuned by on-chip stubs, as can be seen in Figs.8 and 9 . A series array of two junctions, each of 3 square microns, was used.

4. We used two different IF amplifier chains, one with a 1.5 GHz FET with approximately 11K noise temperature, the other with a 4 GHz Berkshire Technology

HEMT with 4K noise temperature.

5. The Josephson effect was suppressed by a superconducting coil.

400 GHz Measurements

The video response of the receiver over the range 100-600 GHz was studied with a Fourier transform spectrometer, Fig.10 . Two peaks are visible in the diagram, one just above 200 GHz and one close to 400 GHz. The approximate positions of the peaks could be predicted from a simple circuit model, where each junction was represented by a capacitance of 165 fF in parallel with its normal state resistance.

Two initial Y-factor measurements with the same mixer chip are shown in Fig.11 . The best performance was at the lower end of the available local oscillator band, with a lowest noise temperature of 220K DSB.

Summary

The dipole / ellipsoidal lens configuration was investigated in terms both of antenna pattern and of matching to SIS junctions. The pattern measurements showed low side lobe levels, and a non-astigmatic beam over the whole band 95-120 GHz. The best receiver noise temperature was 145K DSB at 98 GHz, a value we believe will be improved with the use of integrated tuning structures.

The initial measurements with the other receiver, in which a double dipole antenna is combined with a hyperhemispherical lens, yielded a best noise temperature of 220K DSB at 402 GHz.

The Kapton laminate strip should function well up to 8 GHz as an intermediate frequency connection to the mixer chips.

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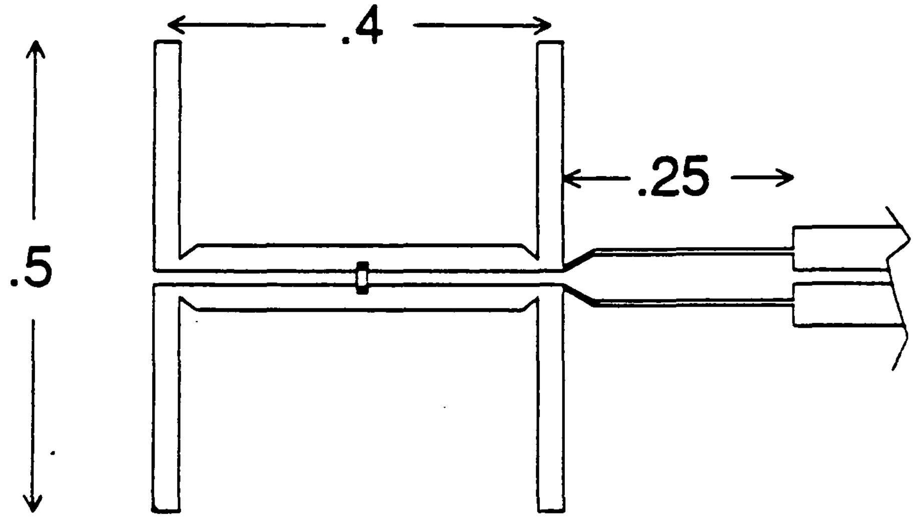

Fig.1 : The geometry of the 100 GHz double dipole antenna. The dimensions are in units of wavelength at the design frequency.

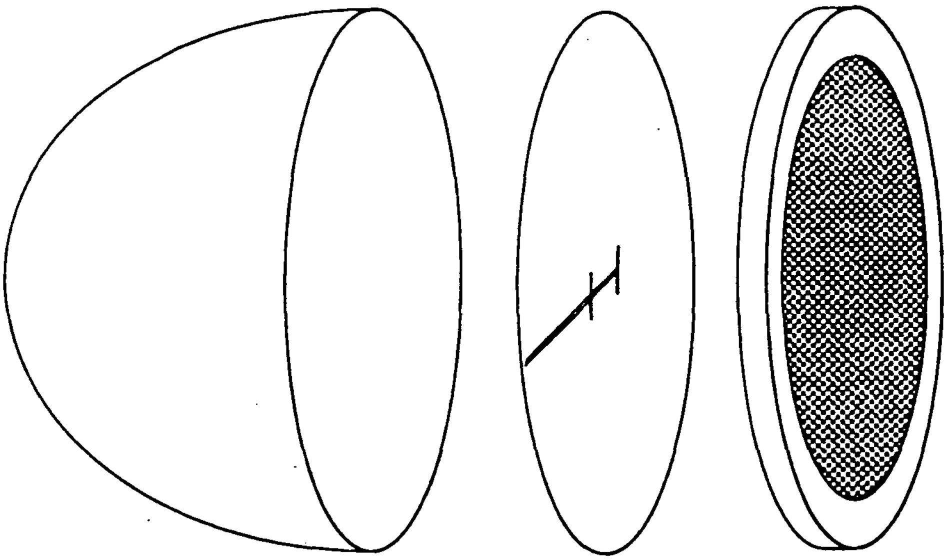

Fig. 2 : The antenna chip is placed between a quartz lens and a quarter wavelength thick quartz slab with a reflector.

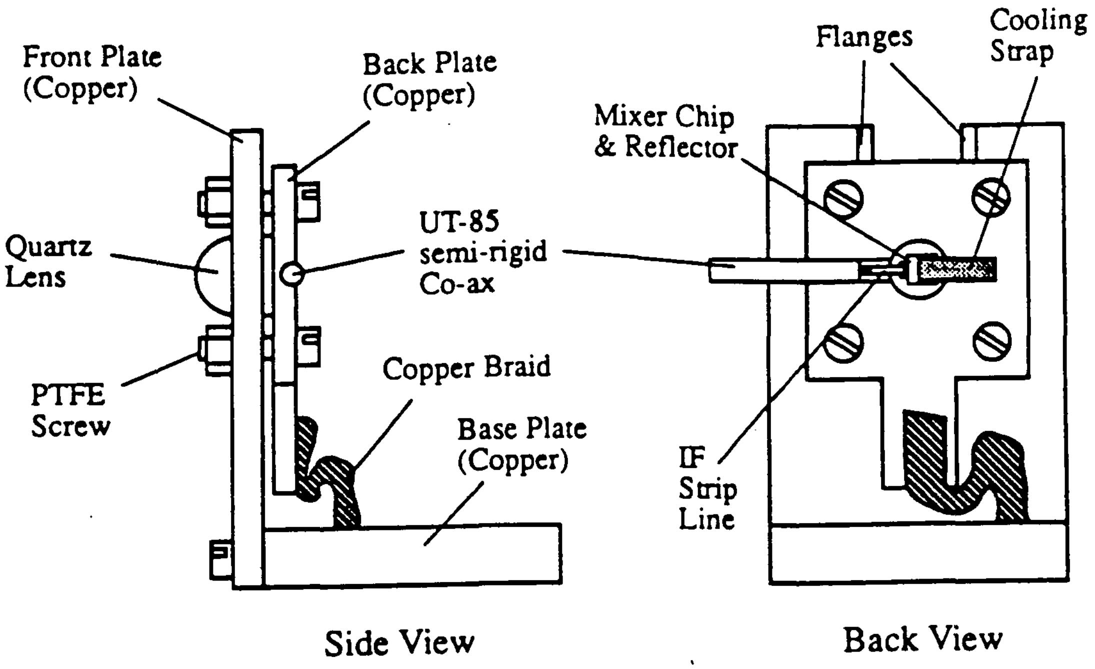

Fig.3 : The fixture that holds the lens and the mixer chip. The diameter of the lens in this figure is 11mm.

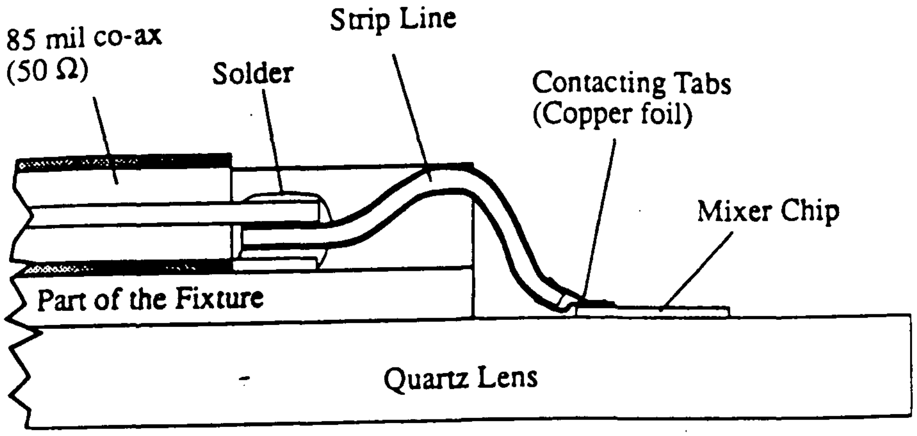

Fig.4 : The flexible Kapton laminate strip line used for the DC & IF connections. The tabs at the end of the strip are glued to the contact pads on the chip with silver paint.

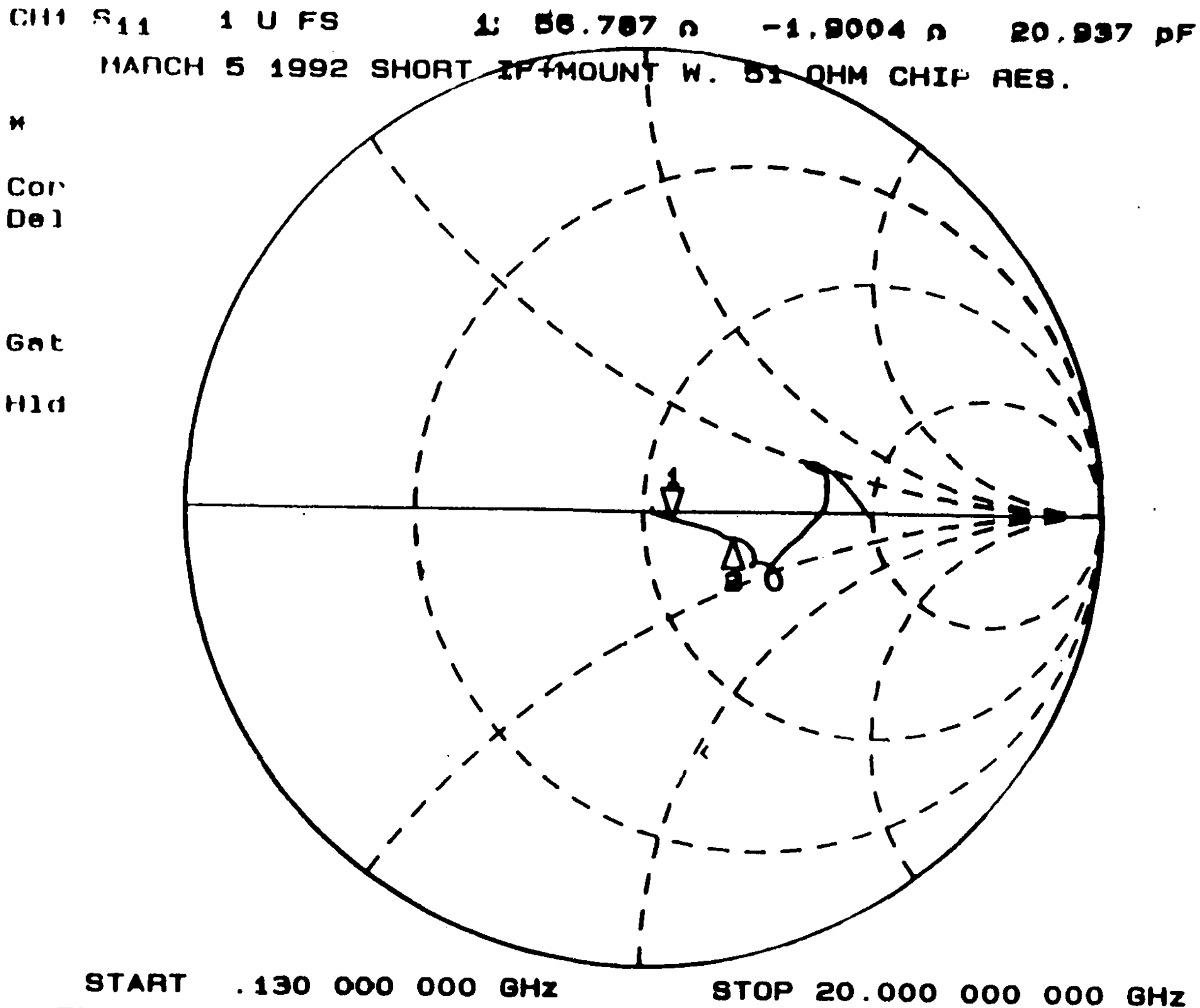

Fig.5 : The room temperature S11 reflection on the IF line in Figs. 3 & 4, with the mixer chip replaced with a chip resistor (51 ohms). A time gate was applied around the co-ax to strip transition, the strip itself and the resistor. Marker 1 is at 4 GHz and Marker 2 is at 8 GHz.

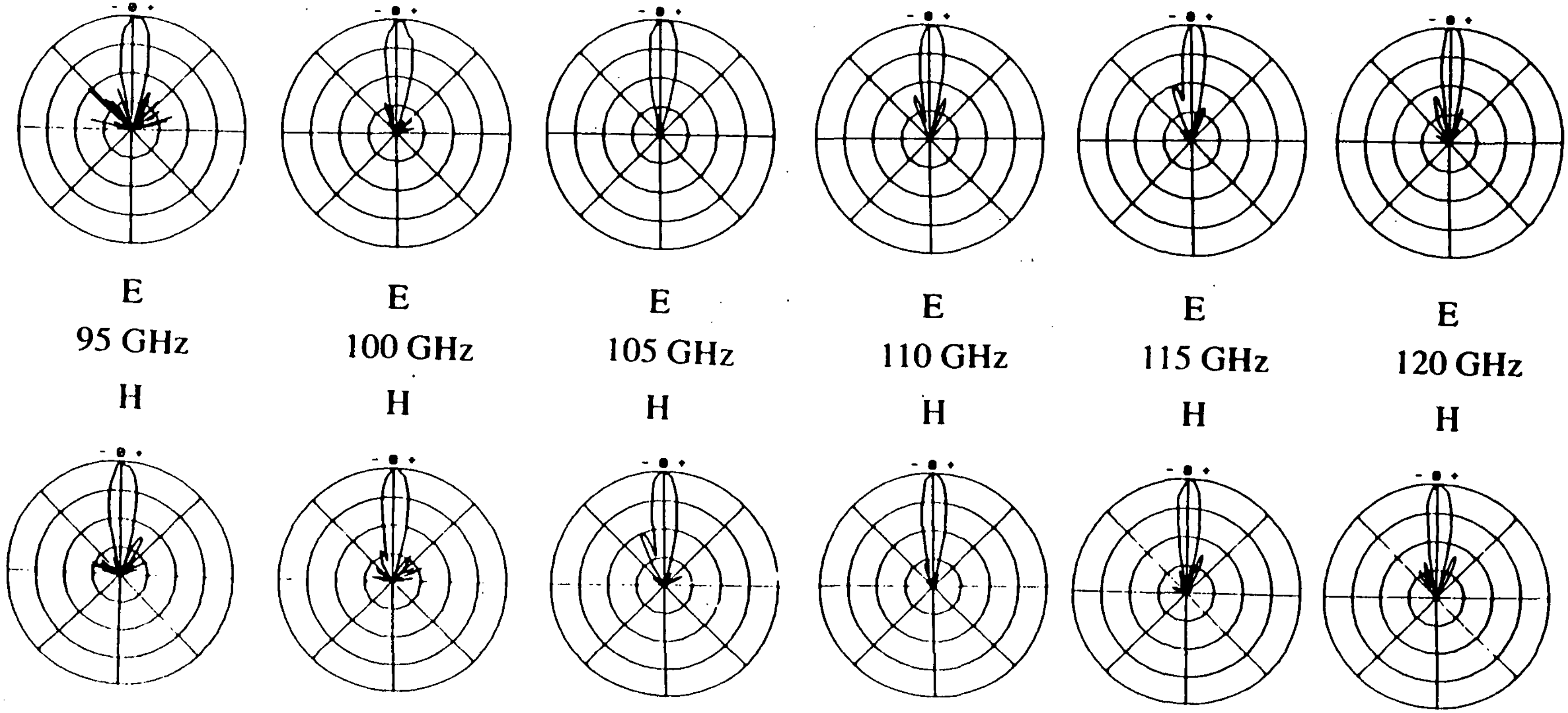

Fig.6 : Antenna patterns of the double dipole / ellipsoidal lens combination. The patterns were measured with a Bismuth bolometer, and the radial scale is 5 dB per division.

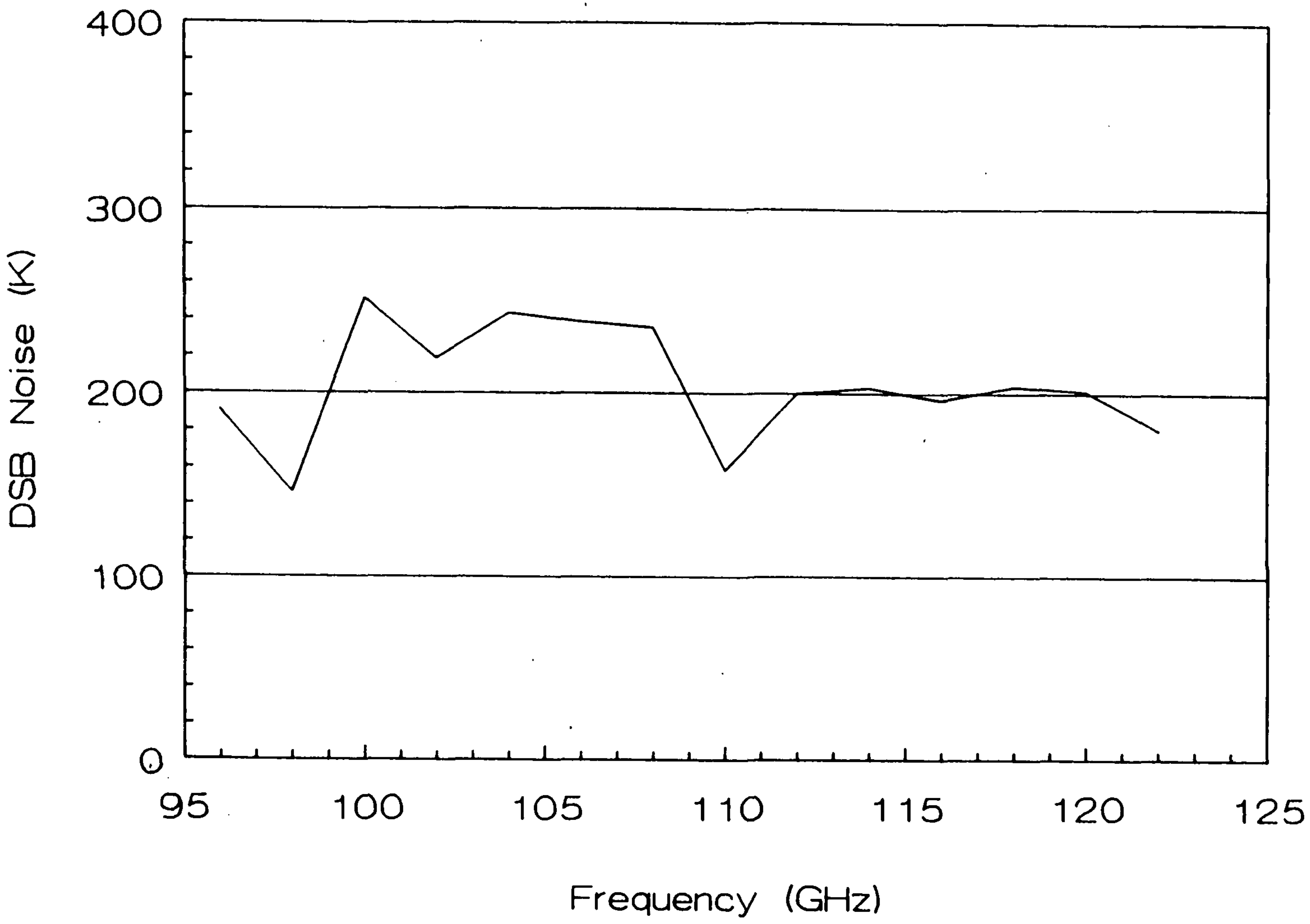

Fig.7 : The double sideband noise temperature of the 100 GHz receiver. The data was corrected for the transmission of the LO injection beam splitter (95%) .

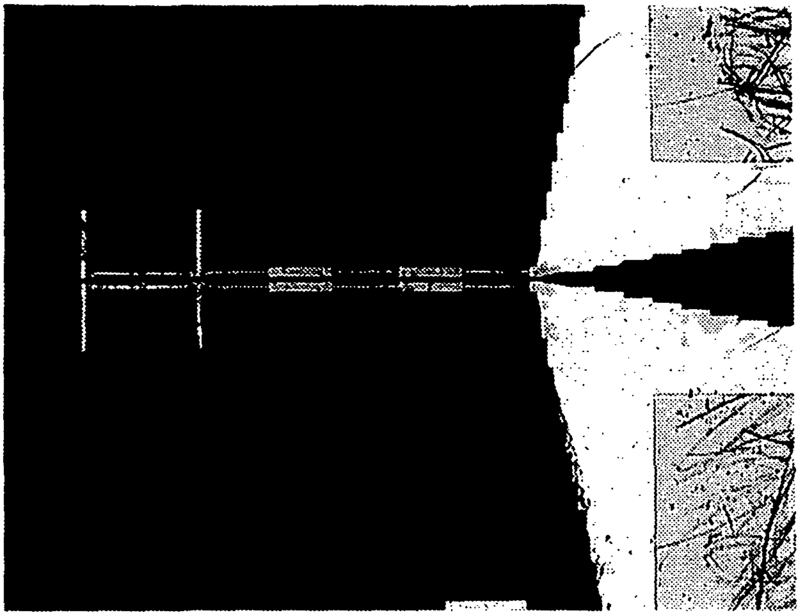

Fig.8 : The 400 GHz mixer chip.

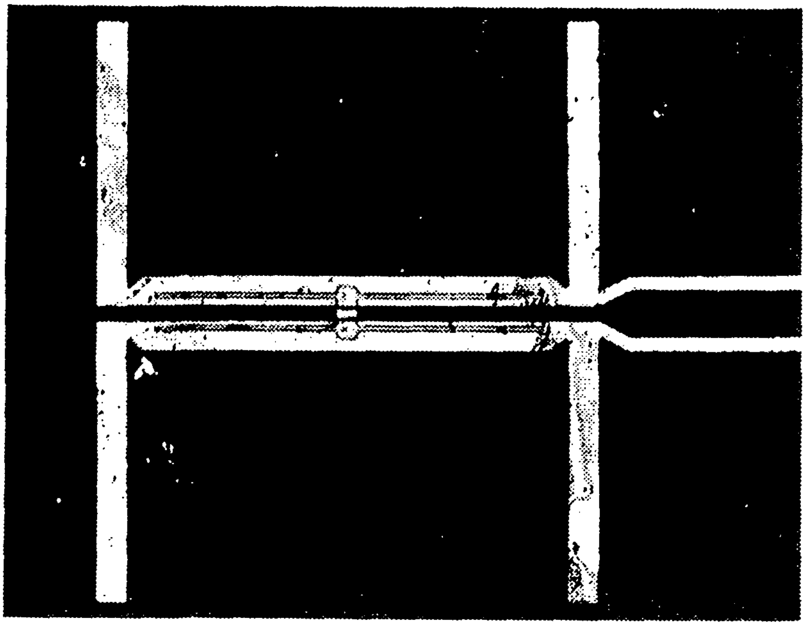

Fig.9 : The 400 GHz antenna chip, detail.

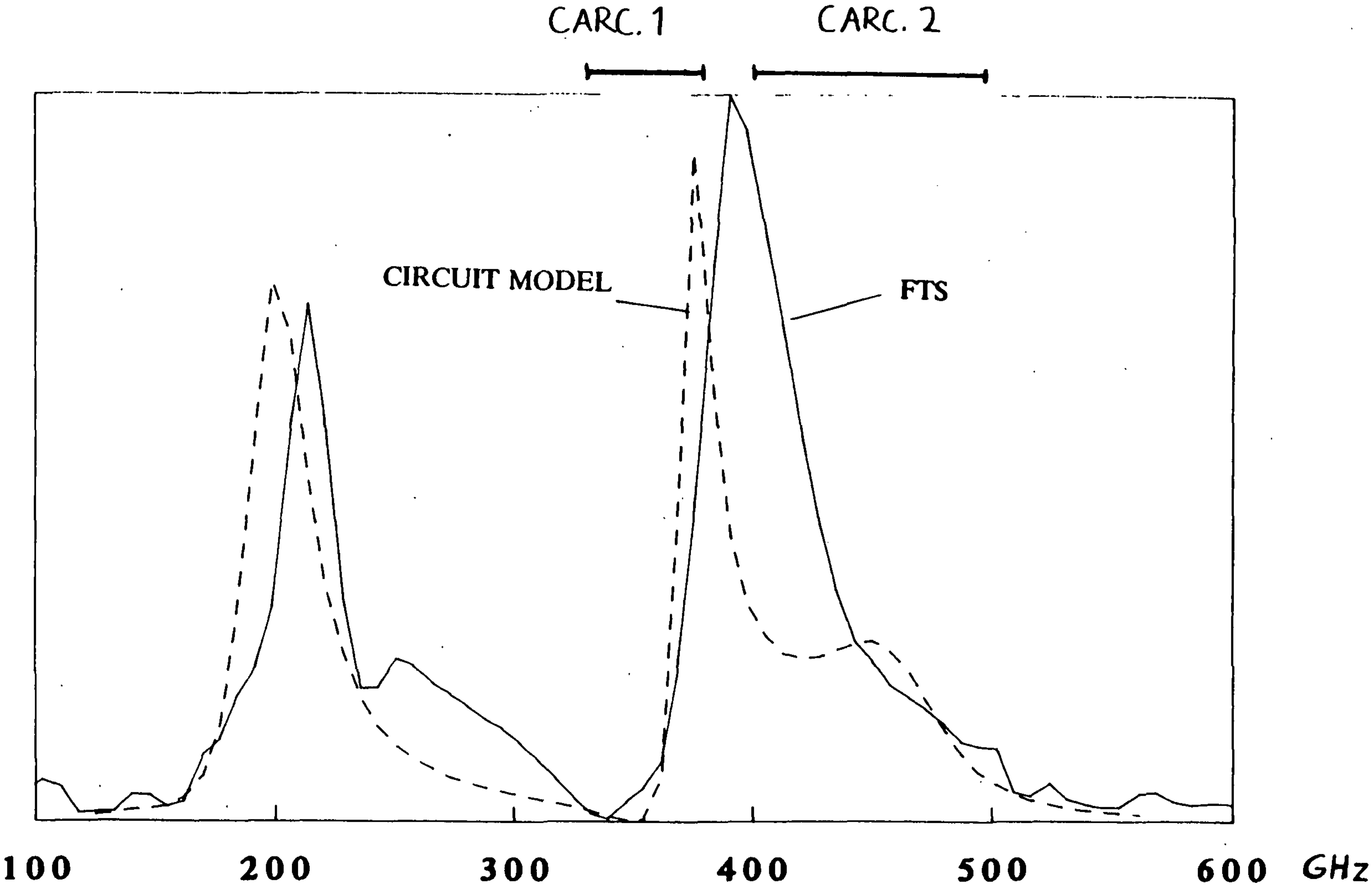

Fig.10 : The Fourier transform spectrogram (arbitrary units on the vertical scale). "CARC2" marks the frequency range where noise temperature measurements have been made.

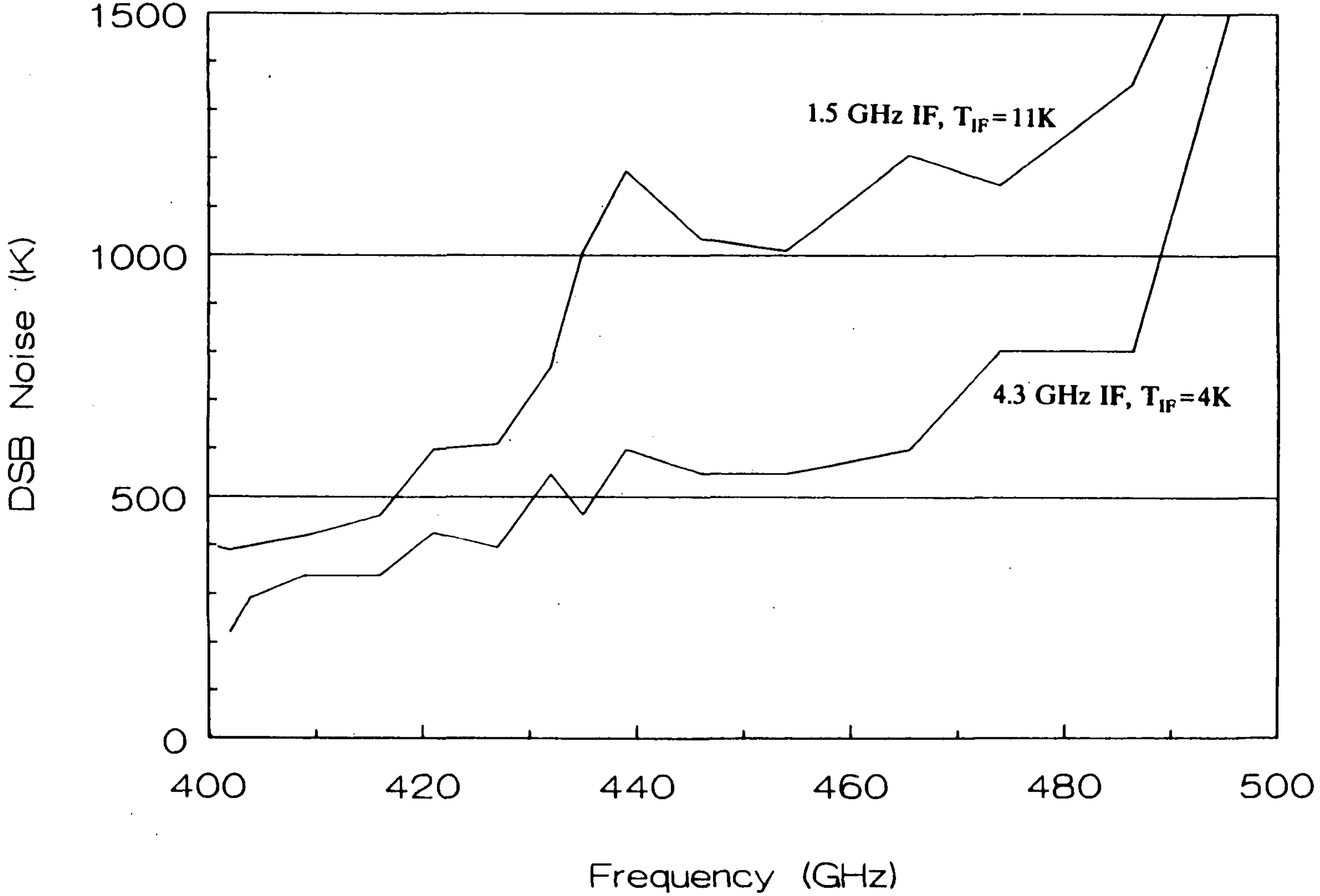

Fig.11 : DSB Noise measurement with the 400 GHz receiver. The data was corrected for the transmission of the LO injection beam splitter (65%) .