

NATIONAL RADIO ASTRONOMY OBSERVATORY
Charlottesville, Virginia

ELECTRONICS DIVISION INTERNAL REPORT NO. 327

Cryogenic Phase Array Feed : Receiver Temperature

D. Anish Roshi^{1,2}, Roger D. Norrod¹, Robert Simon¹, J. Richard Fisher²,
Karl F. Warnick³, Brian D. Jeffs³

¹ National Radio Astronomy Observatory, Charlottesville,

² National Radio Astronomy Observatory, Green Bank,

³ ECE Dept., Brigham Young University, Provo, UT, USA

June 23, 2011

Cryogenic Phase Array Feed : Receiver Temperature

D. Anish Roshi^{1,2}, Roger D. Norrod¹, Robert Simon¹, J. Richard Fisher²,
Karl F. Warnick³, Brian D. Jeffs³

¹ National Radio Astronomy Observatory, Green Bank,

² National Radio Astronomy Observatory, Charlottesville,

³ Brigham Young University, Provo

June 23, 2011

Version 0.1

Abstract

This report summarizes the results of receiver temperature measurements made with the cryogenic phased array feed (CPAF) in the Indoor-Outdoor test facility at Green Bank. The 'Kite' dipoles were mounted on the array during these measurements. Results of the measurements made by Roger with a single ('isolated') dipole mounted on the array and at the cryostat interface are also included in the report. The main results are : (1) The noise temperature measured by terminating the cryostat interface with a 50Ω load is 10 K; (2) receiver temperatures with isolated 'Fat' dipole and 'Kite' dipole are 12 K and 17.4 K at 1640 MHz respectively; (3) the median receiver temperature of the 'Kite' dipole array is 30 K between frequencies 1380 and 1860 MHz.

1 Experimental setup and Data analysis

The cryogenic 'Kite' dipole array receiver noise measurements were made in the Indoor-Outdoor test range. A conical ground shield was placed around the array during the measurement. The outputs of the front-end were connected to the NRAO data acquisition system (DAQ) through the BYU IF system. Both polarizations were connected to the DAQ for measurements made with the 'Kite' dipole array.

The DAQ records 8 bit quantized voltages, sampled at 1.25 MHz from all the 19x2 signals from the array. A tone burst is injected at the beginning of the data acquisition to calibrated the relative phase between ADC channels. The offline program skips the tone burst part of the data and computes a series of 128 point FFT from the time series. Average self and cross products of these voltage spectra are then obtained. A plot of the self power spectra at 1640 MHz are show in Fig 1, which shows RFI picked up by the feed array. For receiver temperature measurements, we used average spectral power from about 10 RFI free channels. As seen in Fig 1, the spectral power of dipole output 8Y is about 10 dB low; we suspect problem with this channel and so the measurements made for 8Y are not reliable.

Data taken by Roger and Bob Simon are with a power meter. The bandwidth of these measurements are 0.6 MHz.

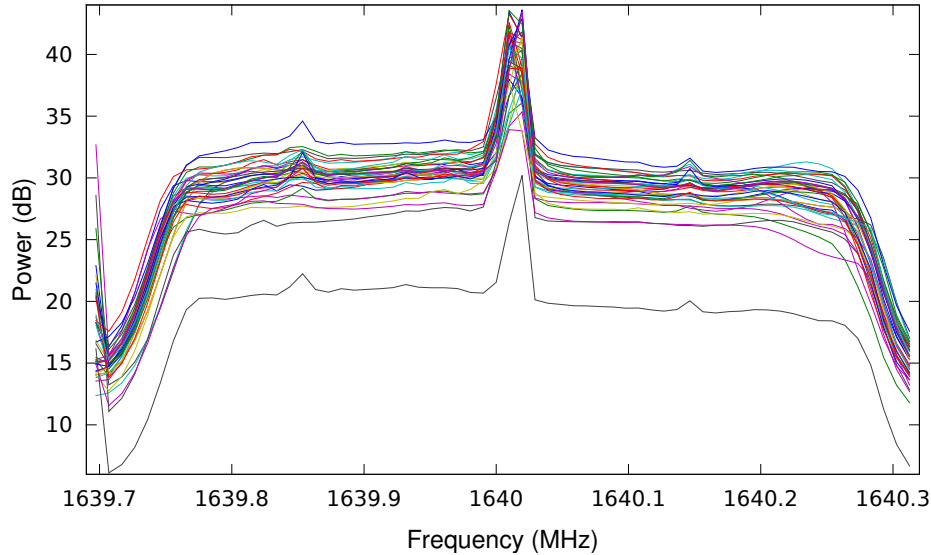


Figure 1: A typical set of spectra obtained using the DAQ showing the presence of RFI. Power spectra from all the 19x2 receiver channels are plotted. The spectrum with ~ 10 dB low power corresponds to channel 8Y; we suspect problem with this receiver channel.

2 Coaxial load and Isolated dipole measurements

The noise temperature at the dipole 1 cryostat interface is measured using a 'hot' 50Ω termination ($T_{hot} = 304$ K) and a 'cold' 50Ω termination ($T_{cold} = 79.4$ K). The measured temperature as a function of frequency is shown in Fig. 2(left). These measurements were made on July 30, 2010 by Roger. The mean (obtained across frequency) temperatures for the X and Y polarization interfaces are 9.1 and 10.8 K respectively.

The receiver temperature with single ('isolated') dipole is measured in the Indoor-Outdoor test range on April 11, 2011 by Roger. A single polarized 'Fat' dipole was first mounted at dipole 1X location. The dipole impedance is close to 50Ω . Fig. 2(right) shows the measurement results. Measurements at frequencies close to 1600 MHz are affected by RFI. The hot and cold load temperatures are 301 and 7.8 K respectively. A polynomial fit to the temperature vs frequency after excluding the RFI is also shown in Fig. 2(right). The measured temperature (T_{meas}) and those obtained from polynomial fit (T_{fit}) are tabulated in Table 1. The measurements were repeated with dual polarized 'Kite' dipole placed at dipole 1 location. The results are shown in Fig. 3 (Left) and tabulated in Table 1. In Fig. 4, we compare the receiver temperature measured with the two types of dipole. The 'kite' dipole receiver temperature is about 3 to 5 K higher than that of 'fat' dipole at frequencies above 1360 MHz.

Measurements were also made by Roger to check whether any increase in receiver temperature is seen when the array is covered with Radome. The results of these measurements are shown in Fig. 3(Right). No increase in receiver temperature is seen when the dipole is covered with Radome.

3 Receiver temperature of 'Kite' dipole array

Two sets of hot/cold measurements were made on June 14, 2011 with the DAQ. The first set of measurements is limited to 6 frequencies (1300, 1400, 1500, 1640, 1700 and 1800 MHz). The second

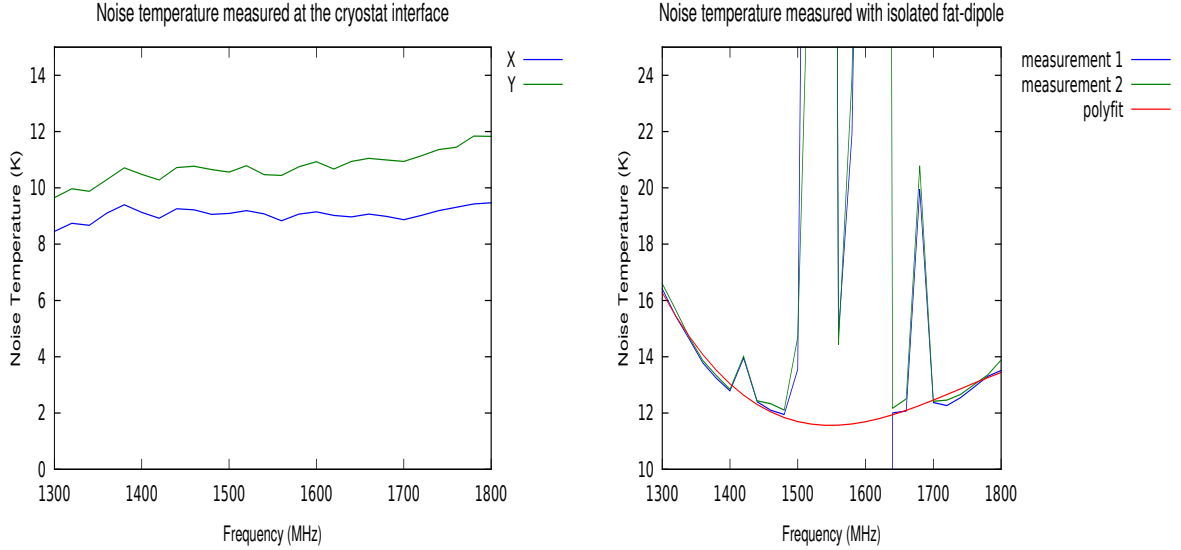


Figure 2: **Left** : Noise temperature measured at the cryostat interface vs frequency. The measurement was made at dipole 1 interface. **Right** : Receiver temperature measured with an isolated Fat dipole vs frequency. The red curve is a polynomial fit to the temperatures not affected by interference. These measurements were made by Roger.

set of measurements is taken for 49 frequencies (1040 to 1980 MHz in steps of 20 MHz and at 1000 MHz). During the first measurement the sky was covered with 'thick' rain cloud and during the second measurements the sky had cleared a bit but rain cloud were still present. Roger and Bob made another set of hot/cold measurements with power meter (0.6 MHz bandwidth) on June 15, 2011. These measurements are limited to a subset of dipoles. The hot and cold temperatures used for the calculation are 300 and 7.5 K respectively.

The estimated receiver temperature for different dipoles are shown in Fig. 5(Left). These values are obtained from the first set of measurements made with the DAQ. The mean and median temperature obtained from the 19 dipoles as a function of frequency are shown in Fig. 5(Right). The measurements near frequencies 1500 to 1620 MHz may be affected by RFI. If this is true, then the frequency range where the noise temperature is ≤ 30 K (median value) is 1380 to 1860 MHz (bandwidth 480 MHz). The receiver temperatures for the different dipoles with median temperature ≤ 30 K are shown in Fig. 6(Left).

We found ~ 3 K difference between the receiver temperatures obtained from Roger's measurement and those obtained from the second set of measurements made with the DAQ (see Fig. 6(Right)). This difference is presumably due to the presence of rain clouds during the DAQ measurements.

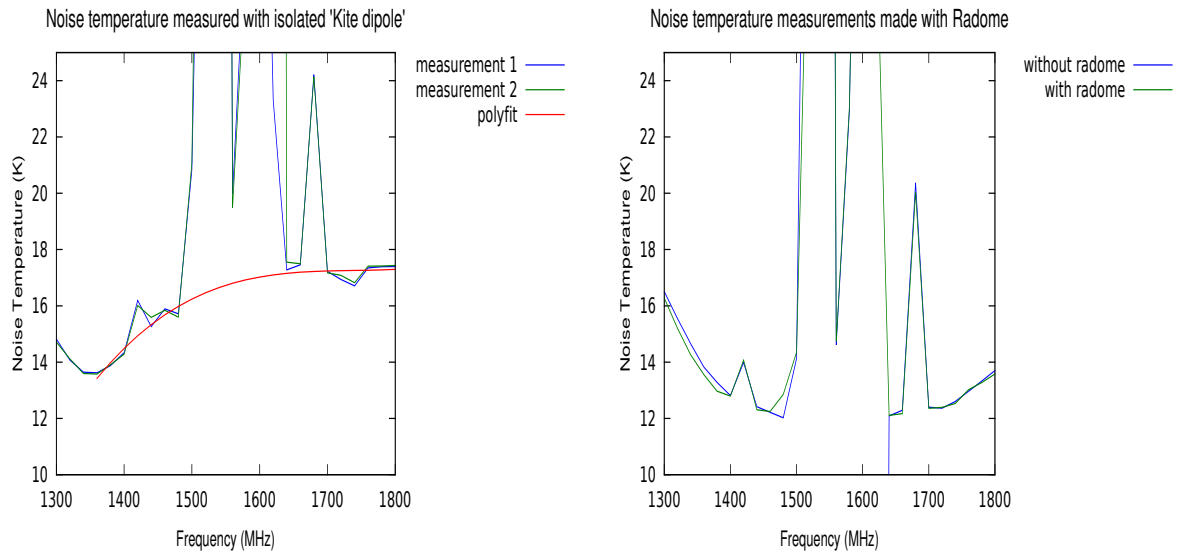


Figure 3: **Left :** Receiver temperature measured with an isolated 'Kite' dipole vs frequency. The dual polarized 'Kite' dipole was placed at dipole 1 location. The red curve is a polynomial fit to the temperatures above 1360 MHz. **Right:** Receiver temperature measurements made with Radome. Receiver temperatures with the fat-dipole at dipole 1 location and covering the array with the Radome are shown by green curve. These measurements are compared with receiver temperature obtained with the fat-dipole that is not covered with Radome (shown in blue). No increase in noise is seen when the dipole is covered with Radome. These measurements were made by Roger.

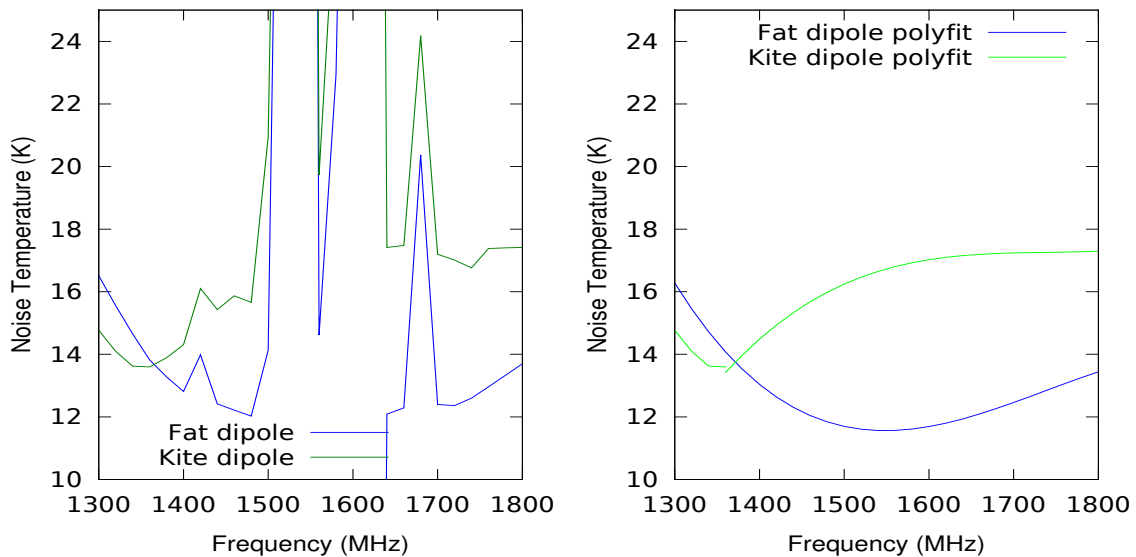


Figure 4: Comparing receiver temperature measured for isolated 'Fat' and 'Kite' dipoles. The mean of the two measurements made on each type of dipoles vs frequency are shown on the left. The polynomial fits to the temperatures in the RFI free frequencies are shown in the right figure. For frequencies above 1360 MHz the receiver temperature of isolated 'Kite' dipole is about 3 to 4K higher than that of 'Fat' dipole.

Table 1: Receiver temperature of isolated Fat and Kite dipoles

Freq (MHz)	Fat dipole		Kite dipole	
	T_{meas} (K)	T_{fit} (K)	T_{meas} (K)	T_{fit} (K)
1300.00	16.51	16.28	14.77	
1320.00	15.55	15.45	14.10	
1340.00	14.65	14.72	13.62	
1360.00	13.82	14.07	13.60	
1380.00	13.28	13.52	13.89	13.98
1400.00	12.81	13.04	14.31	14.49
1420.00	13.98	12.63	16.10	14.93
1440.00	12.42	12.30	15.43	15.33
1460.00	12.22	12.04	15.87	15.68
1480.00	12.02	11.84	15.66	15.98
1500.00	14.13	11.70	20.95	16.24
1520.00	50.37	11.61	51.19	16.46
1540.00	149.57	11.56	136.25	16.65
1560.00	14.62	11.57	19.73	16.80
1580.00	22.94	11.61	28.95	16.93
1600.00	48.66	11.69	43.00	17.02
1620.00	-64.64	11.80	115.10	17.10
1640.00	12.09	11.94	17.41	17.16
1660.00	12.29	12.09	17.48	17.19
1680.00	20.37	12.27	24.18	17.22
1700.00	12.40	12.46	17.20	17.24
1720.00	12.36	12.66	17.01	17.25
1740.00	12.60	12.86	16.76	17.26
1760.00	12.96	13.06	17.38	17.27
1780.00	13.33	13.25	17.40	17.28
1800.00	13.70	13.44	17.41	17.29

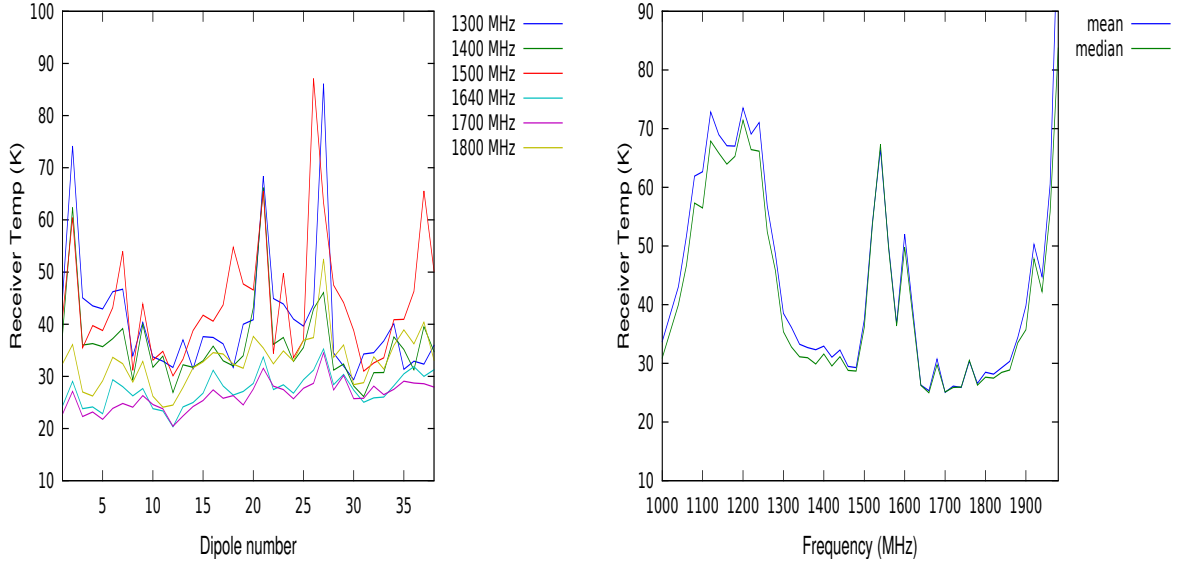


Figure 5: **Left** : Receiver temperature of cryogenic 'Kite' dipole array for different dipoles. These values are obtain from the first set of measurements made with the DAQ (see text). Dipole number 1 to 19 corresponds to the X polarization and 20 to 38 corresponds to the Y polarization. Measurements made for 8Y may not be reliable due to problem in the corresponding receiver channel. **Right** : Mean and median receiver temperatures of the 19 dipoles and both polarization vs frequency. The frequency range 1500 to 1620 MHz may be affected by RFI. The noise temperature is ≤ 30 K in the frequency range 1380 to 1860 MHz. These values are obtained from second set of measurements made with the DAQ.

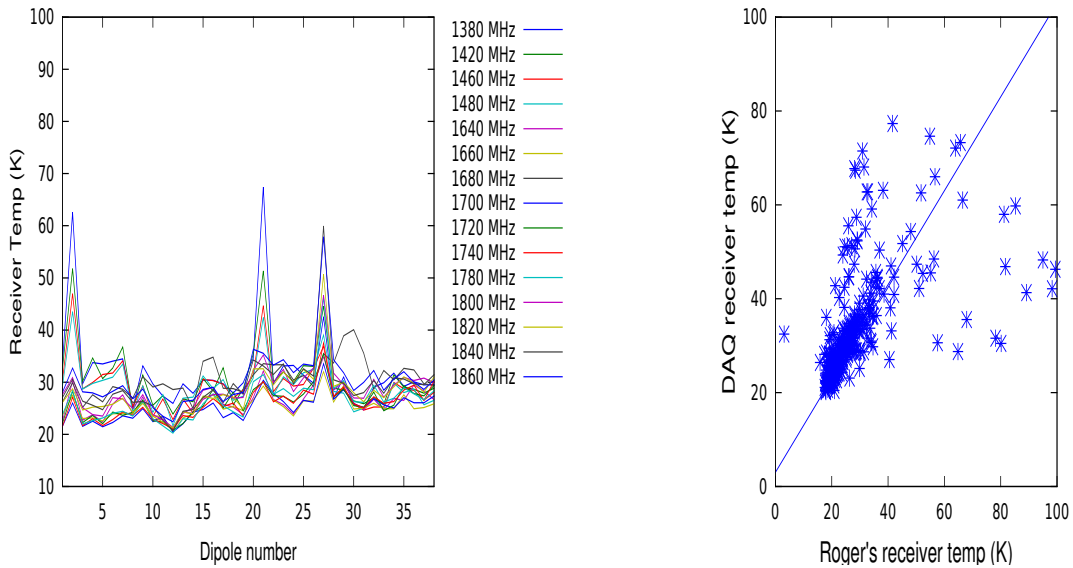


Figure 6: **Left** : Receiver temperature vs dipole number for those frequencies with median temperature ≤ 30 K. Dipole number 1 to 19 corresponds to the X polarization and 20 to 38 corresponds to the Y polarization. **Right** : Comparison of receiver temperature measured with the DAQ and those measured by Roger. DAQ temperature values are about 3 K higher than Roger's values presumably because of rain clouds during the DAQ measurements.