Summary of the initial tests of the mopra mm receiver

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These results are principally based on the 86 GHz observations of the planet saturn.

1 Receiver

We have several ways to estimate the receiver T_{sys}:- from Hot/Cold measurements at the cassegrain focus (above the optics box), and from a detailed analysis of the skydip data.

Both schemes are consistent and encouraging.

The Hot/Cold measurements show that the receiver T_{sys} is around 70 K over the band 85 - 98 GHz, as shown in figure 1.

The receiver noise temperature T_{rx} is a double-sideband, single polarisation result, measured at the cassegrain focus. It includes about 23K due to loss through the polarisation box and the optics box mounted above the receiver dewar.

T_{rx} is calculated from the Y-factor given by the ratio of a HOT load (absorber at 273K + $T_{ambient}$) and a COLD load (absorber in liquid nitrogen at 80K). These loads were alternately placed at the quasi-optical beam waist (focus) of the antenna which is situated at the centre of the first plane mirror in the optics box.

The combined antenna and sky noise temperature T_{sky} is calculated from the Y-factor given by the ratio of a HOT load and the COLD sky at the zenith.

It should be noted that the T_{sys} at the CS frequency is about 20K higher than at other frequencies; we attribute this to the cloud cover present during the CS

c. efficiency : 40 - 50 Jy/K .... now converging to 45 Jy/K

For a 15m antenna with a 3 m central blocking, and $6m^2$ feed legs blocking, this amounts to an efficiency of about:

$$\eta = 35\%$$

If due entirely to surface errors, this implies a surface RMS (σ) $\sim$ 0.25mm, which is significantly worse than the manufacturing error.

d. illumination - there is a pronounced coma lobe;

It is positioned at ~45 degrees to the az axis. Its amplitude is around 10dB. A subreflector offset of a few mm would do this. Figure 4 shows a set of ra/dec scans, taken at EL = 69 degrees on saturn. It should be borne in mind that these scans can will in general give a pessimistic view of the magnitude of the coma lobe: a pointing error will depress the main peak but not the coma lobe.

Calculations by G.James/C. Granet show that such a coma lobe will result from a 4mm subreflector offset, with a corresponding gain loss of 0.3dB. Such a subreflector offset is consistent with the earlier holography results at 12GHz. (These found $X \sim +2mm$, $Y \sim +1mm$).

4 Spectral Baseline Ripple

During the tests of the 256 MHz bandwidth system it was noticed that the spectral baseline had a 60 MHz ripple, with an amplitude of 2 K (peak to peak). This corresponds to a 5m signal path length.

The problem was traced to the Goretex membrane over the vertex roof aperture. The quasi-optics path from the mixer to the Goretex is 2.5m; the ripple is due to a small fraction of the SIS mixer noise escaping out to the Goretex, reflecting back (total path = 5m) and interfering with the direct signal.

Removing the Goretex fixed the problem. It was also possible to fix the problem by tilting the Gortex plane by 10 degrees so that the reflected signal did not return to the mixer. It should be noted that some such cure is very necessary: wind drumming the Goretex causes the ripple phase to vary, so cancellation schemes will fail.

The Goretex membrane (woven teflon) has a transmission loss at 100 GHz of 0.1 dB (2.3%). Let T be the SIS noise which interferes with the reflected signal; let ΔT be the reflected signal; then since the ripple is due to voltage addition/subtraction, we have :

$$(\sqrt{T}+\sqrt{\Delta T})^2-(\sqrt{T}-\sqrt{\Delta T})^2=2K$$

$$\Delta T \cong 1./(4.T)$$

But $\Delta T = 0.023\epsilon T$

where ϵT is the SIS energy leaking out towards the Goretex.

The ripple requires $\epsilon T^2 \sim 11$, with $\epsilon \leq 1$. With $T \sim 4.5K$ we have $\epsilon \sim 55\%$.

There is some evidence that the bandshape of the samplers in one-bit mode is level dependent. This may require an automatic levelling control loop before the sampler input. Further tests in the lab. are required to determine if such an ALC is necessary.

5 Pointing

This is consistent with the x-band pointing ... That is, there are no significant offsets in the optics between the 2 frequencies.

The current model is only fair ... say $\sigma \sim 15$ arcsec rms, (RSS of both axes).

6 Current status and plans

The 3mm receiver was shut down on sunday 13 November and returned to Epping. In the next 6 months it is planned to engineer the system into a dual polarisation, single or double sideband tunable receiver covering the band 86 to 115 GHz. We also plan to have the receiver remotely tunable from the MOPRA control room.

7 Recommendations

1. Holography at 30 GHz. The Optus series B satellites have a 30 GHz beacon which would provide a higher quality survey of the antenna.

observations.

Figure 2 shows a good example of a skydip. The calibration for these is an ambient temperature paddle which covers the beam as it exits the optics box. (See figure 3 for a sketch of the optics). The fitted curve has three parameters, $T_{rx+optics}$, $T_{scattered}$ and T_{sky}.

The analysis of the skydips from a number of days puts the $T_{scattered}$ at about 40 K and the T_{sky} at 20 K (that is, a zenith optical depth of about 10%).

The T_{sys} budget is thus:

all up T_{sys}	130 K
$T_{rx+optics}$	70 K
T_{sky}	20 K
$T_{scatter}$	40 K

We note that J.Payne had predicted a contribution of ~20K from ground radiation seen through the perforated panels.

Thus, to within a reasonable fudge error of 20K the measurements are consistent with an excellent receiver T_{sys}, and a reasonable site.

2 Site

Our best result (out of just 4 or 5 days) shows that the sky dip is well fitted to:

$$\log(1 - T_{sky}/300) = \tau * sec(z)$$

with the zenith T_{sky} of ~20 K, (and a zenith optical depth ($\tau \sim 0.075$)

The fit is good enough (on several different days) that we can probably exclude any serious beam spillover that has an elevation dependence.

3 Optics

a. The focus curve is clean, with the peak at $\sim$ +9.0mm, and a half-width of 8mm.

b. beamwidth : $\sim$ 45 arcsec at 86 GHz. (Full width to half power)

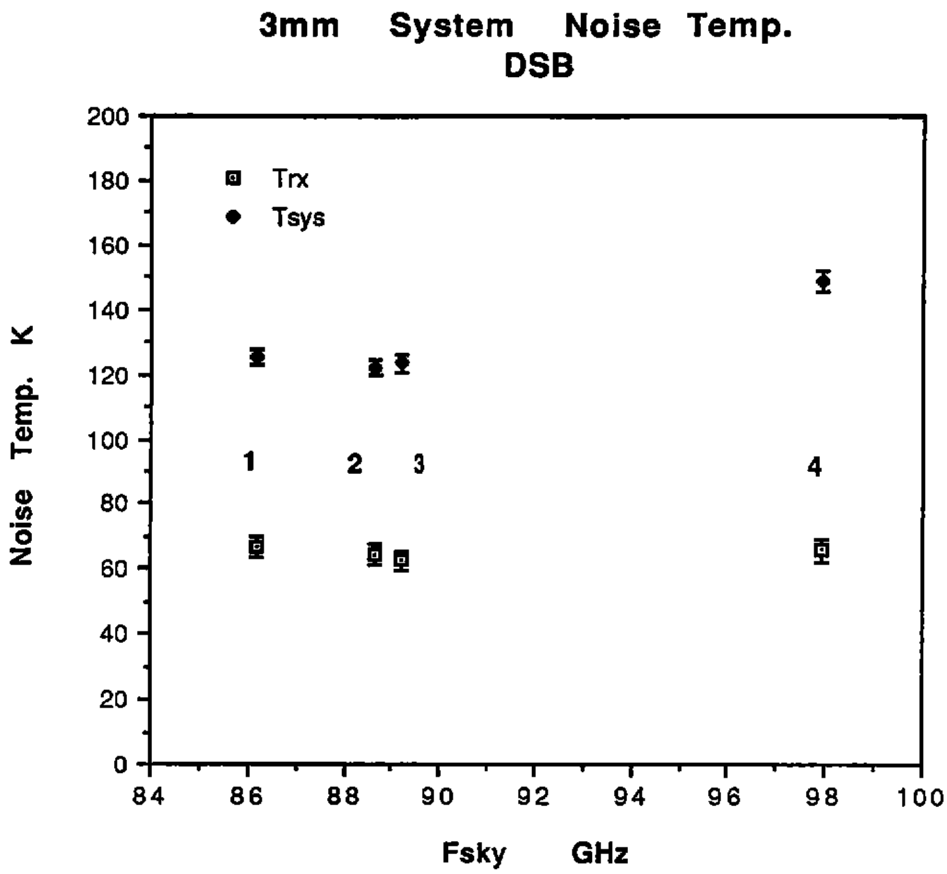
2. The 30 GHz system would also allow us to improve the alignemnt of the optics; it would allow us to make a better informed assessment of the mm-system beam optics.

3. Resetting the surface (to 0.1mm), and realigning the optics should boost the efficiency - by perhaps 2 dB. (to 30 Jy/K).

4. A full 22m solid aperture would of course make a much more signficiant improvement.

5. The 30 GHz system is needed to assess to change in focal length with elevation, as well as possible lateral shifts of the subreflector with elevation.

6. The Goretex membrane needs to be tilted by 10-15 degrees in order to remove the 60 MHz baseline ripple.

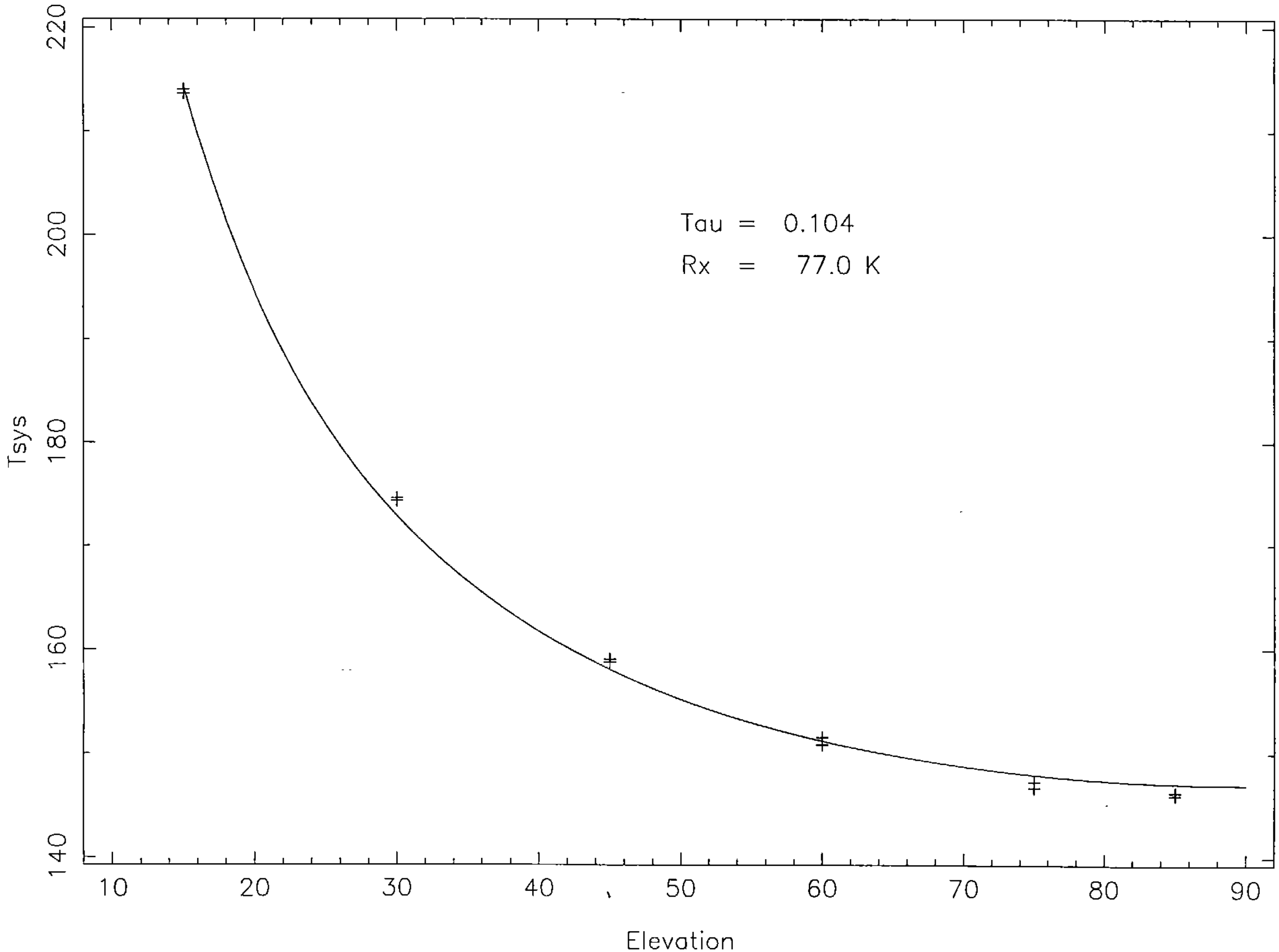


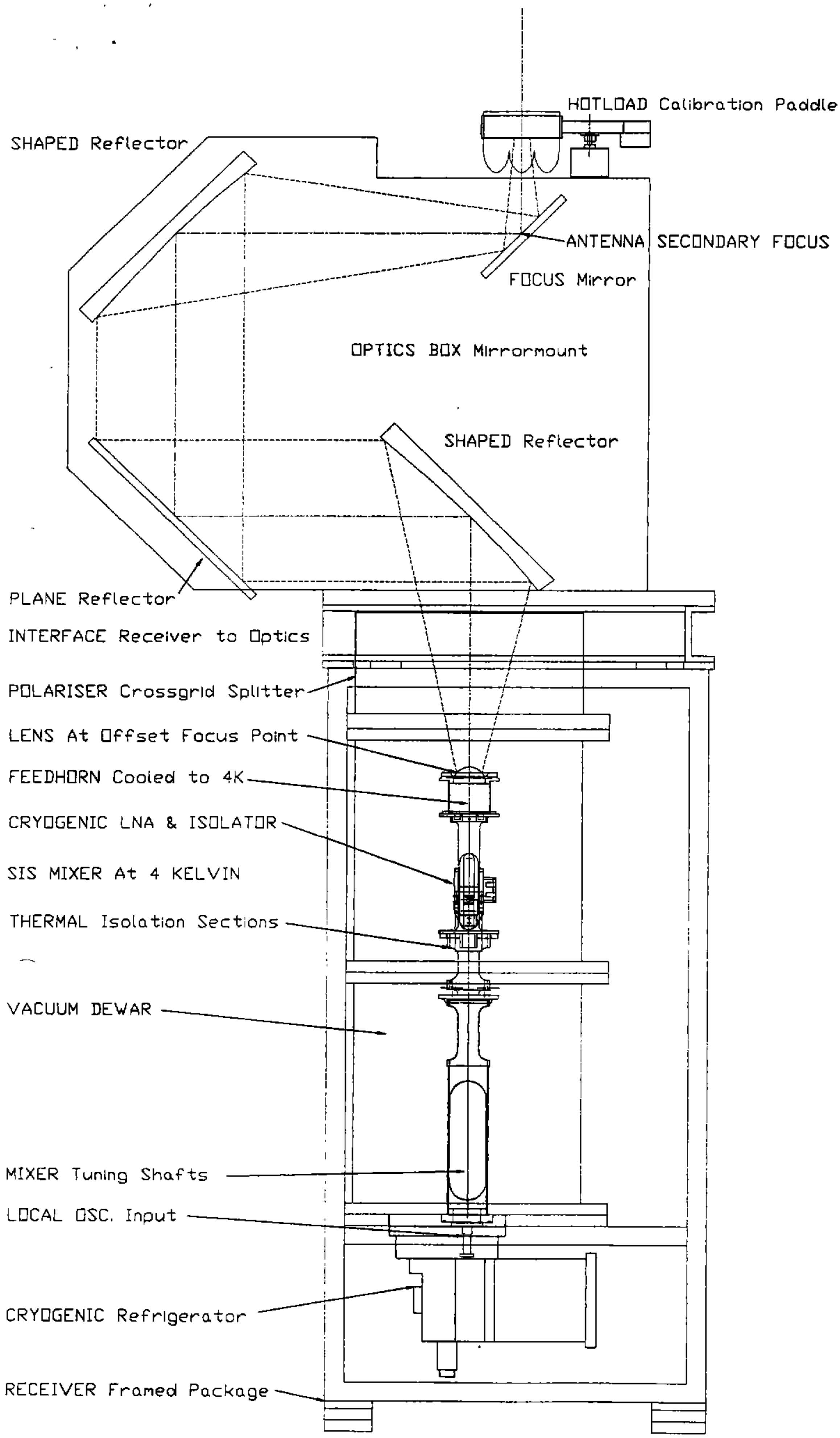
Trx is measured at the cassegrain focus of the antenna (above the optics box).

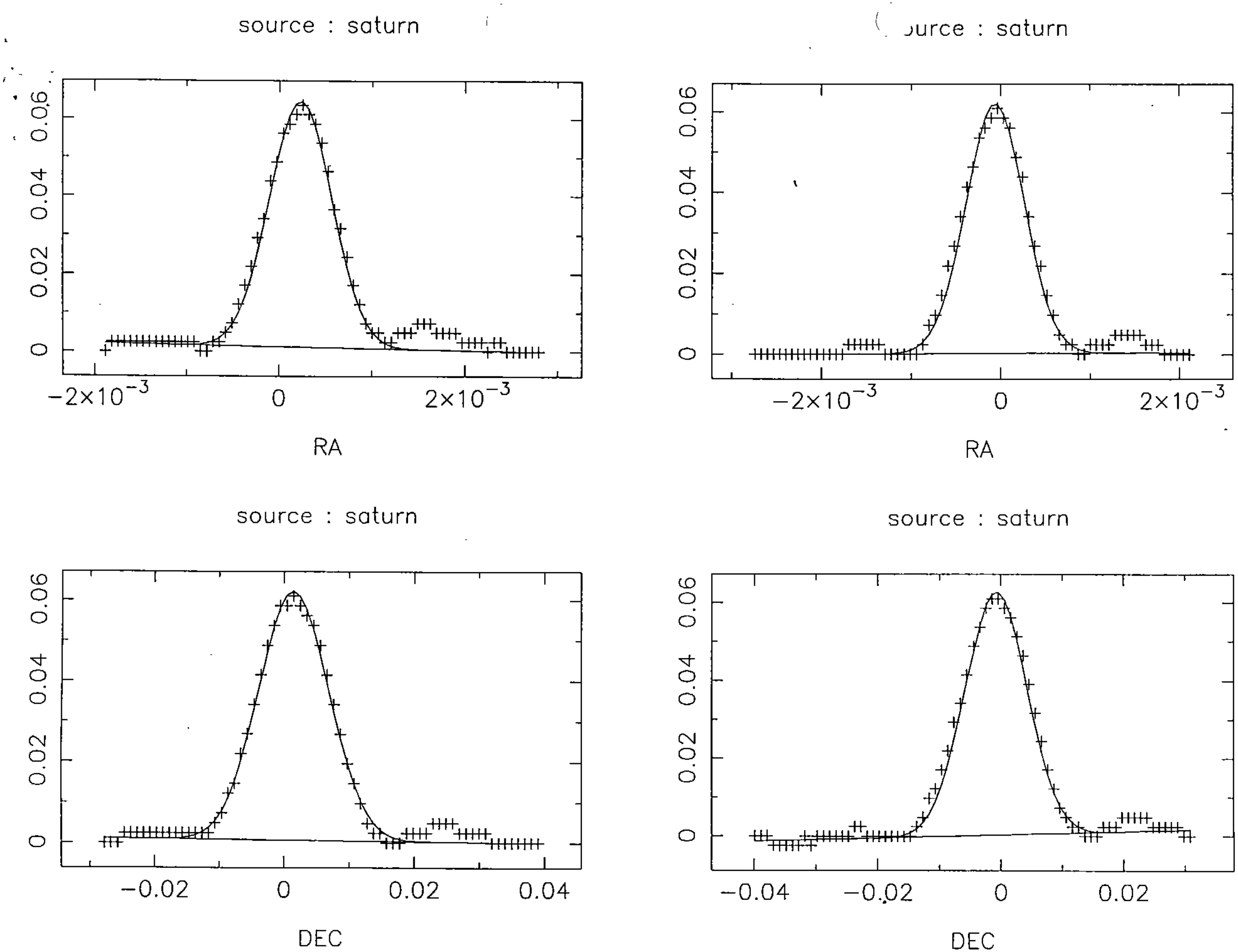
Tsys is the sum of Trx and the temperature contribution from the sky and the antenna measured with the antenna pointing at the zenith.

No.	Line	Fsky GHZ	LO GHz	Trx (DSB) K	Tsky K	Tsys K
1	Sio	86.18	84.68	66.7	58.7	125.4
2	HCN	88.632	87.31	64.4	57.4	121.8
3	HCO+	89.189	87.97	62.3	61	123.3
4	CS	97.904	96.404	65.5	83	148.5

Skydip at az 345.8 degrees




HOTLOAD Calibration Paddle
SHAPED Reflector
ANTENNA SECONDARY FOCUS
FOCUS Mirror
OPTICS BOX Mirrormount
SHAPED Reflector
PLANE Reflector
INTERFACE Receiver to Optics
POLARISER Crossgrid Splitter
LENS At Offset Focus Point
FEEDHORN Cooled to 4K
CRYOGENIC LNA & ISOLATOR
SIS MIXER At 4 KELVIN
THERMAL Isolation Sections
VACUUM DEWAR
MIXER Tuning Shafts
LOCAL OSC. Input
CRYOGENIC Refrigerator
RECEIVER Framed Package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