Determination of the noise temperature of a 2.3 GHz radio astronomy receiver system and noise diode

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Abstract

This paper discusses the discovery of a radio astronomy receiver's system temperature.

1 Introduction

By attaching two identical resistors at distinct temperatures to the input of the system, the temperature inherent in the system can be derived since the inherent system temperature is present in both circumstances.

2 Theory

Noise temperature is defined as the temperature to which a standard resistor would have to be heated in order to generate the ascribed amount of Johnson noise.

We use the Y-factor method to divulge the system temperature (Jonas, 2005).

$$Y = \frac{X_{hot}}{X_{cold}} \tag{1}$$

$$\therefore Y = \frac{T_N + T_{hot}}{T_N + T_{cold}} \tag{2}$$

$$\therefore T_N = \frac{T_{hot} - YT_{cold}}{Y - 1} \tag{3}$$

$$\sigma^2_{T_N} = \sigma^2_{T_{hot}}(\frac{dT_N}{dT_{hot}})^2 + \sigma^2_{T_{cold}}(\frac{dT_N}{dT_{cold}})^2 + \sigma^2_Y(\frac{dT_N}{dY})^2 \tag{4}$$

Equation 4 indicates the uncertainty associated with the calculated Y-value.

3 Procedure

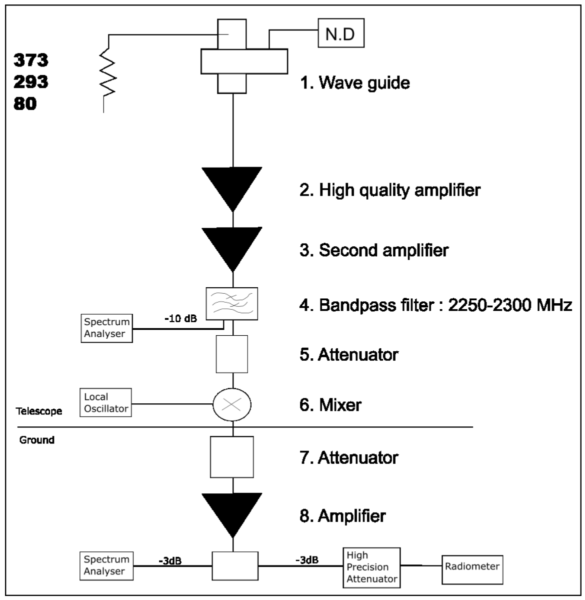

Figure 1: Radio astronomy receiver

A high precision attenuator is inserted in the receiver just before the radiometer, as shown in figure 1.

This attenuator is initially set to zero.

The resistor attached at the top of the radio receiver is cooled to 80 $\pm$ 1 K by placing it in a polystyrene container and surrounding it with liquid helium.

The value on the radiometer is read off.

An identical, but distinct, resistor encapsulated in heating windings is heated to 373 $\pm$ 1 K.

The cold resistor is disconnected and the heated resistor is connected in its place, as input into the receiver system.

The value on the radiometer is read off.

The attenuator is then adjusted so that the value on the radiometer is identical to that attained with the previous resistor.

The value on the attenuator is then read off, yielding the Y factor required by the theory. A rough Y can also be attained by taking the ratio of the hot reading over the cold reading.

These measurements are then repeated with the noise diode show in 1 turned on.

Equation 3 was used to calculate the system temperature and equation 4 was used to calculate its uncertainty.

4 Results

	measured	uncertainty		measured	uncertainty			calculated	uncertainty			
Cold temp	0.1	0.001	Y factor	4.43	0.02	dB					dTn	don
Hot temp	0.303	0.001		2.77332	0.0127716		Tn	85.22679647	3.3937229	K	dTh	0.317999
			Rough Y	3.03	0.0403			64.33497537			dTc	2.445827
											dY	8681.338
heated	373	1	K									
normal	293	1	K	B	50000000	hz						
cooled	80	2	K	k	1.381E-23	J/K						

Figure 2: Table of results for system temperature

	measured	uncertainty		measured	uncertainty			calculated	uncertainty			
Cold temp	0.315	0.001	Y factor	1.96	0.02	dB		don			dTn	don
Hot temp	0.536	0.001		1.570363	0.0072318		Tn	433.7081131	8.7075218	K	dTh	3.073956
			Rough Y	1.701587	0.0085765			337.6244344			dTc	7.580496
											dY	811204.7
heated	373	1	K									
normal	293	1	K	B	50000000	hz						
cooled	80	2	K	k	1.381E-23	J/K						

Figure 3: Table of results for diode temperature

temperature	calculated	uncertainty	units
T_N	85.2	3.4	K
T_{diode}	348	12	K

Table 1: Table of noise temperatures

5 Conclusion

We have acquired an accurate estimate of the system temperature of the radio receiver, and the noise diode, through a simple, convenient experimental procedure.

References

Jonas, J. (2005), *Radio Astronomy Honours Course*, Rhodes University Department of Physics & Electronics.