A 492 GHz Cooled Schottky Receiver for Radio-Astronomy

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Abstract

We developed a 492 GHz cooled GaAs Schottky receiver driven by a solid state local oscillator with a DSB noise temperature of 550 K measured at the telescope. The receiver-bandwidth is ≈1.0 GHz. Quasi-optical mirrors focus the sky and local oscillator radiation into the mixer. Stability analysis via the Allan variance method shows that the total system including a 1 GHz bandwidth acousto optical spectrometer built in Cologne allows integration times up to 100 sec per half switching cycle. We succesfully used the receiver at the KOSMA 3 m telescope on Gornergrat (3150m) located in the central Swiss Alps near Zermatt during January-February 1992 for observations of the 492 GHz, [CI] $^3P_1 \rightarrow {}^3P_0$ fine structure linie in several galactic sources. These observations confirm that Gornergrat is an excellent winter submillimeter site in accordance with previous predictions based on the atmospheric opacity from KOSMA 345 GHz measurements.

Introduction

After the first 345 GHz observing run in winter 1988/89 [7] followed by three succesfull runs in the subsequent winter periods, the 492 GHz receiver described here and the observations carried out in January-February 1992 are the second step in our development toward solid state LO Schottky receivers at 650 GHz and 800 GHz. The experience we made during the total observing time of 120 days for 345 GHz and 35 days for the 492 GHz receiver is that Gornergrat is an excellent ground based site for submillimeter radioastronomy during the winter period. Together with Mauna Kea, Hawaii, Gornergrat is the only site where 492 GHz observations have been carried out.

Receiver Description

Based on the experience of the 345 GHz receiver [2] we designed and built the receiver described here. The front end section is shown schematically in Fig. 1. The diplexer is a folded Fabry-Perot resonator using a movable elliptical mirror; the semi transparent plates are wire grids with 125 lpi and 35 μm diameter wire; they yield 83 % reflection. A quasi-optical mirror arrangement focuses the sky and local oscillator radiation through a Potter horn into the mixer. The mirrors are corrected for phase errors [5] and were produced on a NC-milling machine at our Institute. Mixer and IF-amplifier are cooled to 20 K. The bandwidth of the HEMT amplifier is ≈1.0 GHz at 1.4 GHz center frequency; its noise temperature is ≈8 K. Local oscillator power is delivered by a 98.2 GHz Gunn oscillator (60 mW) followed by a varactor quintupler, using a diode type 2T2 (R_s=12 Ω, C_j=5 fF) from the SDL, University of Virginia. For an overview of typical multiplier performance see [8]. The local oscillator is PLL stabilized. The Schottky- mixer is fundamentally pumped, has a coaxial IF-section and uses a 1T6 diode from University of Virginia (R_s=20 Ω, C_j=0.35 fF). The mixer is matched to the 50 Ω preamplifier impedance by a simple coaxial transformer, without using a circulator. The receiver optics include two absorbing loads at ambient (295 K) and cold head (35 K) temperatures. The receiver design is very compact; it consists of two packages: a) the optic front plate and dewar, b) the electronics, which fits in a 19" rack. A personal computer is used to controle a) and b) fully remote. Fig. 2 shows the optics and dewar part; the optic-plate diameter is 32 cm and the weight is less than 45 kg, including the cold head.

Receiver Characterization

The DSB receiver noise temperature was measured to be 500 K for a 600 MHz HEMT amplifier and 550 K for the 1 GHz broadband HEMT amplifier, installed at the telescope. Fig. 3 shows the receiver noise temperature versus mixer current for ambient and 20 K; cooling thus reduces the noise temperature by a factor of 2.8. The receiver noise temperature measured over the

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1 GHz bandwidth at the telescope, using the Y-factor method, is shown in Fig. 4. Receiver beam pattern measurements were made in the laboratory; the 1/e opening angle was measured to be 8.9° compared to the calculated value of 8.8°. Fig. 5 shows the two receiver beampattern (horizontal and vertical scan) the Gauss-fit and the 1/e-level which is the 13% power level. Similar to earlier publications [3] we used receiver stability tests, to verify the overall system performance. The Allan variance method [6] adopted in Cologne, using a 1 GHz bandwidth acousto optical spectrometer (AOS) yields an integration time in the total power mode of 100 sec per duty cycle (Fig. 6), without significant increase in baseline structure.

Observing Run on Gornergart

We observed several galactic sources during the observing run in January- February 1992 at the KOSMA telescope. Fig. 7 shows two highlights of the [C I] $^3P_1 \rightarrow {}^3P_0$ 492 GHz lines from the galactic sources S 140 and NGC 1977. The observations confirm that the KOSMA location is an excellent winter submillimeter site in accordance with previous predictions based on the atmospheric opacity from KOSMA 345 GHz measurements [4]. The precipitable water vapor is below 1 mm for about 20% of the time in the winter period. Surprisingly the site does not show a significant variation of transmission between day and night time. A Jupiter map (Fig. 8) shows a clean beam. The half power diameter of 54" results after deconvolution of Jupiter size at the time of observation in a beam FWHM of 48", consistent with the 47" predicted from the 12 dB edge taper measured at the telescope. The telescope surface was measured and adjusted by a holographic method [1] to an rms of $\approx 38\mu m$

Conclusion

We have designed and built a compact, cooled 492 GHz Schottky mixer receiver with solid state LO. The receiver was installed on the KOSMA 3 m telescope on Gornergrat during January-February 1992 and used to observe several galactic sources. It is shown that the telescope surface and the KOSMA site are well suited for 492 GHz observations. The receiver is build modular, compact and lightweight and thus is usable for observations on other telescopes. The receiver noise temperature is 550 K DSB at the telescope over a simultaneous bandwidth of ≈1.0 GHz.

Acknowledgements

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References

[1] FUHR, W. ET AL: *Holographic alignment of the KOSMA 3 m reflector*, Univ. Cologne, in preparation.

[2] HERNICHEL, J.: *Aufbau und Inbetriebnahme des 345 GHz Empfängers für das Kölner 3 m-Radioteleskop*, Diplom Thesis, Univ. Cologne, (1989).

[3] HERNICHEL, J., LEWEN, F., MATTHES, K., KLUMB, M., ROSE, T., WINNEWISSER, G., ZIMMERMANN, P.: *Submillimeter Receiver Development at the University of Cologne*, Proc. of Second Intern. Symposium on Space Terahertz Technology, JPL, Pasadena, 641-647 (1991).

[4] KRAMER, C., STUTZKI, J.: *Atmospheric Transparency at Gornergrat*, Technical Memorandum, Univ. Cologne, (1990).

[5] ROSE, T.: *Aufbau eines SIS-Empfangssystem mit quasioptischem Mischer*, Diplom Thesis, Univ. Cologne, (1989).

[6] SCHIEDER, R., TOLLS, V., WINNEWISSER, G.: *The Cologne Acousto-Optical Spectrometers*, Experimental Astronomy **1**, 101 (1989).

[7] WINNEWISSER, G., ZIMMERMANN, P., HERNICHEL, J., MILLER, M., SCHIEDER, R., UNGERECHTS, H.: *CO submillimeter observations from Gornergrat*, Astron. Astrophys. **230**, 248-251 (1990).

[8] ZIMMERMANN, R., ZIMMERMANN, R., ZIMMERMANN, P.: *All Solid State Radiometers for Environmental Studies to 700 GHz*, this Conference.

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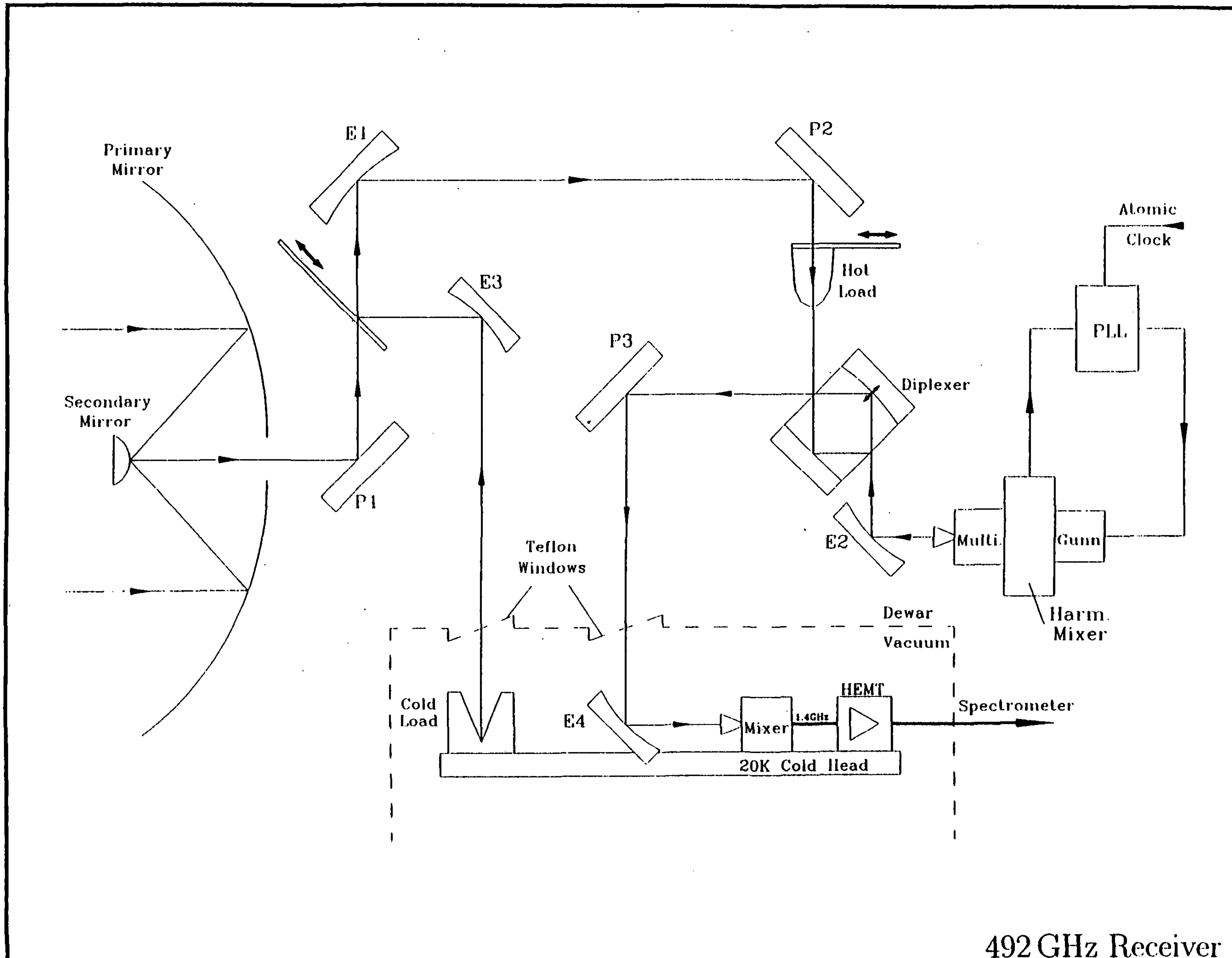
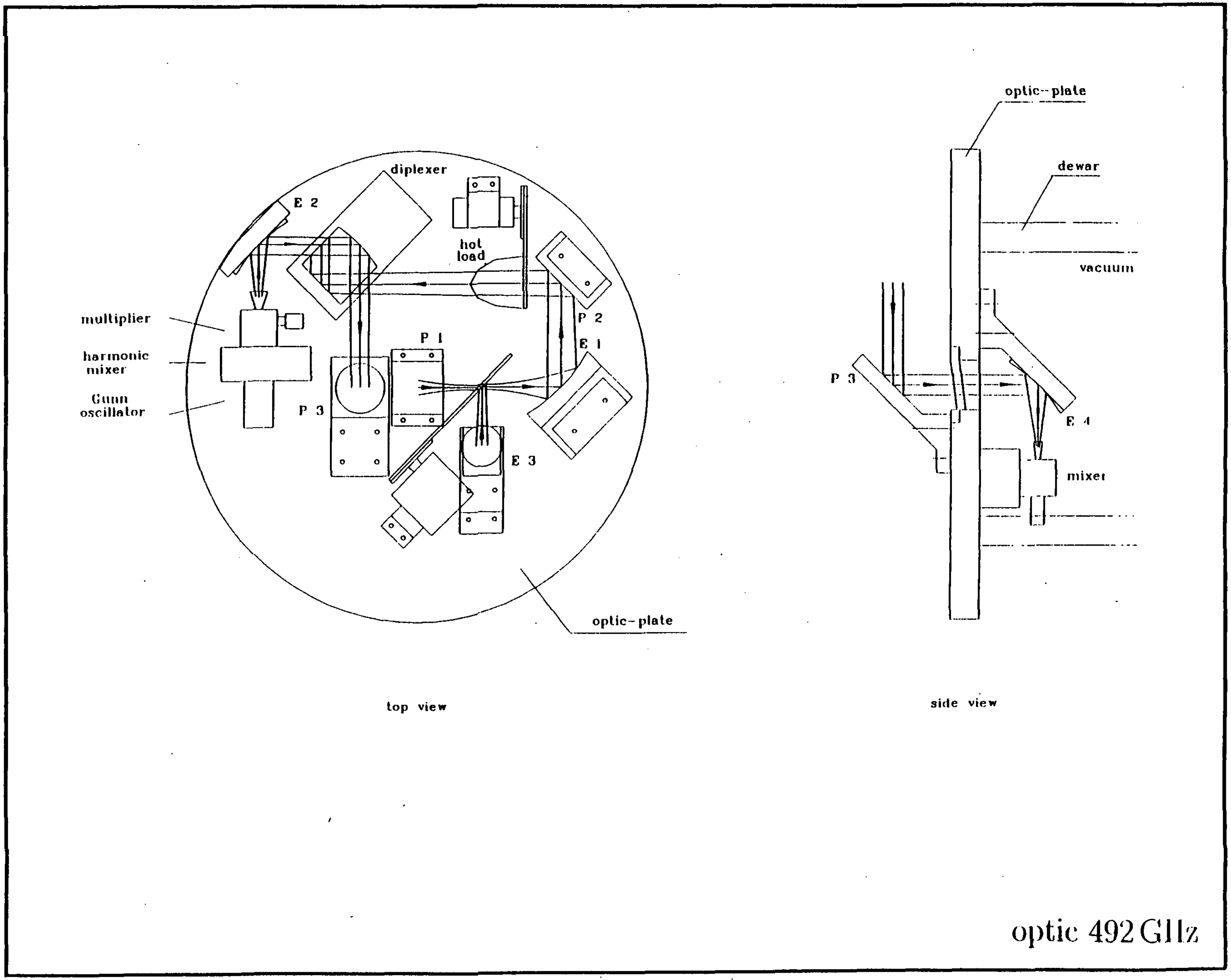


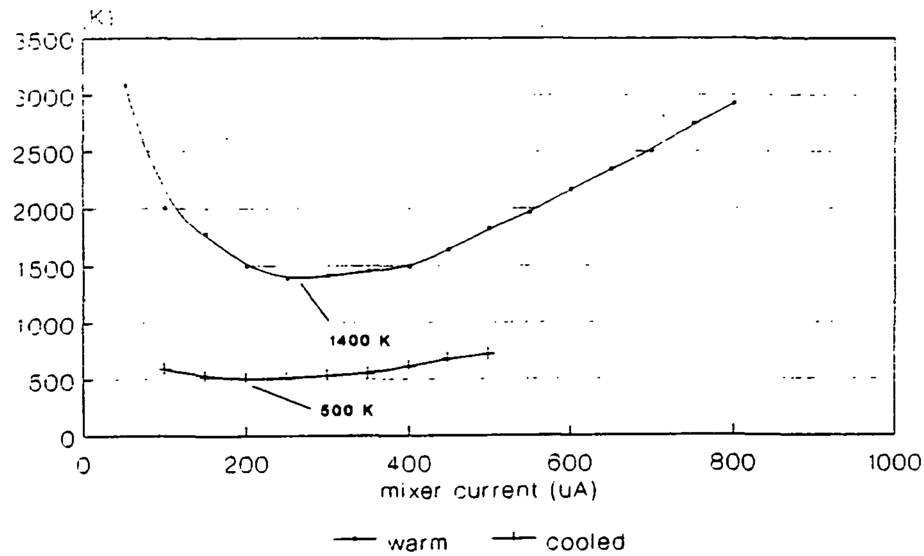
492 GHz Receiver

figure 1

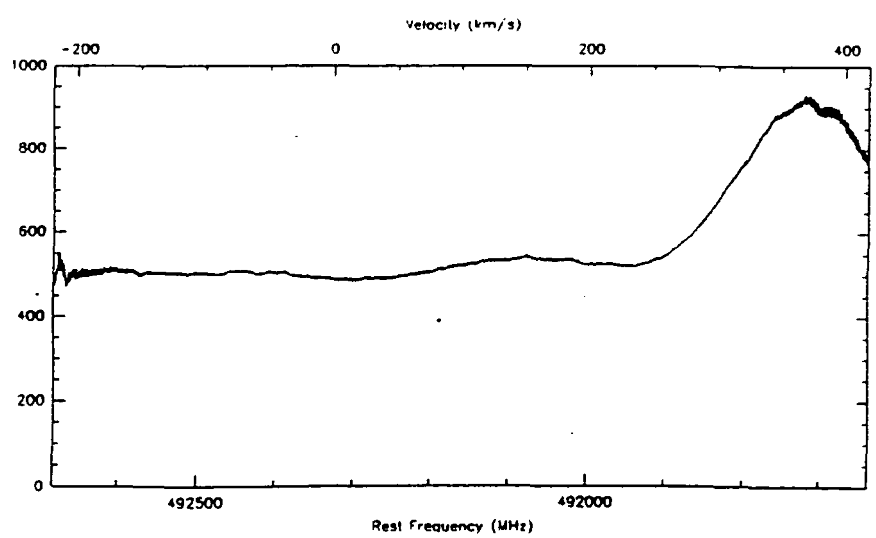


optic 492 GHz

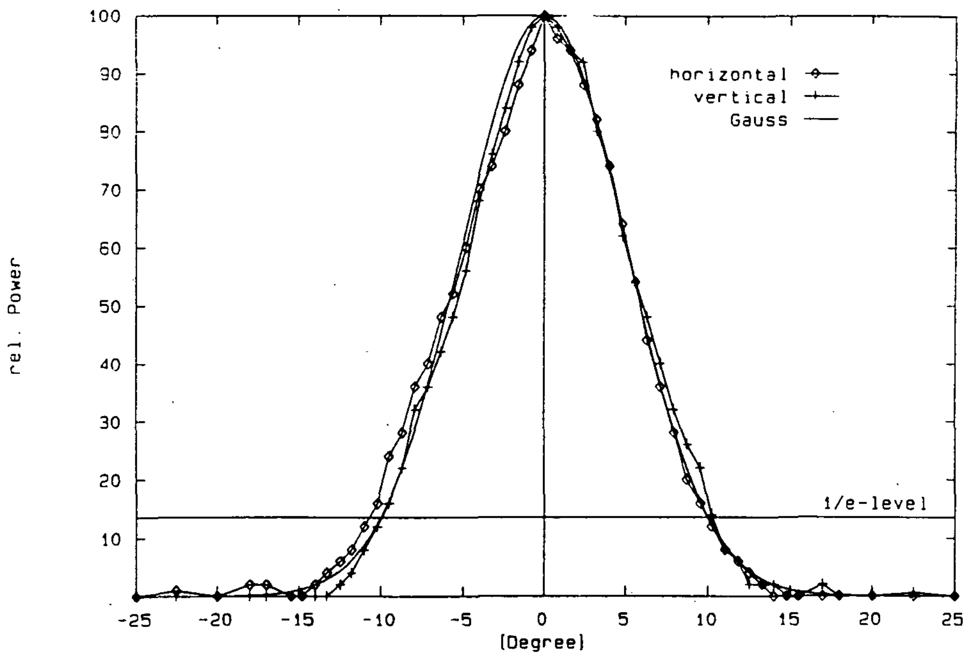
figure 2



receiver noise temperature versus mixer current figure 3

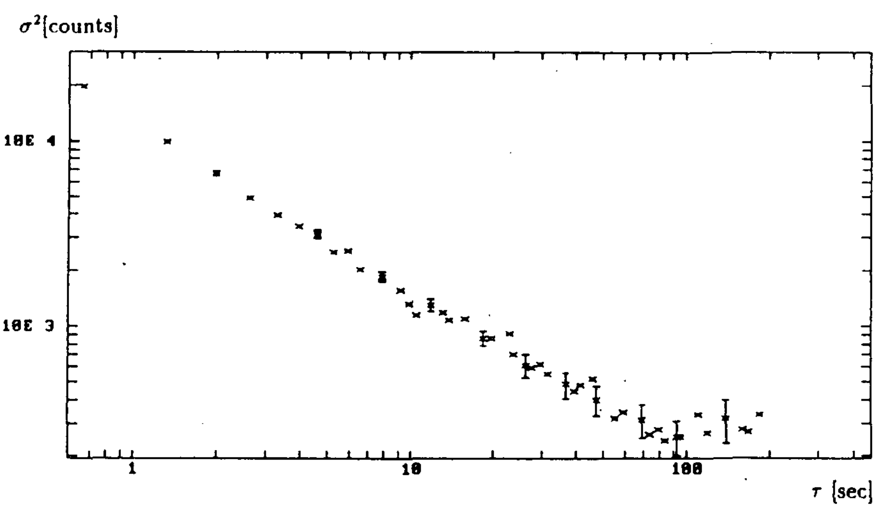


receiver noise temperature versus frequency figure 4



receiver beam pattern 492 GHz

figure 5



Allan plot

figure 6

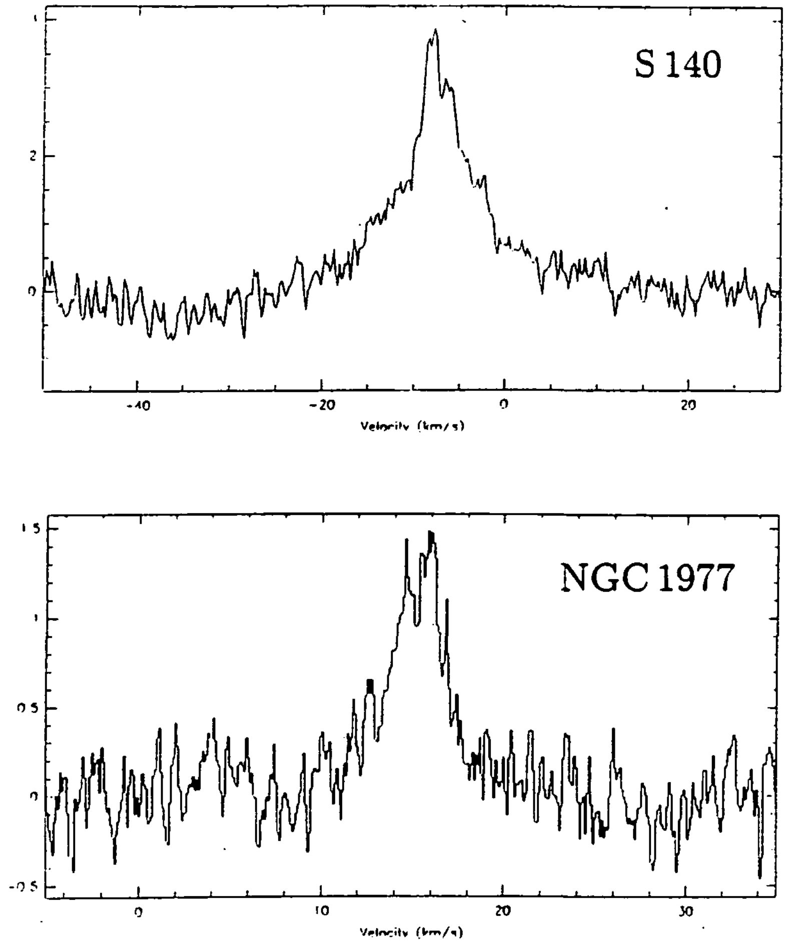
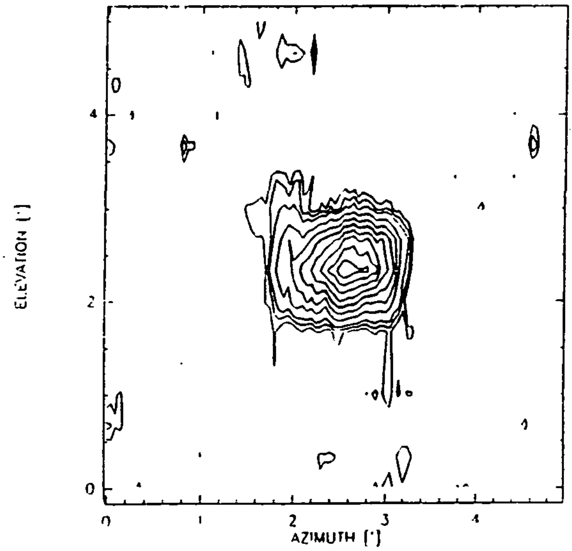


figure 7



Jupiter beam map 492 GHz

10 15 20 (10)·90 % of peak

figure 8