Calculation of the signal levels in a 2.3 GHz radio astronomy receiver

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Abstract

This paper discusses the calculation of theoretical values for the signal levels throughout the the radio astronomy receiver.

1 Introduction

It is important to know the contributions of the different stages in the radio astronomy receiver. At every stage in the receiver the noise contributions can be calculated and the signal strength up to that point can be found.

2 Theory

In order to find the noise temperature contribution offered by an impedance we use the following equation from Jonas (2005) :

$$T_N = \frac{1 - G}{G} T_P \tag{1}$$

Where T_N refers to the noise temperature and T_P refers to the ambient temperature

We define our temperatures as :

ambient	293	K
hot	373	K
cold	80	K

Table 1: Approximate temperatures

The output of a stage is equal to the noise introduced at that point summed with the noise from the output from the prior stage, and then multiplied by the gain of the current stage.

$$
\begin{aligned}
T_{out} &= (T_{in-1} + T_N) \times Gain & (2) \\
w &= k \times B \times T_{out} & (3)
\end{aligned}
$$

Power is related to this total noise temperature by equation 3, where k is Boltzmann's constant and B is the bandwidth of the noise.

3   Procedure

Most of the figures were given. The remaining noise temperatures were calculated within Excel using equation 1. The total signal at each point is calculated using equation 2 and subsequently equation 3. Since the first 3 stages have unlimited bandwidth the total work is undefined at these stages.
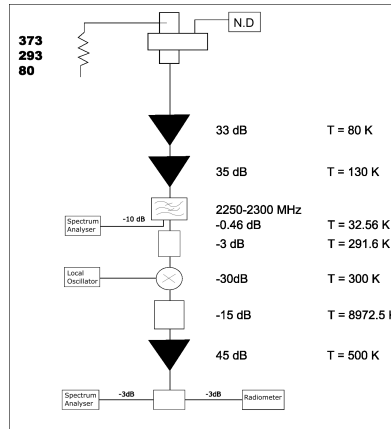
4   Results

Figure 1: Temperatures & gains throughout a radio astronomy receiver

heated		contrib	dB		linear	total	w [watts]	w [dbm]
Tn	0	373	0		1	3.73E+02		
	1	80	33		1995.262	9.04E+05		
	2	130	35		3162.278	2.86E+09		
	3	32.55556	-0.457574906		0.9	2.57E+09	1.78E-06	-2.75E+01
	4	291.6119	-3		0.501187	1.29E+09	8.90E-07	-3.05E+01
	5	300	-30		0.001	1.29E+06	8.90E-10	-6.05E+01
	6	8972.474	-15		0.031623	4.11E+04	2.83E-11	-7.55E+01
	7	500	45		31622.78	1.31E+09	9.07E-07	-3.04E+01

normal		contrib	dB		linear	total	w [watts]	w [dbm]
Tn	0	293	0		1	2.93E+02		
	1	80	33		1995.262	7.44E+05		
	2	130	35		3162.278	2.35E+09		
	3	32.55556	-0.457574906		0.9	2.12E+09	1.46E-06	-2.83E+01
	4	291.6119	-3		0.501187	1.06E+09	7.33E-07	-3.13E+01
	5	300	-30		0.001	1.06E+06	7.33E-10	-6.13E+01
	6	8972.474	-15		0.031623	3.39E+04	2.34E-11	-7.63E+01
	7	500	45		31622.78	1.09E+09	7.50E-07	-3.12E+01

cooled		contrib	dB		linear	total	w [watts]	w [dbm]
Tn	0	80	0		1	8.00E+01		
	1	80	33		1995.262	3.19E+05		
	2	130	35		3162.278	1.01E+09		
	3	32.55556	-0.457574906		0.9	9.09E+08	6.27E-07	-3.20E+01
	4	291.6119	-3		0.501187	4.56E+08	3.14E-07	-3.50E+01
	5	300	-30		0.001	4.56E+05	3.14E-10	-6.50E+01
	6	8972.474	-15		0.031623	1.47E+04	1.01E-11	-7.99E+01
	7	500	45		31622.78	4.80E+08	3.32E-07	-3.48E+01

Figure 2: Excel table showing the power of the signal at stages throughout a radio astronomy receiver

5 Conclusion

The power signals are relatively weak when considered in watts. An interesting point is that for low signals, the attenuators can actually behave as amplifiers as they introduce more noise then the original signal possessed.

References

Jonas, J. (2005), *Radio Telescopes and Instrumentation*, Rhodes University Department of Physics & Electronics.