Ghana System Temperature Report

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1 Introduction

This document outlines measurements made at the Nkutunse 32-m antenna over the period of 12-23 May 2015. The measurements were attempts to measure the system temperature of the receiver, and to understand the effect of the beam waveguide configuration better.

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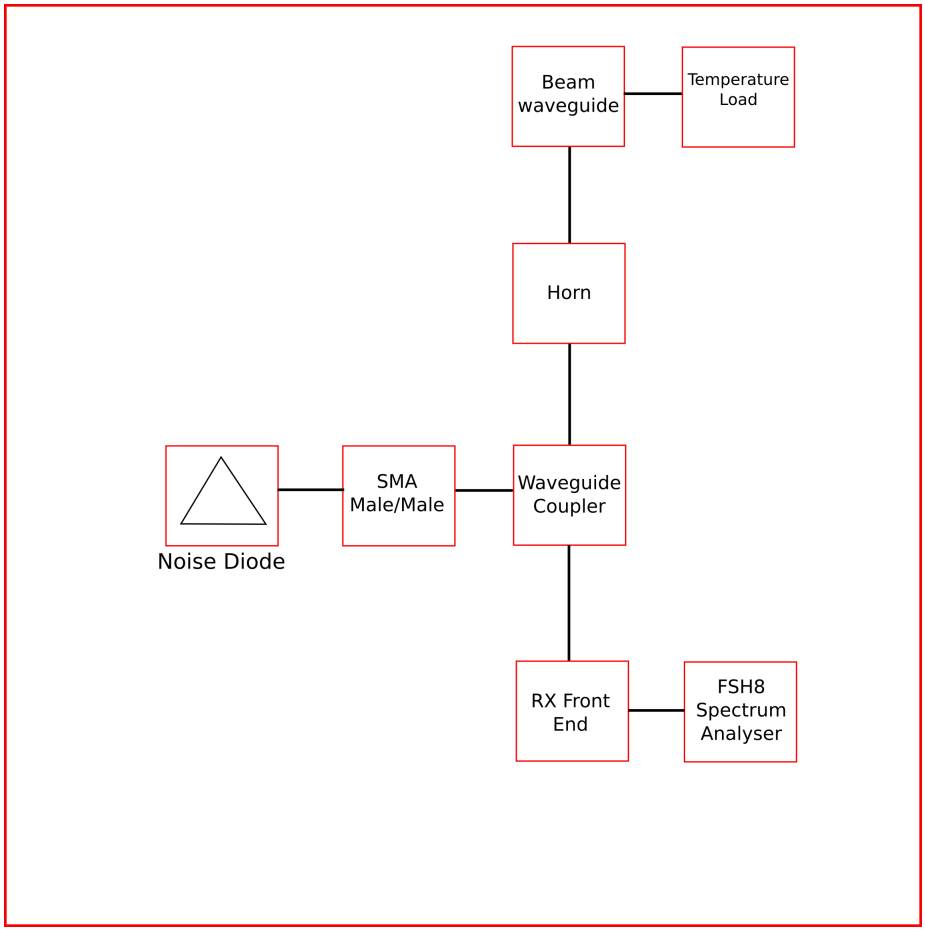


Figure 1: Block diagram of the receiver and ancillary parts

2 Measurement Techniques

- Noise diode injection
- Hot load on the beam waveguide aperture
- Hot load on the horn aperture

For noise diode injection, we estimate T_{sys} as follows:

$$\begin{aligned} Y &= P_{Ndon}/P_{ndoff} && (1)\\ &= (T_{sys}+T_{nd})/T_{sys} && (2)\\ T_{sys} &= T_{nd}/(Y-1) && (3) \end{aligned}$$

For the hot load measurements, we estimate T_{sys} as follows::

$$\begin{aligned} Y &= P_{hot}/P_{cold} && (4)\\ &= (T_{sys}+T_{hot})/(T_{sys}+T_{cold}) && (5)\\ T_{sys} &= (T_{hot}-YT_{cold})/(Y-1) && (6) \end{aligned}$$

The difference between the two, is that the noise injection is added to the receiver signal, *without changing the receiver signal in any way.* For the hot load measurement, we change the signal, since we present two different temperature loads at the input.

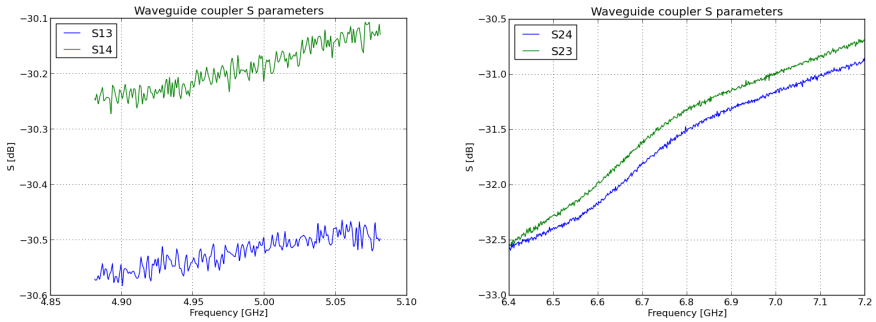
A caveat on the noise diode measurement (not shown in the uncertainties presented here) is that the effective temperature of the noise diode (i.e. the temperature after passing through the SMA connector and waveguide coupler) is estimated by S parameters measured for each component independently. This assumes that the effect is additive, and that no changes to the S parameters occur when the component responses are combined.

3 Noise Diode Calibration

The noise diode is injected into the signal chain directly in front of the LNAs. This is done by coupling the LNA directly onto a waveguide coupler using SMA(male)-SMA(male) connectors. The waveguide coupler has a coupling constant of approximately 30 dB. The actual coupling constant and SMA(male)-SMA(male) connector insertion loss as a function of frequency was measured, and is given in Figure 2 and Figure 3 respectively. The appropriate coupling path used for each of the frequency bands is given in Table 1.

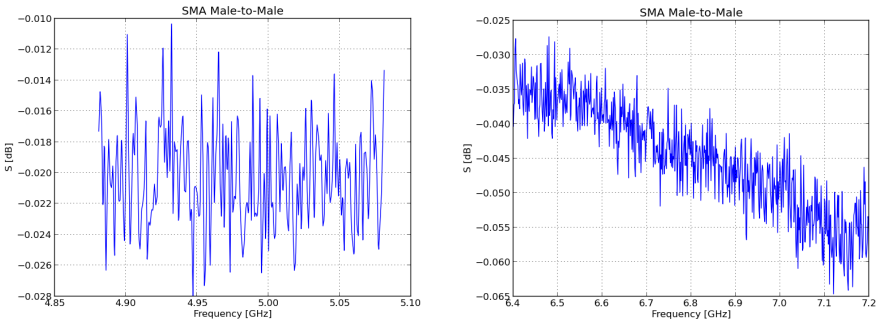
5.0 GHz	6.7 GHz
S13	S24

Table 1: S parameter appropriate to the two noise injection paths used on the Ghana Rx.



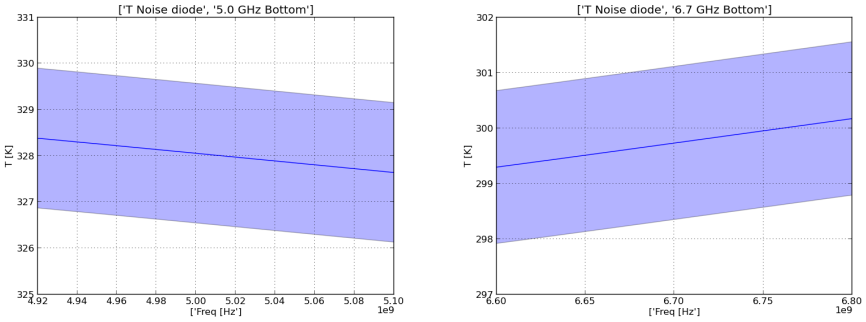
(a) 5.0 GHz Noise diode coupler (b) 6.7 GHz Noise diode coupler

Figure 2: S parameters of the waveguide coupler in the two bands.



(a) SMA male-male connector insertion loss at 5.0 GHz. (b) SMA male-male connector insertion loss at 6.7 GHz.

Figure 3: S12 parameter of SMA male in the two bands.

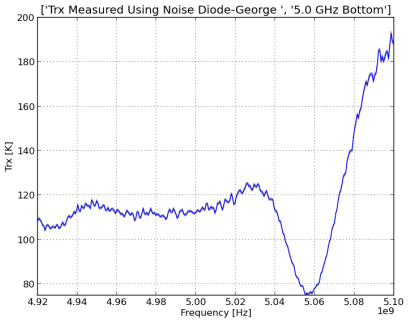


(a) 5.0 GHz T_{ND}

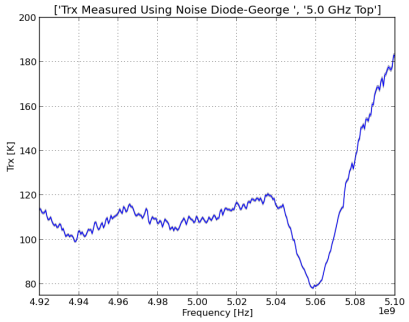
(b) 6.7 GHz T_{ND}

Figure 4: Expected injected T_{ND} for the two RF channels. Very conservative uncertainty estimates used, assuming cascaded worst/best case insertion loss of all in-series components.

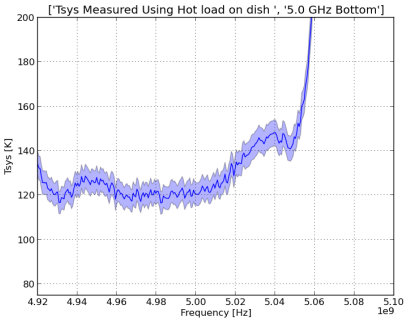
4 Measured System temperatures



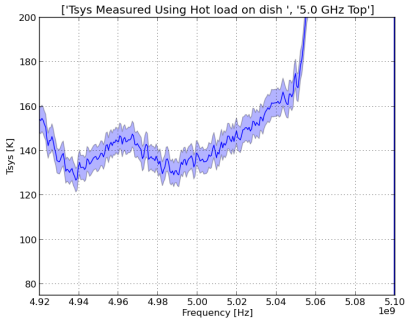
(a) 5 GHz band T_{sys} calculated using noise diode for bottom output. See Equation 3.



(b) 5 GHz band T_{sys} calculated using noise diode for top output. See Equation 3.

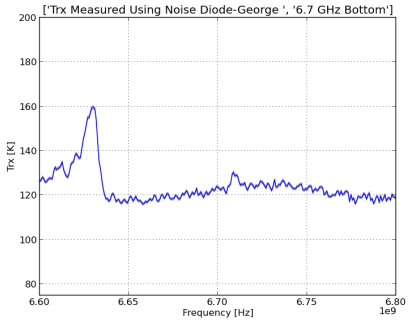


(c) 5 GHz band T_{sys} calculated using hot load for bottom output. See Equation 6.

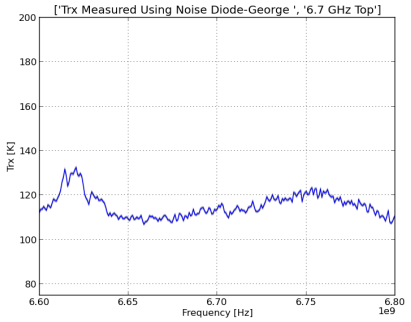


(d) 5 GHz band T_{sys} calculated using hot load for top output. See Equation 6.

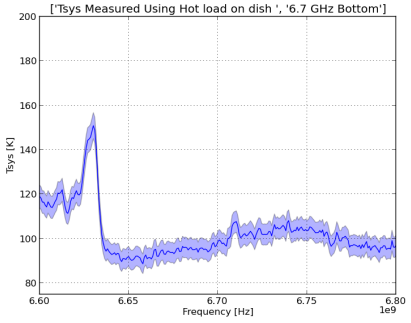
Figure 5: T_{sys} at 5.0GHz band. Temperature uncertainty estimated at 309±5 K for the hot load (measured using infra-red thermometer) and 12.7±2K for the cold sky. This includes beam waveguide.



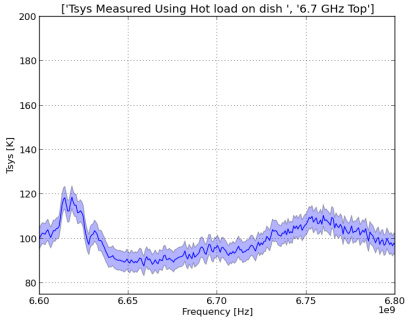
(a) 6.7 GHz band T_{sys} calculated using noise diode for bottom output. See Equation 3.



(b) 6.7 GHz band T_{sys} calculated using noise diode for top output. See Equation 3.



(c) 6.7 GHz band T_{sys} calculated using hot load for bottom output. See Equation 6.



(d) 6.7 GHz band T_{sys} calculated using hot load for top output. See Equation 6.

Figure 6: T_{sys} at 6.7GHz band. Temperature uncertainty estimated at 309±5 K for the hot load (measured using infra-red thermometer) and 12.7±2K for the cold sky. This includes beam waveguide.