Allen Telescope Array

Measurement of the Antonio Feed System Temperature

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Contents

1 General

This document describes the system temperature measurements for the Antonio Feeds at the ATA. In the first part of the document we are describing the measurement equipment, setup, and calculations leading to a frequency resolved system temperature plot. The second part presents an overview of the measured antennas as well as the system temperature, spectra for hot and cold input signal, and Y-factor for each antenna individually.

2 Measurement Setup

This section describes the setup used to measure the frequency resolved feed system temperature. A simplified schematic of the measurement setup is shown in Figure 1. The setup can be separated into three main sections. The Feed includes the log-periodic feed structure, which is linked at the tip to the cryogenic low noise amplifiers. The Room Temperature Signal Conditioning includes the cables, attenuators and amplifiers used to amplify the signal to a state where it can be measured using a spectrum analyzer. The Data Acquisition consists of a spectrum analyzer which records the entire operational band of the feed and stores it as a .csv file.

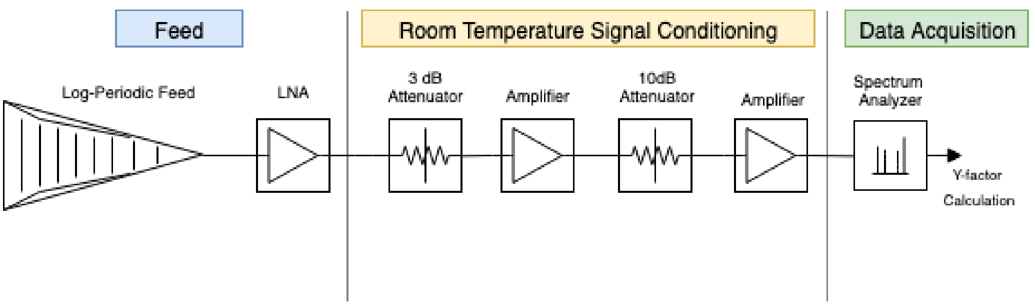


Figure 1: Schematic diagram of the measurement setup.

2.1 Y-Factor Method

The frequency resolved feed system temperature (T_{sys}) is measured using the Y-Factor method [1]. This method is used to determine the effective noise temperature of the receiver system, by measuring the ratio in output power for two different input temperatures T_{hot} and T_{cold}. The equation to calculate the system temperature is given by

$$T_{sys} = \frac{T_{hot} - Y \cdot T_{cold}}{Y - 1}, \tag{1}$$

with

$$Y = \frac{P_{hot}}{P_{cold}}, \tag{2}$$

where P_{hot} and P_{cold} are the measured output power level of the receiver system and T_{hot} and T_{cold} are the corresponding temperature input in Kelvin.

2.2 Hardware

This section describes the hardware components used in this measurement setup. Table 1 lists the exact components, which were used to amplify the output signal of the feed and to record the data. Hence, followup measurements using the same hardware will also result in the same gain and input power level to the spectrum analyzer. This ensures that the T_{sys} measurement is performed within the dynamic range of the setup.

Table 1: List of used components to perform feed system temperature measurements.

Description	Quantity	Designation
Cable	2	AFX-CA-141-10, ABC-CA18-SMSM-5.0M
Attenuator	2	AA18-03H (3dB), AA18-10H (10dB)
Amplifier	2	AOX-010200
Spectrum Analyzer	1	FieldFox N9938A
Hot Load	1	AEC-3 Absorber ATA-Feed

The configuration of the spectrum analyzer is shown in Table 2. Note, that with the selected frequency band, RBW, and VBW, the sweep time will be approximately 146 sec. Therefore, no averaging is required. The recorded spectrum is exported as a .csv file format, which can be directly imported into the post processing python software.

Table 2: Spectrum analyzer settings.

Description	Setting
Resolution	801 points
f_{start}	0.1 GHz
f_{stop}	15 GHz
RBW	5 MHz
VBW	3 KHz
Sweep Time	$\approx$ 146 sec
Attenuator	5 dB
File Format	.csv

2.3 Measurement Procedure

The to be measured antennas are pointed at a fixed azimuth and elevation position. The elevation position is a compromise between performance and accessibility. Usually for a T_{sys} measurement using the SKY as a cold load, one wants to point the telescope at zenith, where the atmospheric contribution is the minimum. However, in our case this would prevent us from mounting the hot load on the feed and moving the antenna for each measurement would take to long. For all of the measurements in this report we pointed the antennas at: AZ=330 deg and EL=23 deg.

The system temperature measurement is carried out sequential for each polarization of an antenna. This is required, to reduce the effect of gain drifts over time. The procedure used to measure all antennas is outlined below.

- X-Cold
  1. Connect setup to the X-Pol output of the feed.
  2. Close shroud.
  3. Record data.
- X-Hot
  4. Place absorber on feed.
  5. Record data.
- Y-Hot
  6. Switch setup to the Y-pol output of the feed.

7. Record data.

- Y-Cold

8. Remove absorber from feed.
9. Close shroud.
10. Record data.

2.4 Atmospheric Contribution

Figure 2, shows the sky-model provided by Jill Tarter, which was used for the first measurement of the antonio feed's system temperature. The model shows the frequency resolved sky temperature for 90 deg elevation, with and without the contribution of the galactic plane, red and green line, respectively. In addition to that, it also shows the expected sky temperature when pointing at 20 deg elevation, blue line. One can see that by average the sky temperature is increased by 3 Kelvin in the frequency range between 2 – 12 GHz when pointing at low elevation. This figure also shows a non linear increase in sky temperature above 12 GHz for low elevation.

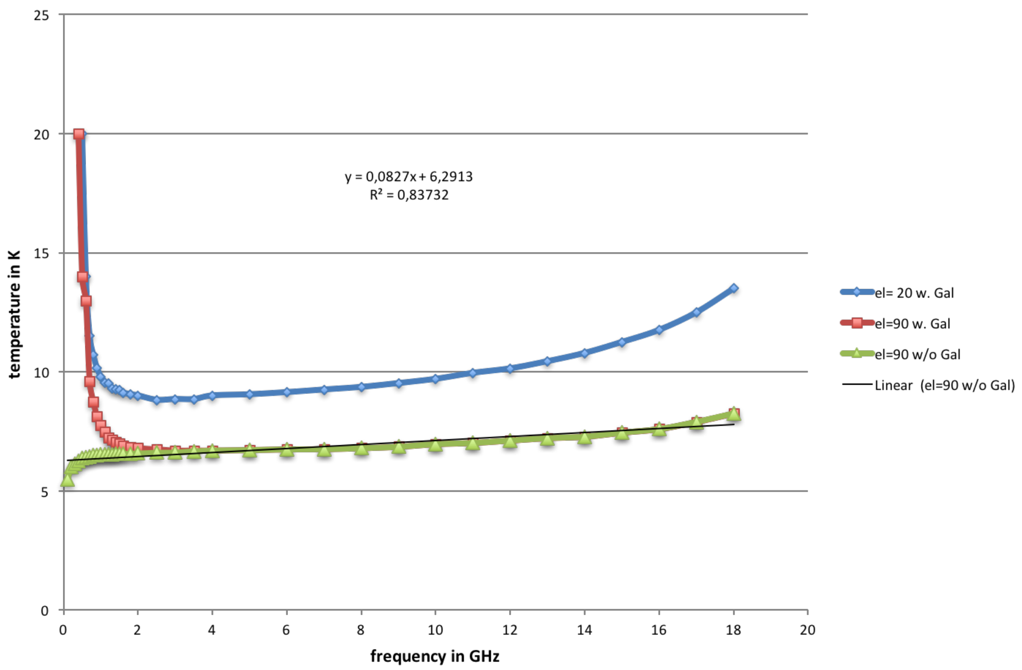


Figure 2: SKY model for T_{sys} measurement at low elevation. Provided by Jill Tarter.

3 Antenna Overview

This section provides an overview of the measured antennas with their corresponding feeds. All information is presented in Table 3, which lists the antennas and feeds in the first two columns. The subsequent two columns show the physical temperature in Kelvin, used to compute the frequency resolved system temperature. The following two columns show the measured system temperature results at a frequency of 3.04 GHz taken from the SRI Array Health Check. The data used for the array health check was collected a week before the the frequency resolved measurements took place. The final column indicates the operational status of the feed based on the information gained by this measurements.

Table 3: Overview of the measured antennas and their feed system temperature.

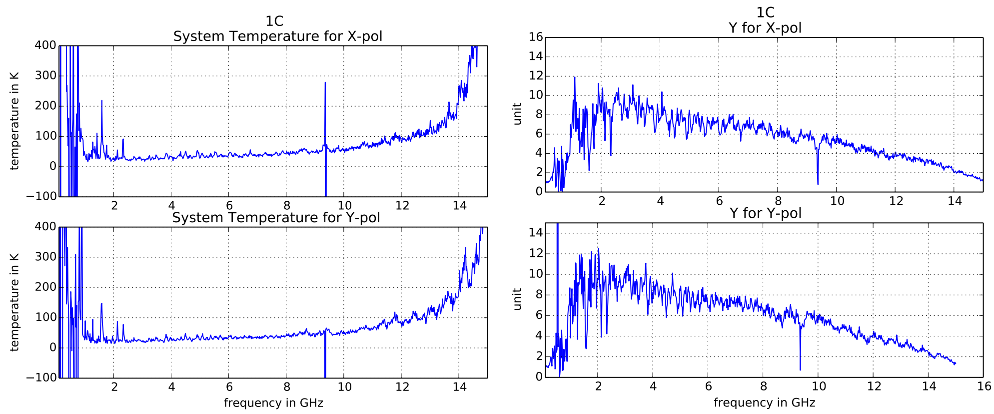
Antenna	Feed	T_{hot}	T_{cold}	$T_{sys}X$	$T_{sys}Y$	Status
1C	5C4-019	292 K	10 K	45 K	45 K	OK
1G	5C4-008	294 K	10 K	190 K	50 K	NOK
1H	5C4-013	294 K	10 K	135 K	∞ K	NOK
1K	5C4-012	292 K	10 K	∞ K	∞ K	NOK
2A	5C4-005	287 K	10 K	40 K	40 K	OK
2B	5C4-010	287 K	10 K	50 K	40 K	OK
2E	5C4-004	290 K	10 K	140 K	40 K	NOK
2H	5C4-018	291 K	10 K	40 K	40 K	OK
2J	5C4-014	291 K	10 K	200 K	40 K	NOK
3L	5C4-011	291 K	10 K	60 K	260 K	NOK
4J	5C4-006	293 K	10 K	40 K	120 K	NOK
5B	5C4-003	290 K	10 K	70 K	120 K	NOK

4 Measurement Results

This section shows the measured frequency resolved system temperature for each antenna. Each figure includes four plots, the first plot (a) shows the frequency resolved system temperature. The second plot (b) shows the calculated Y-factor for that measurement. Plot (c) and (d) show the measured spectra for the cold and hot input signal of the feed, for X and Y polarization, respectively.

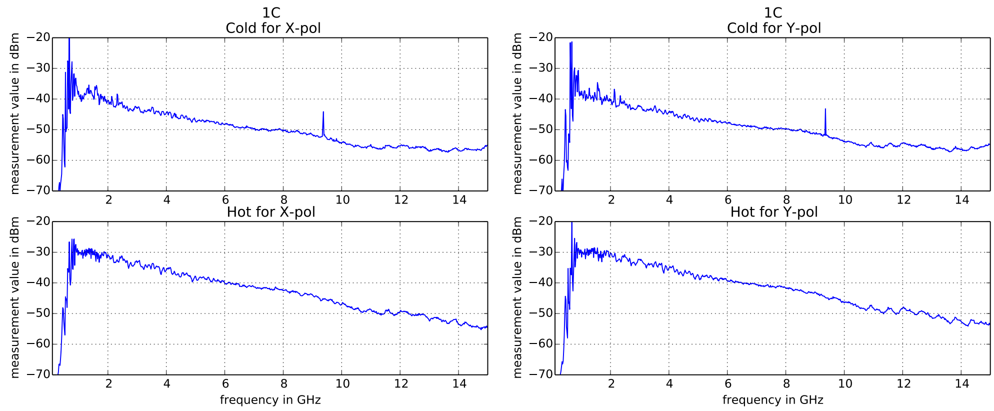
4.1 Antenna 1C

This section shows the measured frequency resolved system temperature for antenna 1C. The system temperature shown in Figure 3 was calculated using $T_{cold} = 10\,K$ and $T_{hot} = 292\,K$. The array health check using the corrector results in an average T_{sys} value of 45 K for both polarizations.



(a) T_{sys}

(b) Y-factor



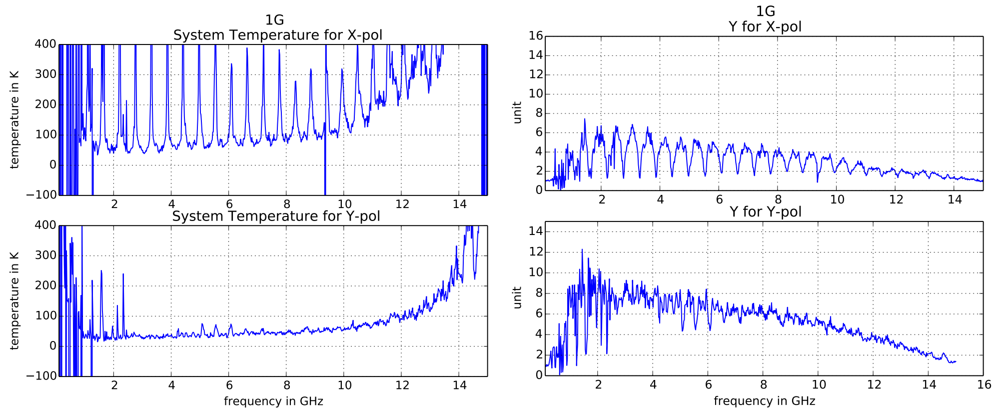
(c) Spectrum X-Polarization

(d) Spectrum Y-Polarization

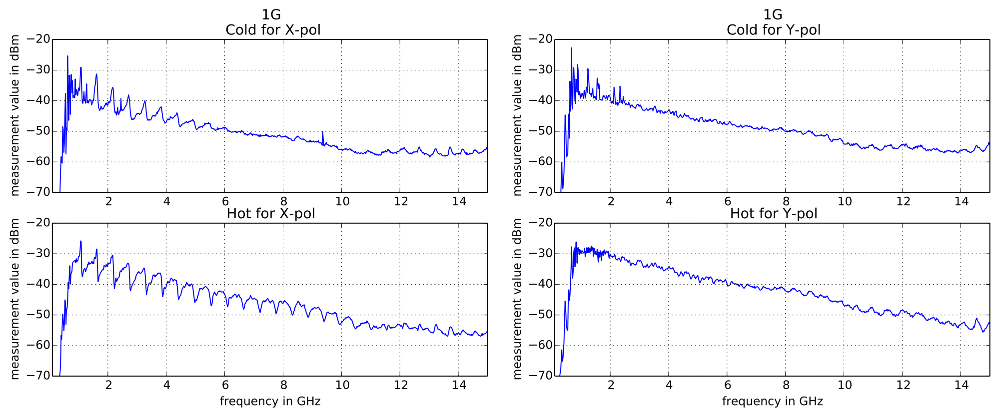
Figure 3: The measured performance of antenna 1C.

4.2 Antenna 1G

This section shows the measured frequency resolved system temperature for antenna 1G. The system temperature shown in Figure 4 was calculated using $T_{cold} = 10\,K$ and $T_{hot} = 294\,K$. The array health check using the corrector results in an average T_{sys} value of 190 K and 50 K for X and Y polarization, respectively.



(a) T_{sys} (b) Y-factor

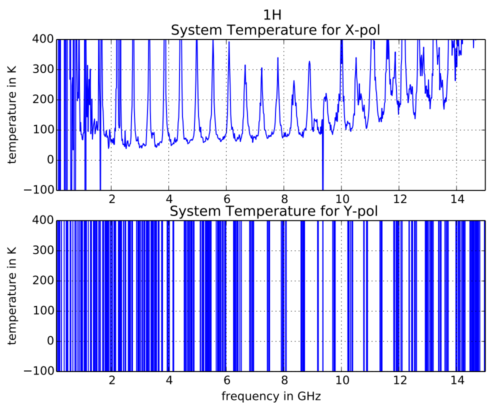


(c) Spectrum X-Polarization (d) Spectrum Y-Polarization

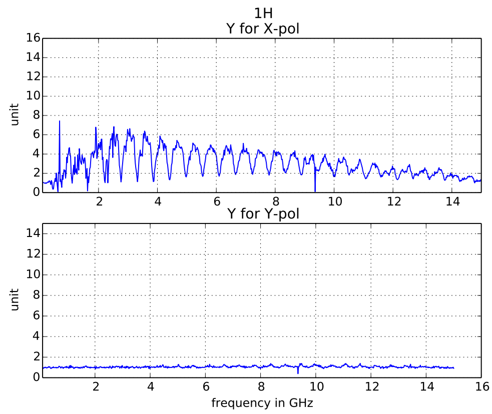
Figure 4: The measured performance of antenna 1G.

4.3 Antenna 1H

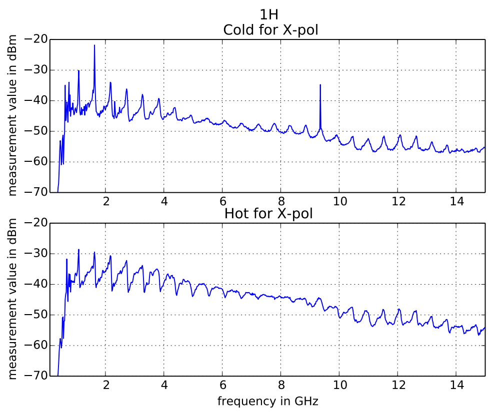
This section shows the measured frequency resolved system temperature for antenna 1H. The system temperature shown in Figure 5 was calculated using $T_{cold} = 10\,K$ and $T_{hot} = 294\,K$. The array health check using the corrector results in an average T_{sys} value of 135 K and ∞ K for X and Y polarization, respectively.



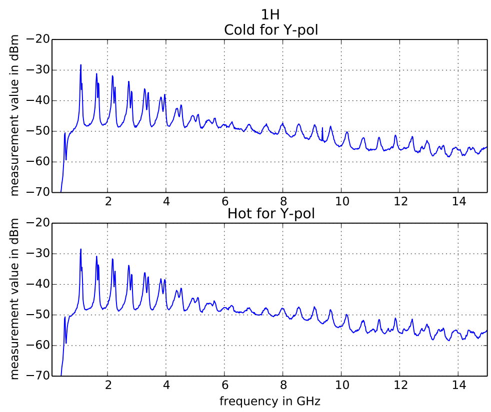
(a) T_{sys}



(b) Y-factor



(c) Spectrum X-Polarization

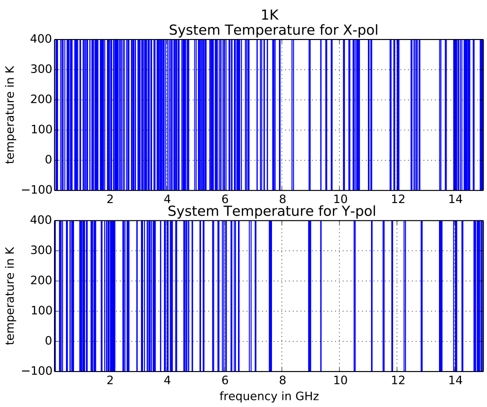


(d) Spectrum Y-Polarization

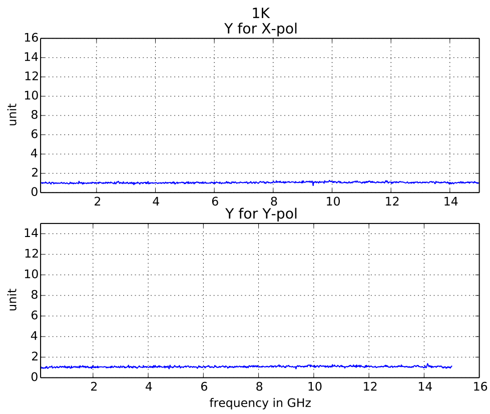
Figure 5: The measured performance of antenna 1H.

4.4 Antenna 1K

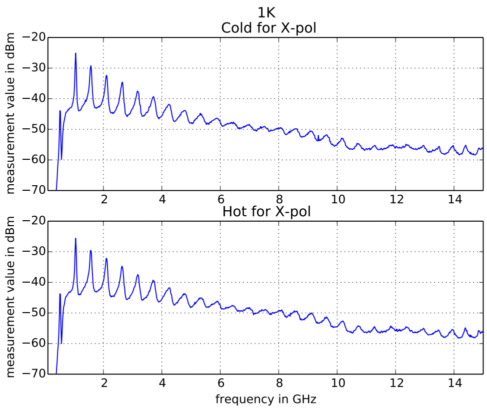
This section shows the measured frequency resolved system temperature for antenna 1K. The system temperature shown in Figure 6 was calculated using $T_{cold} = 10\,K$ and $T_{hot} = 292\,K$. The array health check using the corrector results in an average T_{sys} value of $\infty\,K$ and $\infty\,K$ for X and Y polarization, respectively.



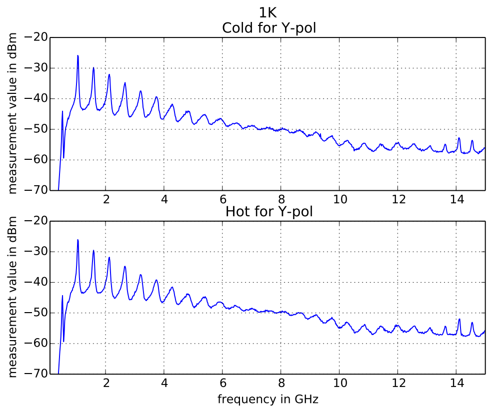
(a) T_{sys}



(b) Y-factor



(c) Spectrum X-Polarization

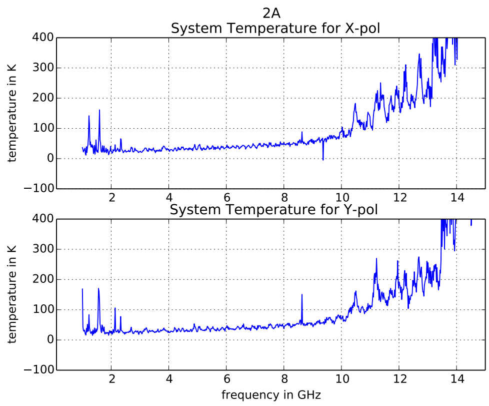


(d) Spectrum Y-Polarization

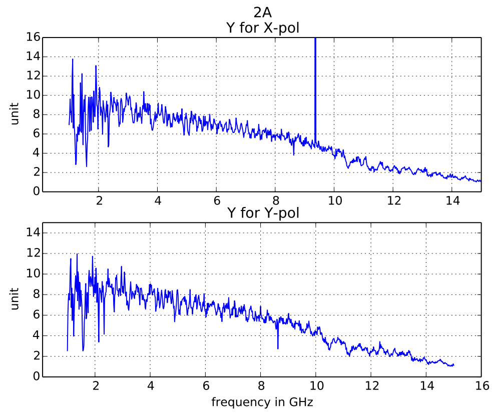
Figure 6: The measured performance of antenna 1K.

4.5 Antenna 2A

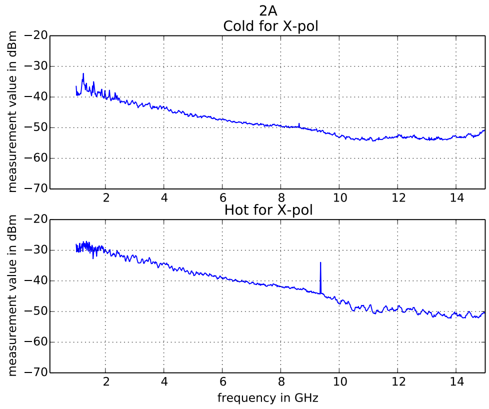
This section shows the measured frequency resolved system temperature for antenna 2A. The system temperature shown in Figure 7 was calculated using $T_{cold} = 10\,K$ and $T_{hot} = 287\,K$. The array health check using the corrector results in an average T_{sys} value of 40 K for both polarizations.



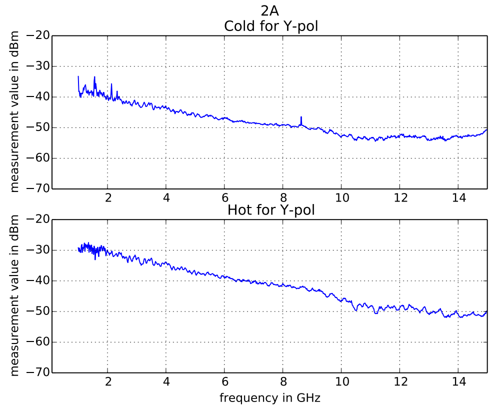
(a) T_{sys}



(b) Y-factor



(c) Spectrum X-Polarization

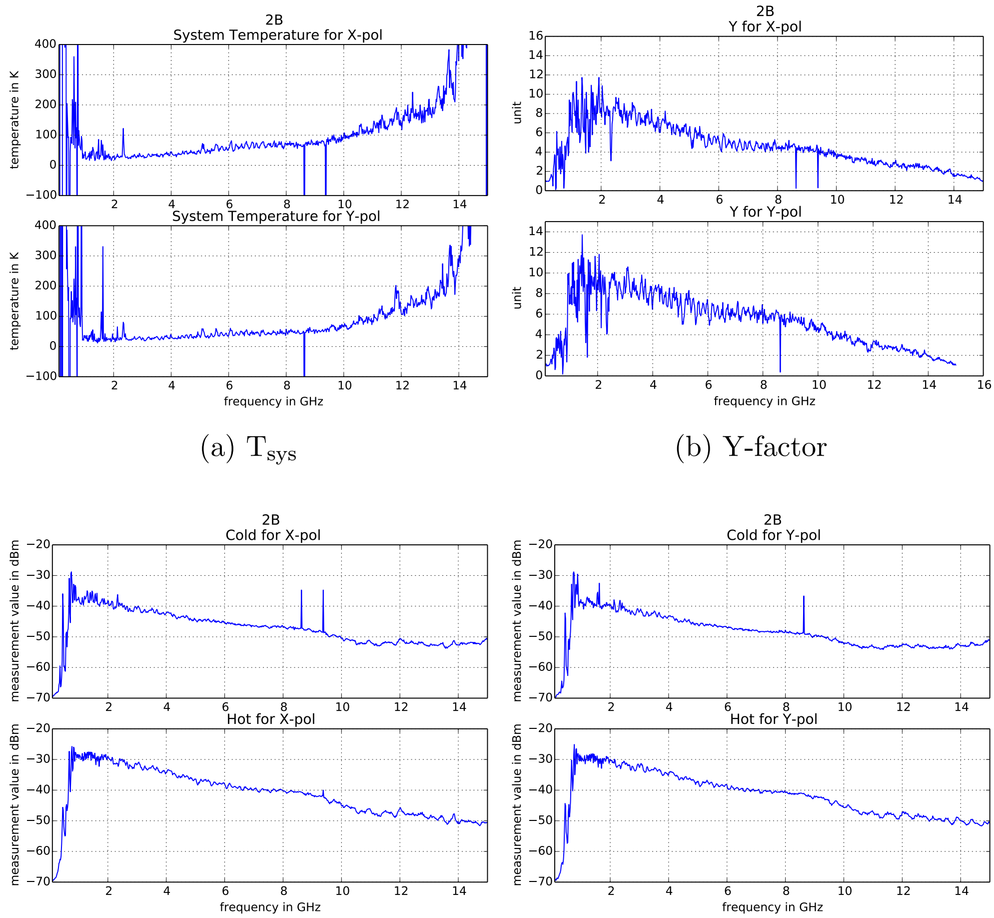


(d) Spectrum Y-Polarization

Figure 7: The measured performance of antenna 2A.

4.6 Antenna 2B

This section shows the measured frequency resolved system temperature for antenna 2B. The system temperature shown in Figure 8 was calculated using $T_{cold} = 10\,K$ and $T_{hot} = 287\,K$. The array health check using the corrector results in an average T_{sys} value of 50 K and 40 K for X and Y polarization, respectively.



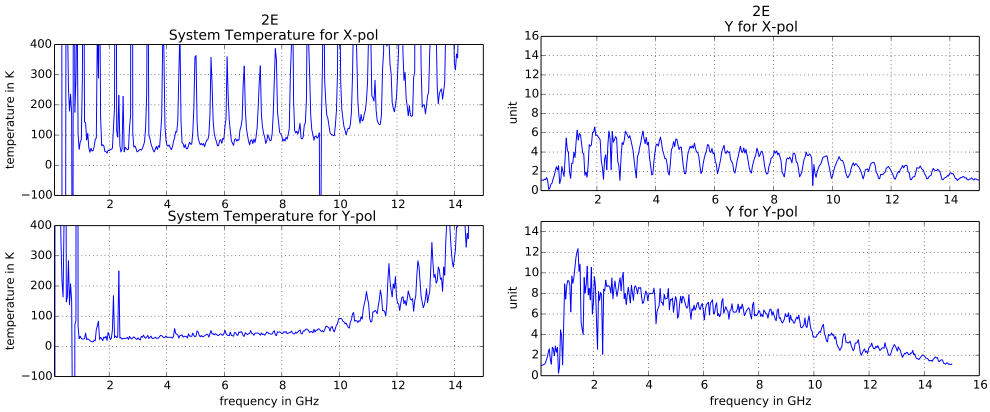
(a) T_{sys} (b) Y-factor

(c) Spectrum X-Polarization (d) Spectrum Y-Polarization

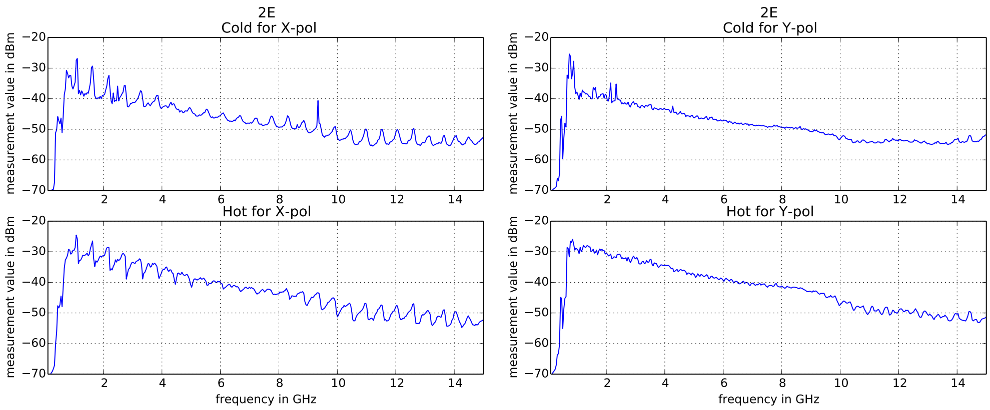
Figure 8: The measured performance of antenna 2B.

4.7 Antenna 2E

This section shows the measured frequency resolved system temperature for antenna 2E. The system temperature shown in Figure 9 was calculated using $T_{cold} = 10\,K$ and $T_{hot} = 290\,K$. The array health check using the corrector results in an average T_{sys} value of 140 K and 40 K for X and Y polarization, respectively.



(a) T_{sys} (b) Y-factor

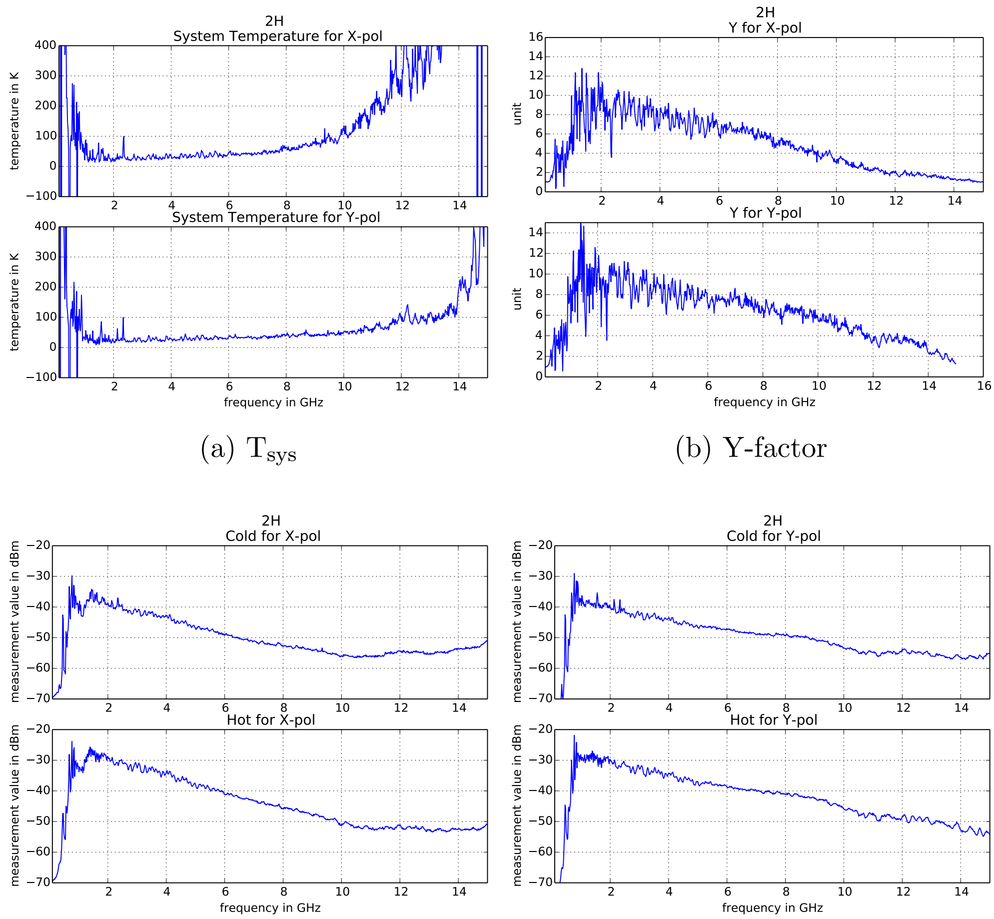


(c) Spectrum X-Polarization (d) Spectrum Y-Polarization

Figure 9: The measured performance of antenna 2E.

4.8 Antenna 2H

This section shows the measured frequency resolved system temperature for antenna 2H. The system temperature shown in Figure 10 was calculated using $T_{cold} = 10\,K$ and $T_{hot} = 291\,K$. The array health check using the corrector results in an average T_{sys} value of 40 K for both polarizations.



(a) T_{sys}

(b) Y-factor

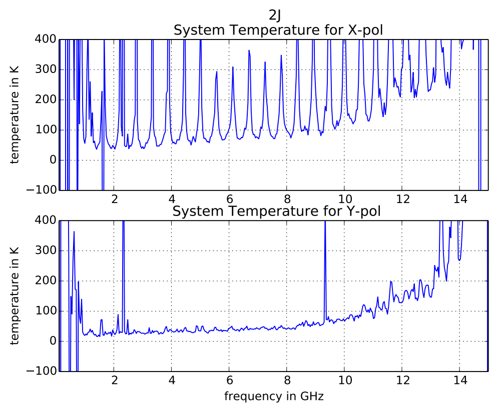
(c) Spectrum X-Polarization

(d) Spectrum Y-Polarization

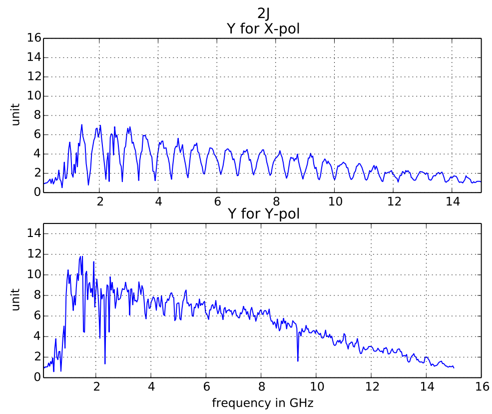
Figure 10: The measured performance of antenna 2H.

4.9 Antenna 2J

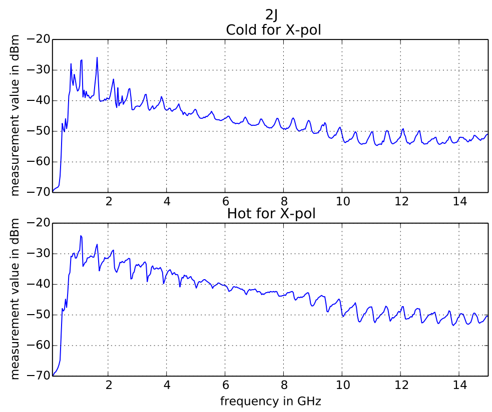
This section shows the measured frequency resolved system temperature for antenna 2J. The system temperature shown in Figure 11 was calculated using $T_{cold} = 10\,K$ and $T_{hot} = 291\,K$. The array health check using the corrector results in an average T_{sys} value of 200 K and 40 K for X and Y polarization, respectively.



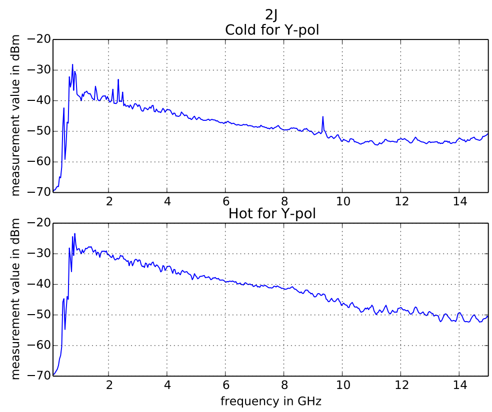
(a) T_{sys}



(b) Y-factor



(c) Spectrum X-Polarization

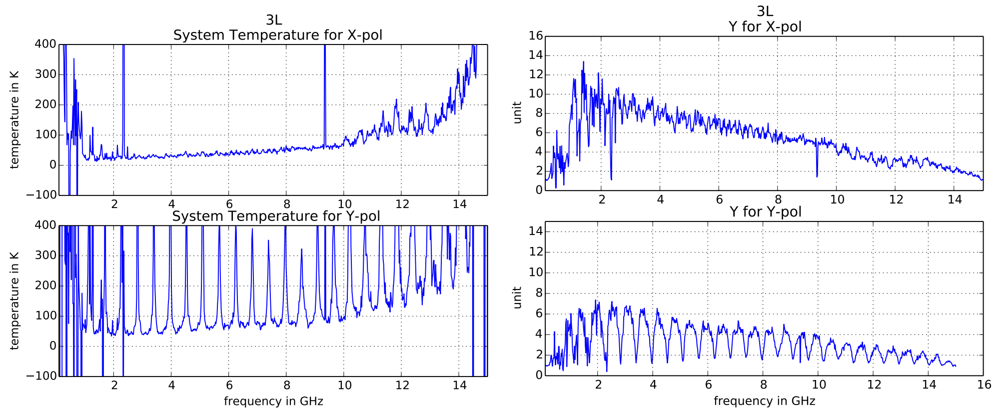


(d) Spectrum Y-Polarization

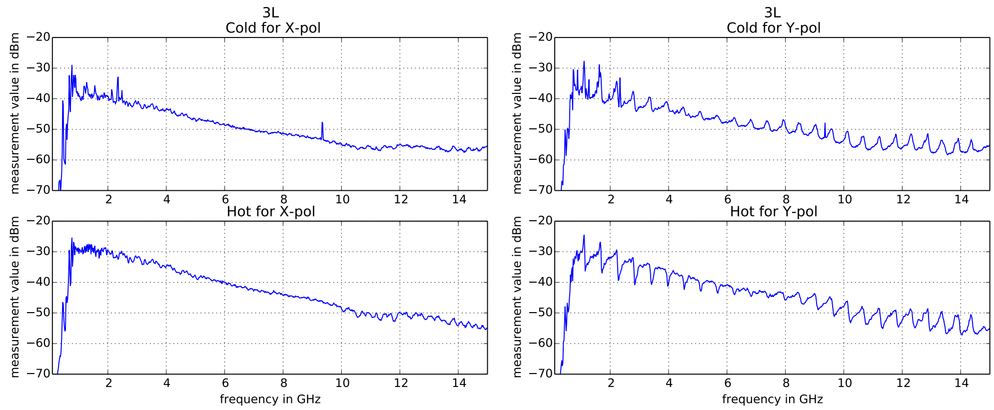
Figure 11: The measured performance of antenna 2J.

4.10 Antenna 3L

This section shows the measured frequency resolved system temperature for antenna 3L. The system temperature shown in Figure 12 was calculated using $T_{cold} = 10\,K$ and $T_{hot} = 291\,K$. The array health check using the corrector results in an average T_{sys} value of 60 K and 260 K for X and Y polarization, respectively.



(a) T_{sys} (b) Y-factor

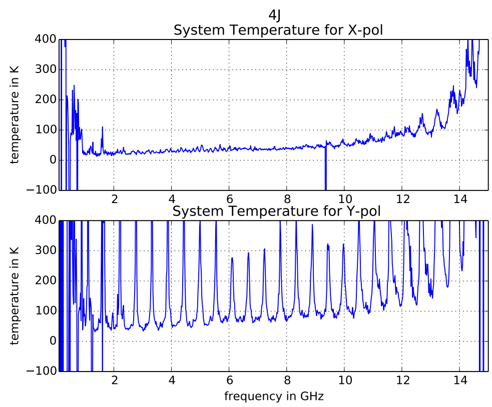


(c) Spectrum X-Polarization (d) Spectrum Y-Polarization

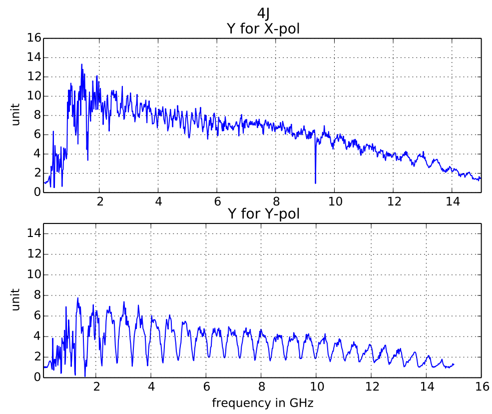
Figure 12: The measured performance of antenna 3L.

4.11 Antenna 4J

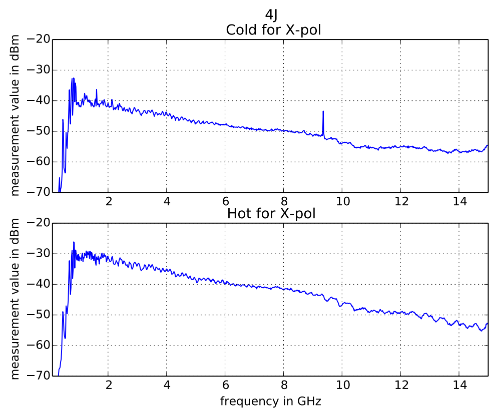
This section shows the measured frequency resolved system temperature for antenna 4J. The system temperature shown in Figure 13 was calculated using $T_{cold} = 10\,K$ and $T_{hot} = 293\,K$. The array health check using the corrector results in an average T_{sys} value of 40 K and 120 K for X and Y polarization, respectively.



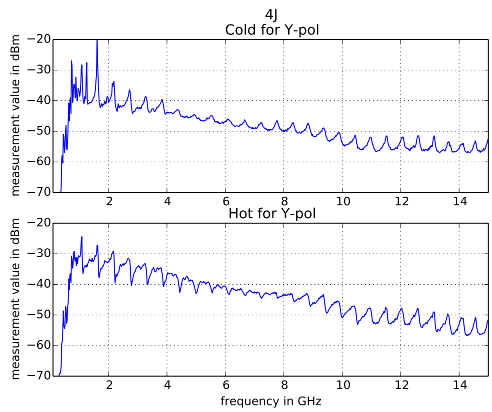
(a) T_{sys}



(b) Y-factor



(c) Spectrum X-Polarization

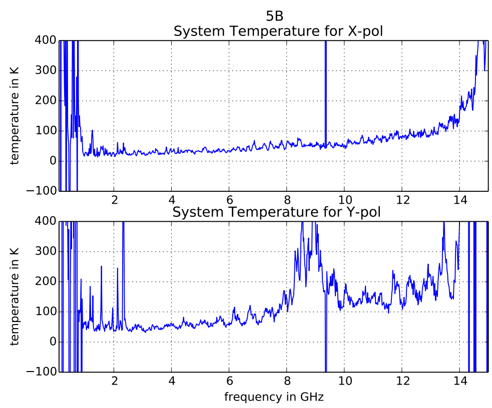


(d) Spectrum Y-Polarization

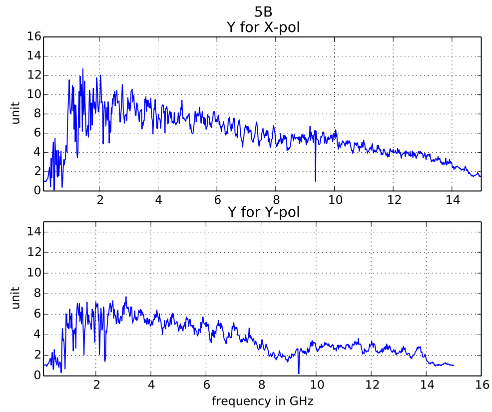
Figure 13: The measured performance of antenna 4J.

4.12 Antenna 5B

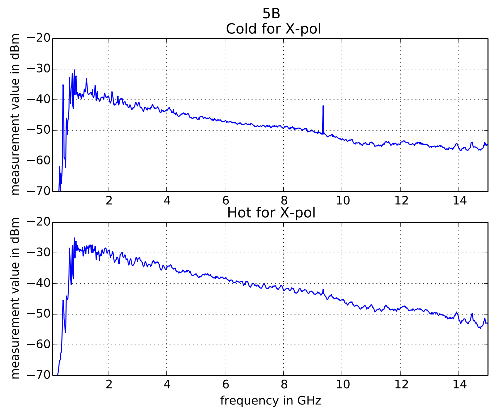
This section shows the measured frequency resolved system temperature for antenna 5B. The system temperature shown in Figure 14 was calculated using $T_{cold} = 10\,K$ and $T_{hot} = 290\,K$. The array health check using the corrector results in an average T_{sys} value of 70 K and 120 K for X and Y polarization, respectively.



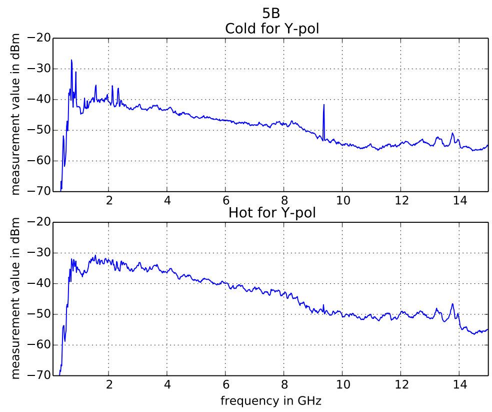
(a) T_{sys}



(b) Y-factor



(c) Spectrum X-Polarization



(d) Spectrum Y-Polarization

Figure 14: The measured performance of antenna 5B.

4.13 Original Measured T_{sys}

This section presents the pervious measured feed system temperature. The plot shown in Figure 15, has been provided bay Jill Tarter. It shows the system temperature for 10 of the currently 12 installed feeds.

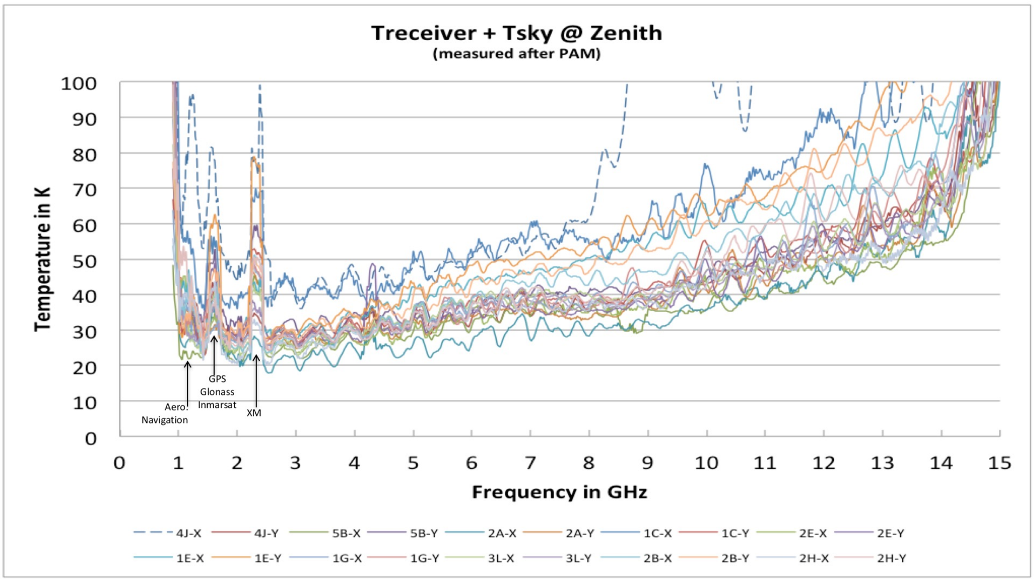


Figure 15: Original T_{sys} measurement of the Antonio Feeds, provided by Jill Tarter. Note, that the slope of the system temperature has been corrected with the SKY model.

5 Conclusion

The direct measurement of the frequency resolved feed system temperature presented in this memo is an effective tool to determine the overall performance of the antenna. Using this method we could directly identify and confirm broken tip arm links in several antennas. This in turn allows us to better test and verify the room temperature part of the ATA RF-signal chain.

This measurement also could confirm an expected increase in system temperature above 12 GHz, which was predicted by the EM simulation of the feed. Further strengthening the correctness of the EM model which is vital for the design of the new tip arm links.

Bibliography

[1] F. Connor, *Noise*, Introductory topics in electronics and telecommunication (Edward Arnold, 1982), ISBN 9780713134599.