Atacama
Large
Millimeter
Array

Calibration Device
Calibration Load Radiating Temperature
Test Report

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1. INTRODUCTION

1.1. Purpose

The aim of the measure is to determine the radiating temperature of the hot load that can be used in ALMA calibration system.

This hot load and its command and control temperature unit are made by RAL. The load is composed of a corrugated piece in aluminium covered by a thin layer of absorbing material (Eccosorb). As Eccosorb is a poor thermal conductor, the temperature difference between the aluminium piece (given by the control unit) and the load surface in Eccosorb has to be determined.

1.2. Reference Documents List (RDL)

The following documents contain additional information and are referenced in this document.

Reference	*Document title*	*Document ID*
[RD1]	Front End Optics Report	FEND-40.02.00.00-035-A-REP
[RD2]	Front End Calibration Device Technical Specification	FEND-40.06.00.00-009-A-SPE

1.3. Acronyms

A limited set of basic acronyms used in this document is given below.

ALMA	Atacama Large Millimeter Array
FE	Front End
GPIB	General Purpose Instrumentation Bus
HEMT	High Electron Mobility Transistor
RD	Reference Document
SIS	Superconductor Insulator Superconductor
SSB	Single Side Band

2. MEASUREMENT SET-UP

To determine the difference between the temperatures indicated by the control unit, and the real radiating temperature of the load, we first calibrate the radiating temperature levels using an ambient load (of temperature given by a high accuracy temperature sensor), and a cold load immerged in liquid nitrogen.

The measurement set-up is shown on Figure 1.

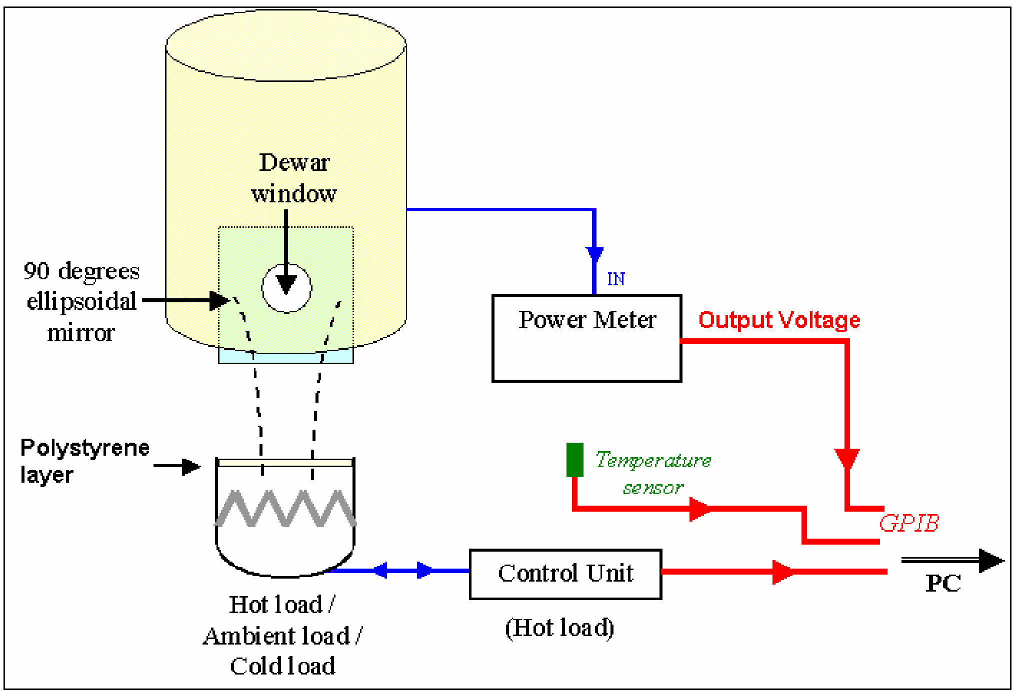

Figure 1: Calibration load measurement set-up

The radiating power of each load is read on a power meter and recorded on a computer via a GPIB interface.
In the same time, the computer also record the ambient temperature variation (Pt100 sensor, 4 wires measurement), and the temperature measured in the aluminium part of the hot load (Pt100 sensor, measurement with 4 wires given in the rear panel of the control unit).

To reduce problems due to heat convection of the hot load with the ambient air, a piece of polystyrene was placed in front of the cold load and the hot load during each measurement.

The measurements are made in two frequency bands: the 100 GHz (3mm) frequency band and the 300 GHz (1mm) frequency band.

One of the objectives of these measurements was to ensure that there was no saturation of the receiver. If we had saturation this would have put us into the position where we need to calibrate the system. To ensure this for 83 and 103 GHz measurement are made using a HEMT receiver, and for 300 and 351GHz we used a 2SB mixer with a University of Virginia 6 junction array.

3. MEASUREMENTS IN 3MM RANGE

Measurements in the 3mm range are made with a receiver composed of a Schottky mixer and a millimeter HEMT amplifier.
The measurements were made at two frequencies at the beginning and the end of the receiver bandwidth: 83GHz and 103GHz. For those two frequencies, the radiating temperature of the load was measured when applying a load temperature consign of 50°C, 60°C, 70°C, 80°C and 87°C.

The polystyrene cover placed in front of the hot and cold load is transparent at those frequencies

3.1. Measurements at 83 GHz and 103 GHz

The graphs below show 4 curves of the temperature deviation against the requested temperature. These are as follows:

1. Black; the temperature deviation read on the platinum thermometer
2. Red; the minimum deviation measured
3. Green; The maximum deviation
4. Blue the corrected radiometer temperature, taking account of receiver drift etc.

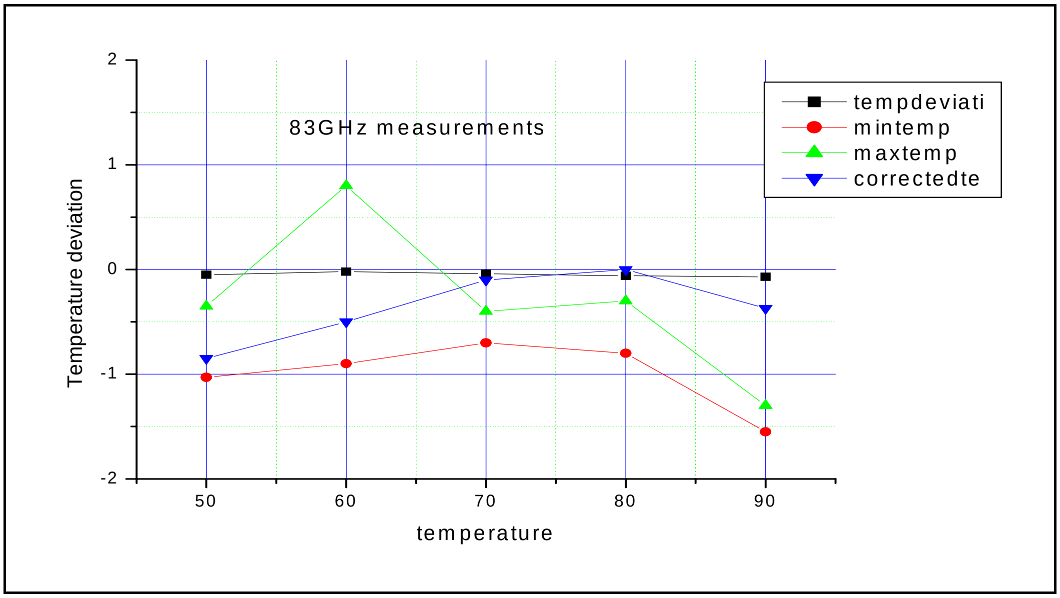

Figure 2: Measurement at 83 GHz

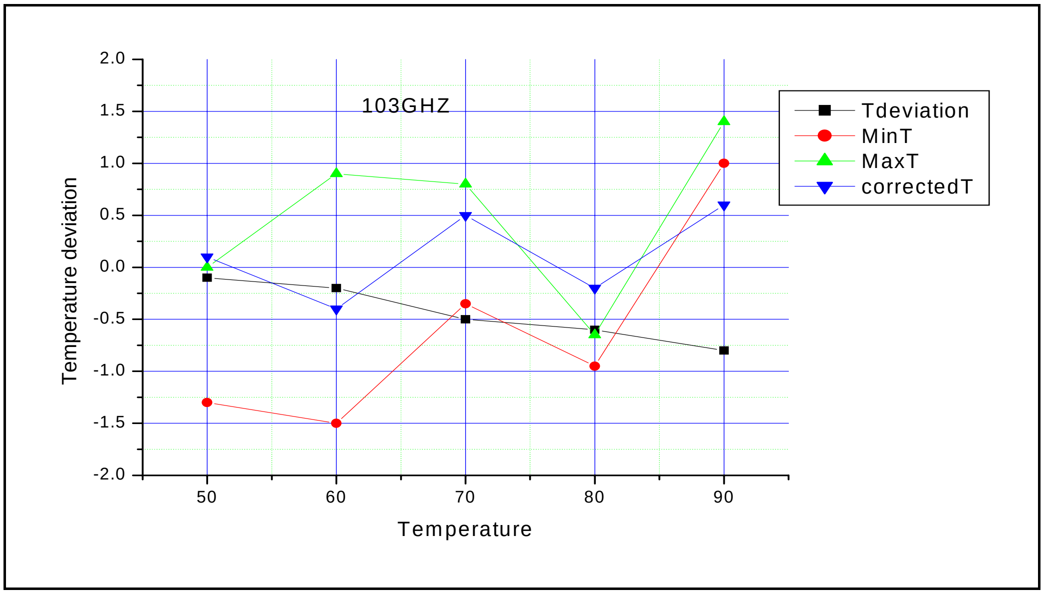

Figure 3: Measurement at103 GHz

4. MEASUREMENTS IN 1MM RANGE

The measurements were made with a SIS SSB receiver (with a mixer composed of 4 junctions, to prevent saturation problems), at 300 GHz and 351 GHz. For those two frequencies, the radiating temperature of the load was measured when applying a load temperature consign of 50°C, 60°C, 70°C, 80°C and 87°C.
For those measures, the absorption of the polystyrene layer is not negligible and has been determined.

4.1. Effects by Polystyrene layer

Effects due to the polystyrene layer: measurement of the polystyrene absorption in the 1mm range:

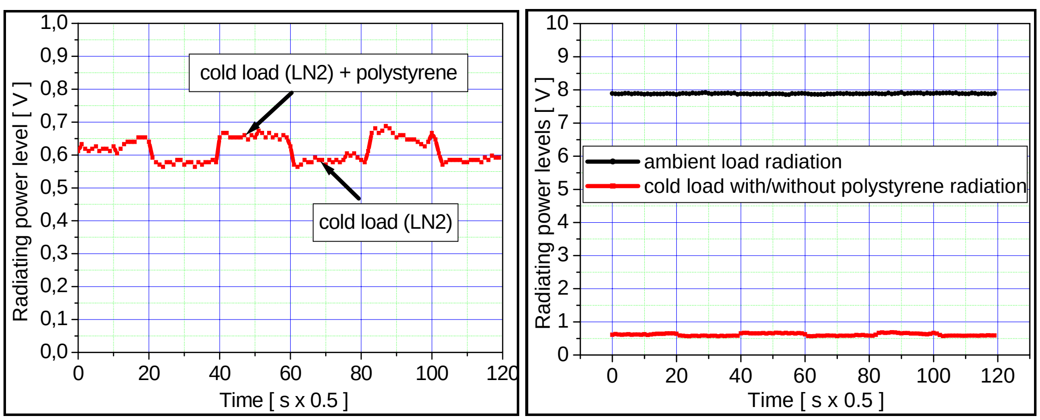

Figure 4: Measurement of the polystyrene absorption in the 1mm range

Polystyrene layer absorption at 351GHz = 1.1%
Polystyrene layer absorption at 300GHz = 1%

4.2. Measurements at 300 GHz and 351 GHz

The graphs below show 5 curves of the temperature deviation against the requested temperature. These are as follows:

1. Black; the temperature deviation read on the platinum thermometer
2. Cyan; platinum thermometer reading corrected with the loss of the expanded polystyrene window
3. Red; the minimum deviation measured
4. Green; The maximum deviation
5. Blue the corrected radiometer temperature, taking account of receiver drift etc.

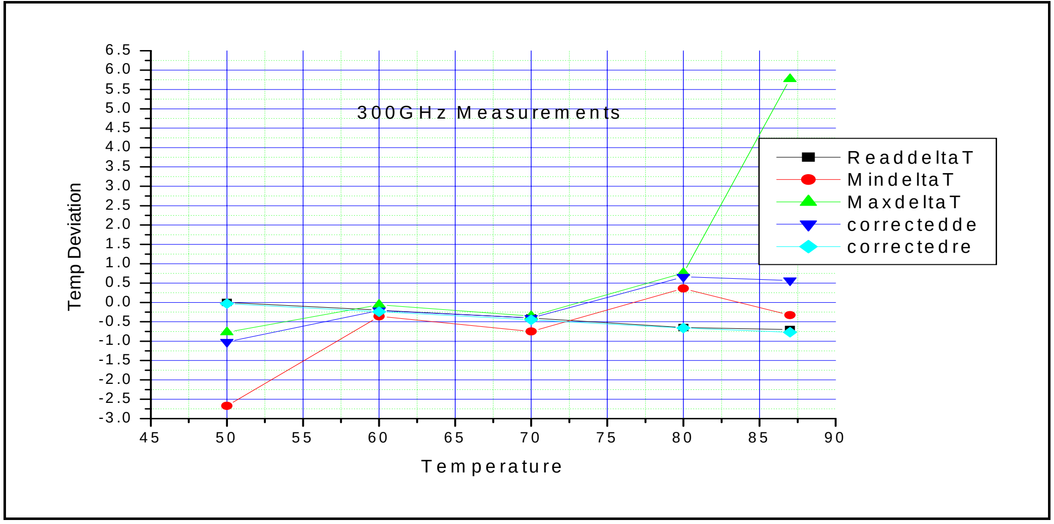

Figure 5: Radiating load temperature values at 300GHz after correction

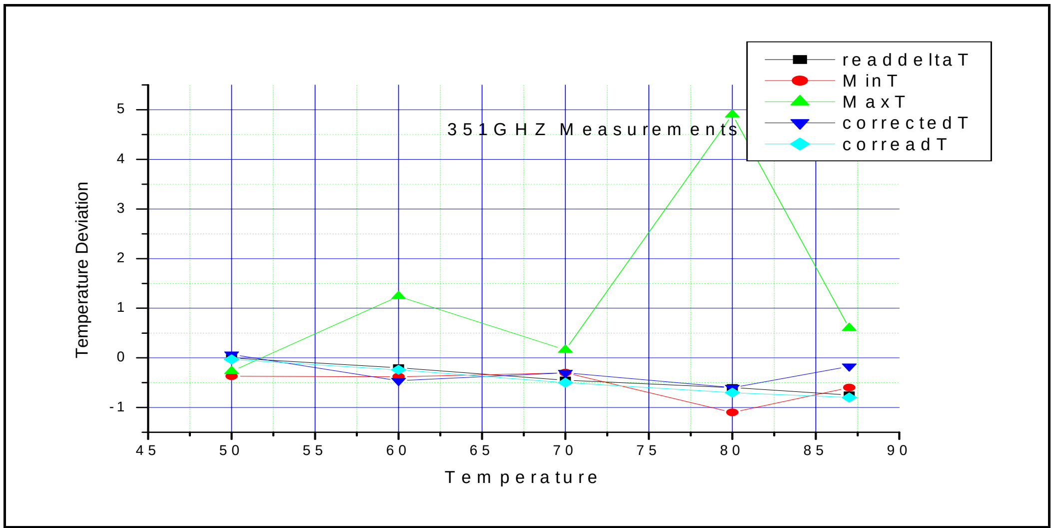

Figure 6: Radiating load temperature values at 351GHz after correction

4.3. Correlation between measurements

Correlation between measured radiating power and measured (4 wires) load temperature:

On Figure 7 to 10, we notice a good correlation between the 4 wires load temperature measurement and the simultaneously measured radiating load temperature.

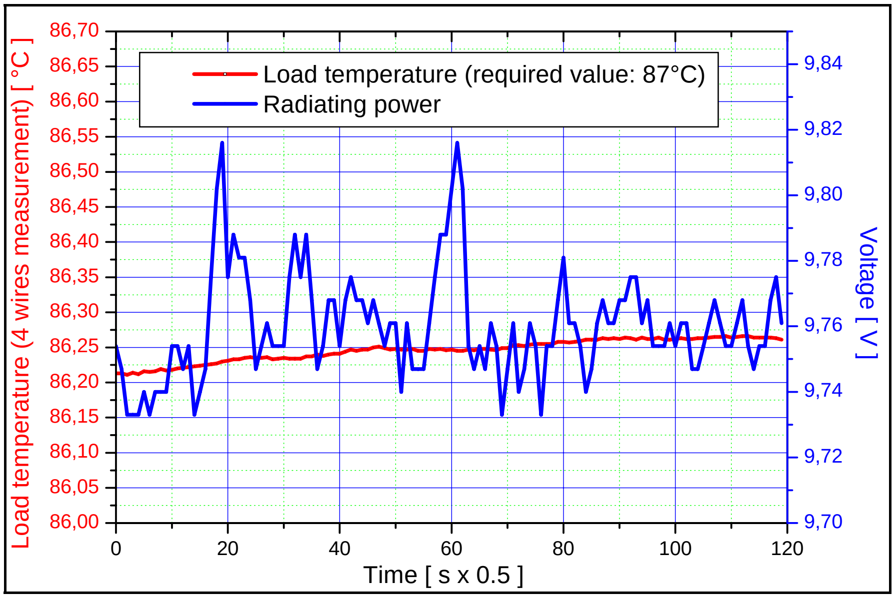

Figure 7: Simultaneous Load temperature 4 wires measurement (red curve) and radiating power measurement (applied consign: 87°C, f=351GHz)

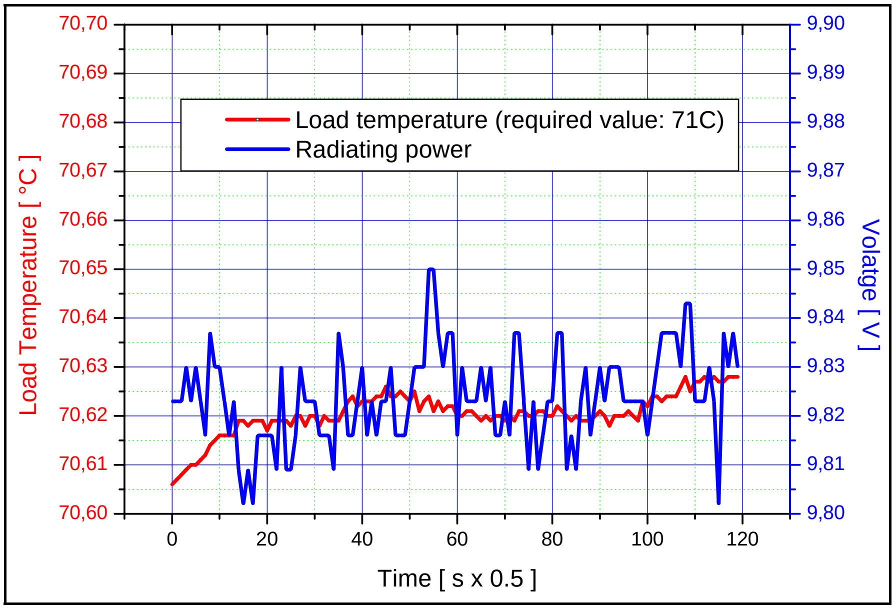

Figure 8: Simultaneous Load temperature 4 wires measurement (red curve) and radiating power measurement (applied consign: 71°C, f=351GHz)

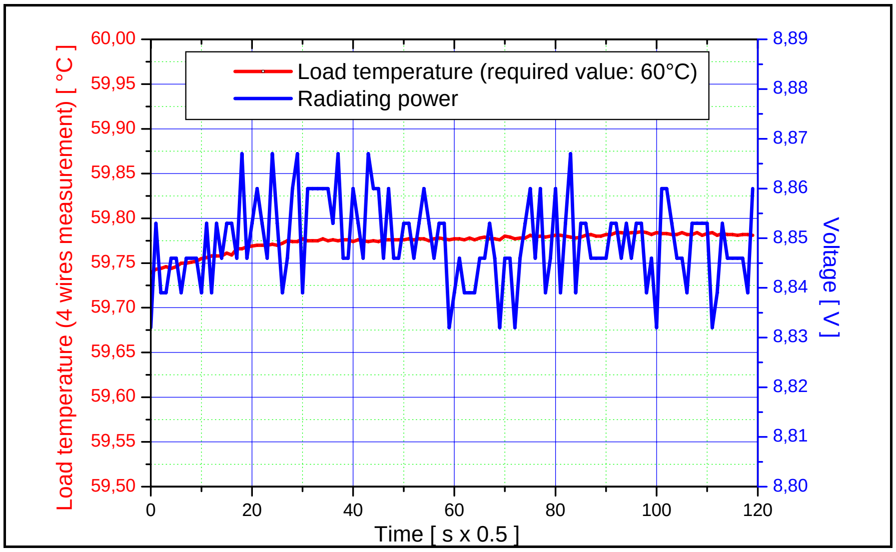

Figure 9: Simultaneous Load temperature 4 wires measurement (red curve) and radiating power measurement (applied consign: 60°C, f=351GHz)

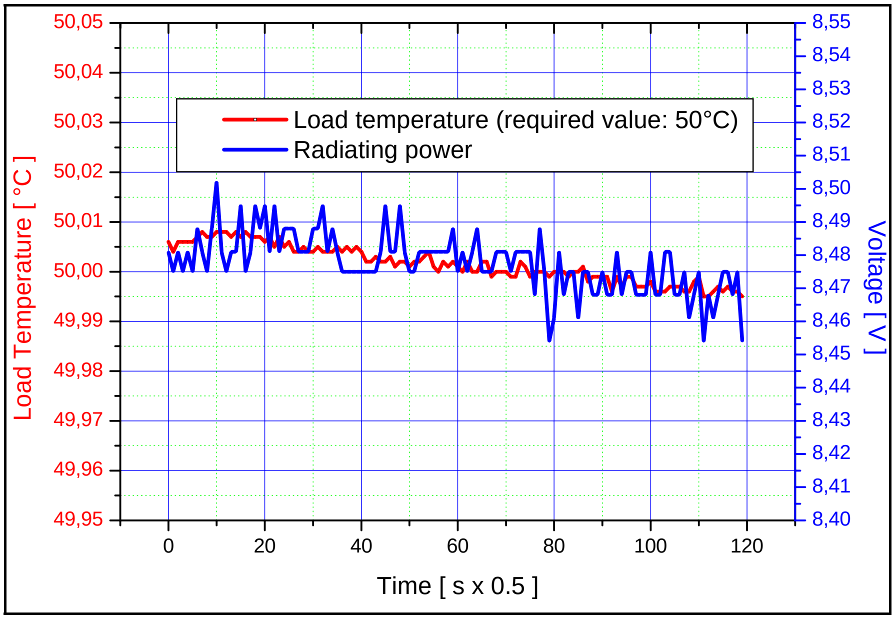

Figure 10: Simultaneous Load temperature 4 wires measurement (red curve) and radiating power measurement (applied consign: 50°C, f=351GHz)

5. COMMENTS

On some of the measurements there is a large discrepancy between the minimum and maximum values of the receiver temperature. A slow drift in the receiver gain with respect to time can explain most of this. The measurements were made over an over about an 8-minute time cycle. These consisted as follows:

1. Tcold
2. Tambient
3. Thot
4. Tambient
5. Tcold

There was 1 minute on each charge and then about a 30 second interval between each measurement whilst the loads were interchanged. Some of these problems are easy to see as the case of the 300GHz 87K measurements in Figure 11.

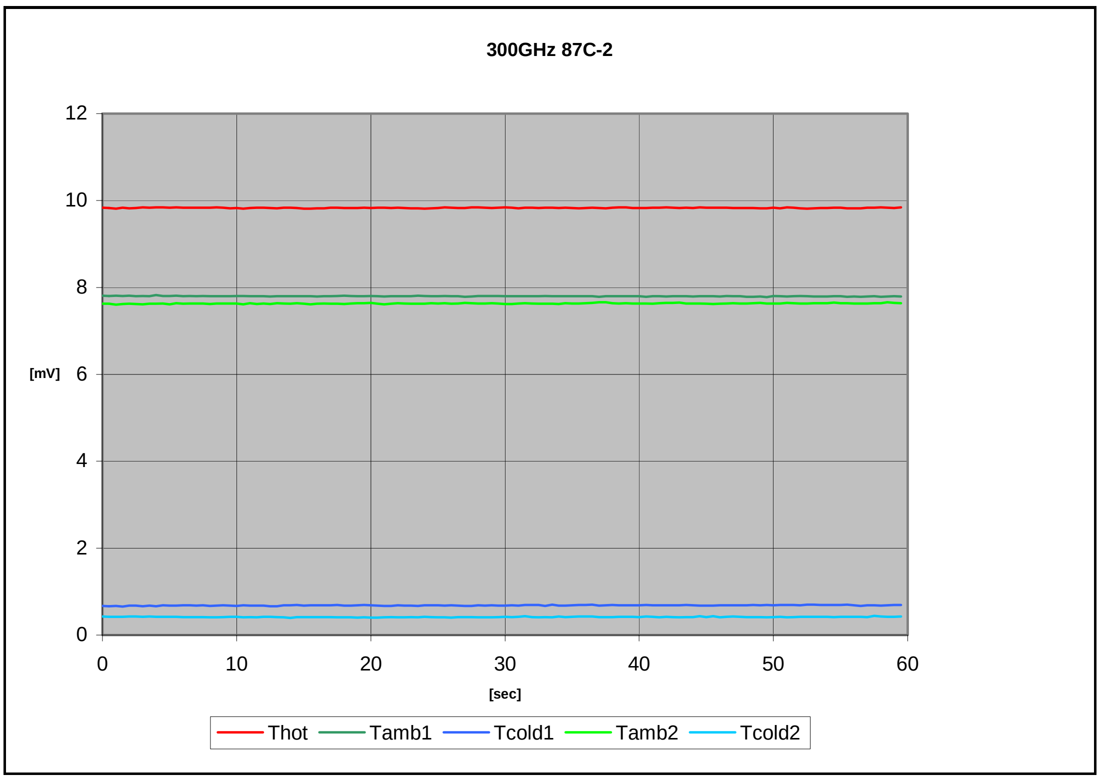

Figure 11: Receiver measurement at 300GHz the hot load at 87C

As can be seen there are 2 separate values of the ambient temperature and the cold temperature. If an average Tcold and Tambient were taken

This is due to a long-term drift of the receivers and is the main cause of the relatively large discrepancy in the maximum and minimum of these results. To overcome this we have tried to correct the results by postulating the cold and ambient readings with those of the hot. With this we get a corrected temperature. As can be seen that the uncorrected readings are normally better than +/- 1.5ºC. There are a few exceptions to this such as 80ºC at 351GHz where the maximum error was 5ºC and 5.8ºC at 300GHz at 87ºC.
On close inspection, most of these poor results can be explained by measurement problems such as small jumps in the output power. If these measurements are ignored or manually corrected we can see that the error in the measurements were of the order of +/- 0.7ºC.

It is now obvious that to measure within the accuracy of +/-0.5C a different and more complex measurement scheme would be required. This would require chopping between the 3 loads a lot more quickly. A system where we chopped between Tcold and T ambient, for a 1minute which was then changed between Tambient and Thot was tried, but this did not give any better results.

6. CONCLUSION

The ALMA calibration load was measure at 4 different frequencies, 83, 103, 300 and 351GHz. The results show that with in the accuracy of the measurements we can measure a temperature by radiometric means within the accuracy of +/-0.7C against the read temperature of the platinum thermometer. It is believed that this could be improved to +/- 0.5C, if we chopped quickly between the 3 loads

7. MEASUREMENT TABLE

Freq.	Temperature			Radiometer		Average/ Corr. T	Delta		
[GHz]	[°C]			[°C]		[°C]	[°C]		
	req.	read	corr.	min T	max T		min	max	corr.
83.0	50.0	49.95		48.9	49.6	49.1	-1.05	-0.35	-0.85
83.0	60.0	59.8		58.9	60.6	59.3	-0.90	0.80	-0.50
83.0	70.0	69.6		68.9	69.2	69.5	-0.70	-0.40	-0.10
83.0	80.0	79.4		78.6	79.1	79.4	-0.80	-0.30	0.00
83.0	87.0	86.3		84.75	85	85.93	-1.55	-1.30	-0.37
103.0	50.0	49.9		48.6	49.9	50	-1.30	0.00	0.10
103.0	60.0	59.8		58.3	60.7	59.4	-1.50	0.90	-0.40
103.0	70.0	69.5		69.15	70.3	70	-0.35	0.80	0.50
103.0	80.0	79.4		78.45	78.75	79.2	-0.95	-0.65	-0.20
103.0	87.0	86.2		87.2	87.6	86.8	1	1.40	0.60
300.0	50.0	50	49.97	47.3	49.2	48.95	-2.67	-0.77	-1.02
300.0	60.0	59.8	59.76	59.4	59.7	59.55	-0.36	-0.06	-0.21
300.0	70.0	69.6	69.55	68.8	69.2	69.15	-0.75	-0.35	-0.40
300.0	80.0	79.35	79.34	79.7	80.1	80	0.36	0.76	0.66
300.0	87.0	86.3	86.23	85.9	92	86.8	-0.33	5.77	0.57
351.0	50.0	50	49.97	49.6	49.7	49.9	-0.37	-0.27	-0.07
351.0	60.0	59.8	59.76	59.38	61	59.3	-0.38	1.24	-0.46
351.0	70.0	69.55	69.5	69.2	69.66	69.2	-0.30	0.16	-0.30
351.0	80.0	79.4	79.3	78.2	84.2	78.7	-1.10	4.90	-0.60
351.0	87.0	86.25	86.2	85.6	86.8	86.03	-0.6	0.6	-0.17