Callisto calibration

$$V = a + b \cdot \log(c)$$

General equation describing logarithmic detector, where

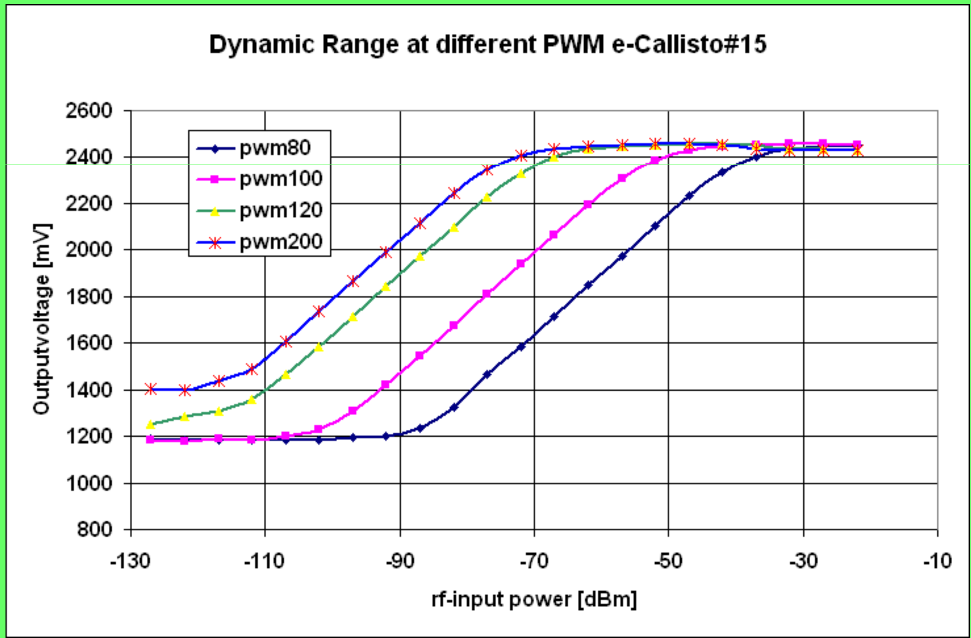
V = output voltage of the instrument -> FIT-file

a = offset voltage of the instrument

b = detector konversion constant (mV/dB)

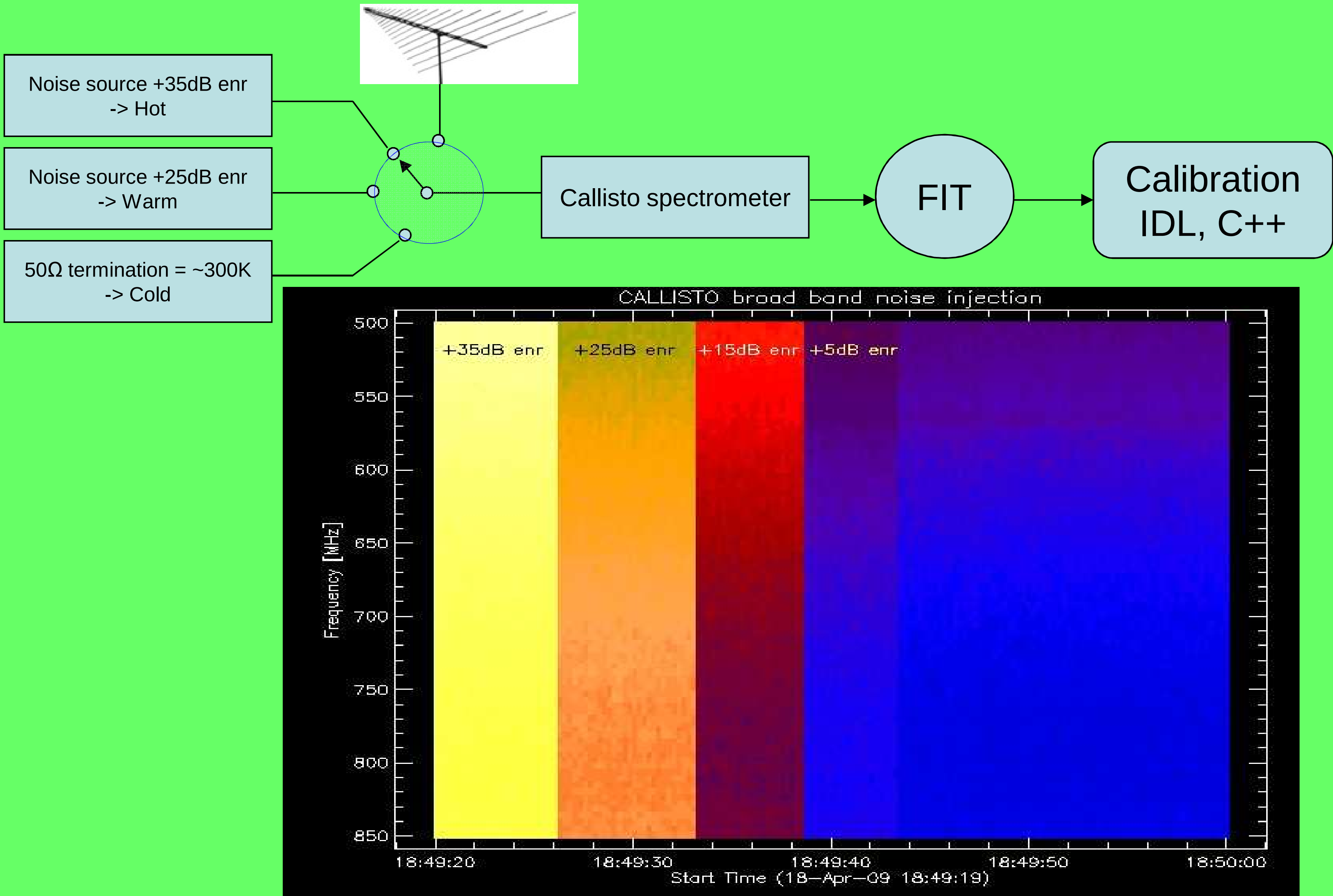
c = system temperature, where c = Trx+Ta = Trx + S*Aeff/(2*k) where Aeff=(G*λ^2)/(4*π)

$$c = 10^{\frac{(V-a)}{b}}$$

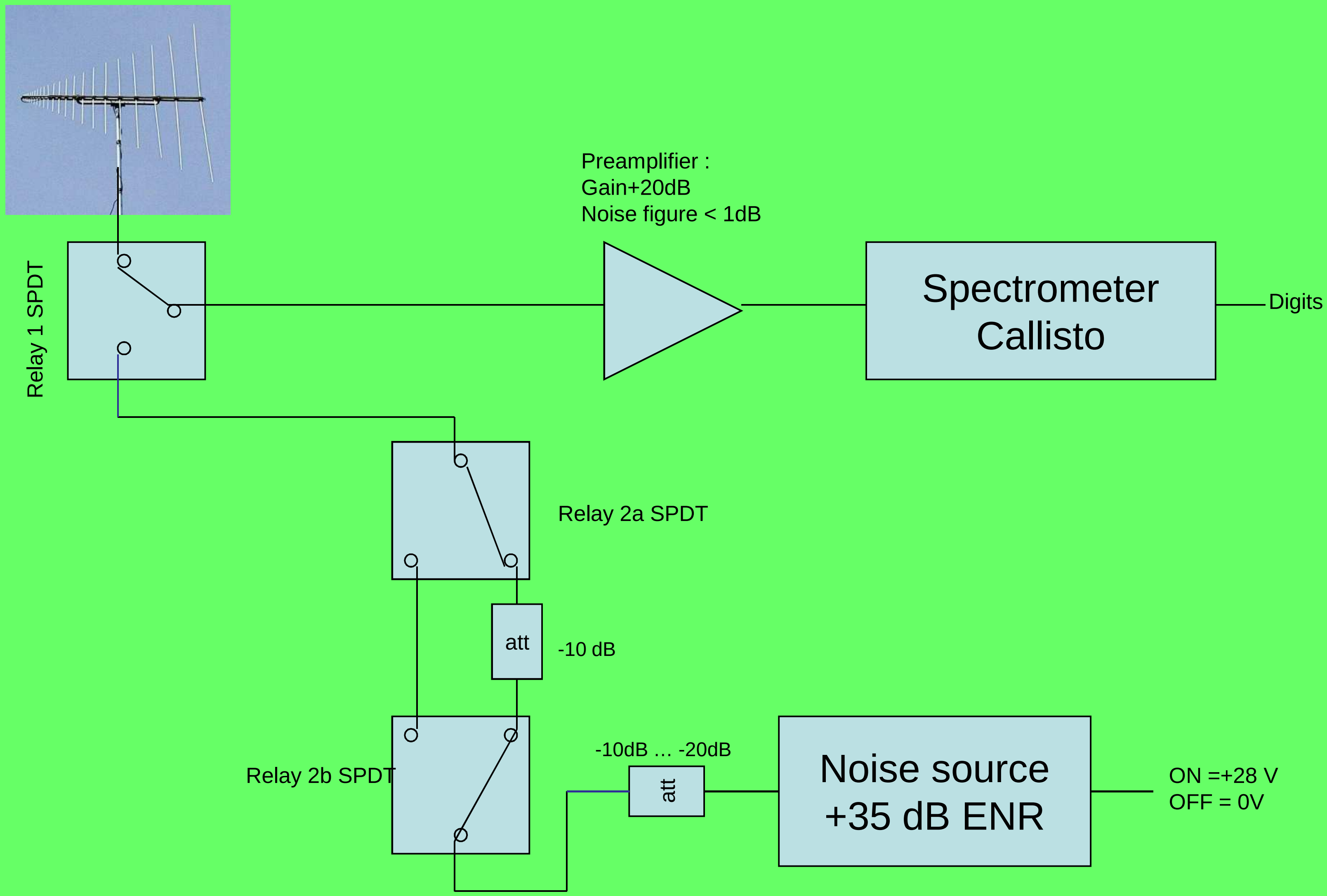


This equation above describes the function of the logarithmic detector.
To solve this equation, we need in principle 3 independent measurements

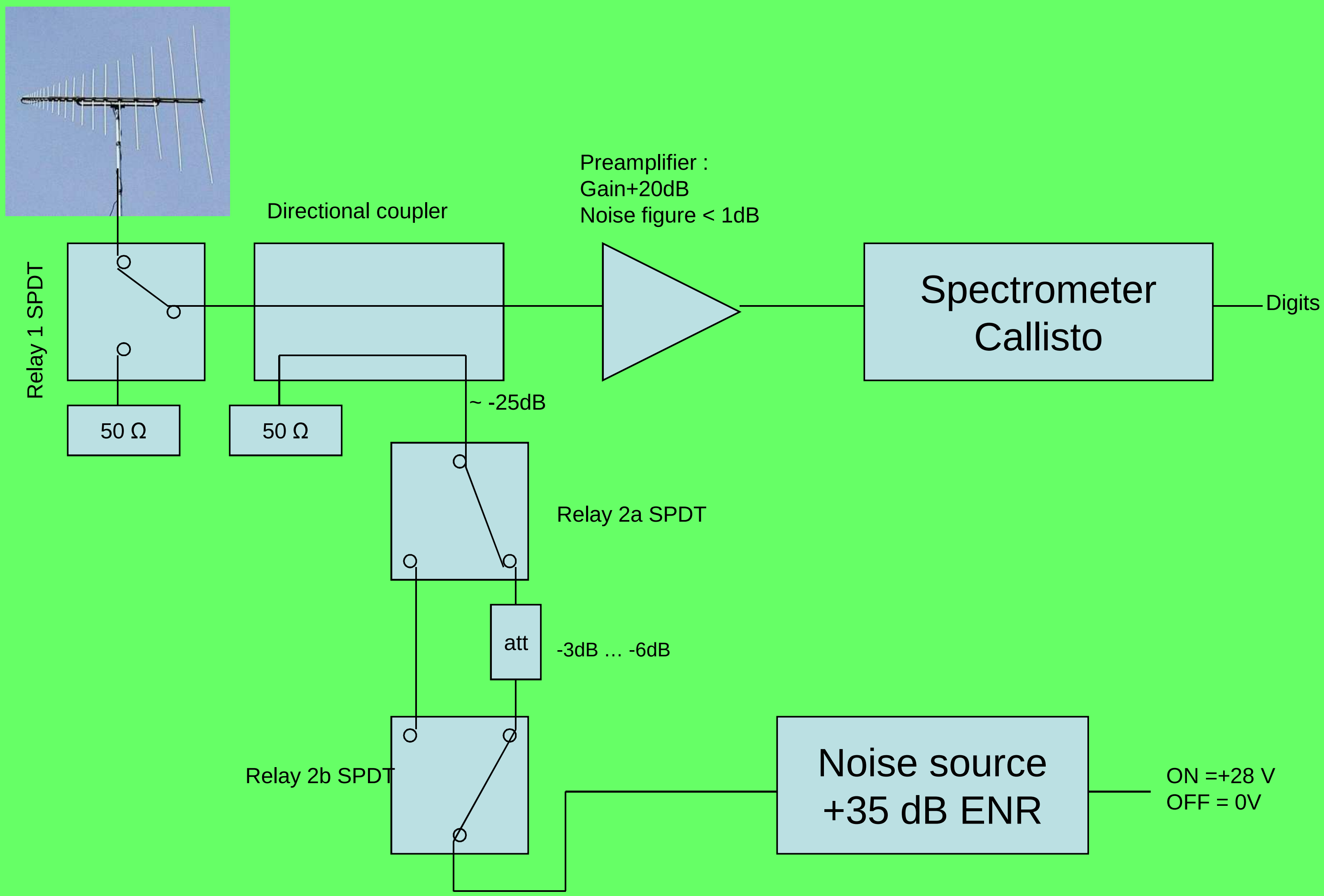
Callisto calibration steps



Calibration unit with Relays



Calibration unit with directional coupler



Callisto calibration

Given

$$\mathbf{Vcold} = \mathbf{Vo} + \mathbf{b} \cdot \mathbf{log}(\mathbf{Trx} + \mathbf{Tcold})$$

50 ohm termination = 300 K

$$\mathbf{Vwarm} = \mathbf{Vo} + \mathbf{b} \cdot \mathbf{log}(\mathbf{Trx} + \mathbf{Twarm})$$

Noise source 10% = 25 dB enr = 94'868 K

$$\mathbf{Vhot} = \mathbf{Vo} + \mathbf{b} \cdot \mathbf{log}(\mathbf{Trx} + \mathbf{Thot})$$

Noise source 100% = 35 dB enr = 948'683 K

Known: Vcold, Vwarm, Vhot, Tcold, Twarm and Thot
Unknown: Vo, b and Trx

This set of non-linear equations cannot be solved mathematically correct, it can only be solved numerically

But since Trx ~ Tcold << Twarm < Thot, the set of equations can be simplified. This simplification leads to a set which can be solved straight forward.

Callisto calibration

Given

$$\mathbf{Vcold} = \mathbf{Vo} + \mathbf{b}\cdot\log(\mathbf{Trx} + \mathbf{Tcold})$$

50 ohm termination = 300 K

$$\mathbf{Vwarm} = \mathbf{Vo} + \mathbf{b}\cdot\log(\mathbf{Twarm})$$

Noise source 10% = 25 dB enr = 94'868 K

$$\mathbf{Vhot} = \mathbf{Vo} + \mathbf{b}\cdot\log(\mathbf{Thot})$$

Noise source 100% = 35 dB enr = 948'683 K

$$\mathbf{Find}(\mathbf{Vo},\mathbf{b},\mathbf{Trx}) \rightarrow \begin{bmatrix} \dfrac{(-\mathbf{Vwarm}\,\ln(\mathbf{Thot}) + \ln(\mathbf{Twarm})\cdot\mathbf{Vhot})}{(-\ln(\mathbf{Thot}) + \ln(\mathbf{Twarm}))} \\ \ln(10)\cdot\dfrac{(-\mathbf{Vhot} + \mathbf{Vwarm})}{(-\ln(\mathbf{Thot}) + \ln(\mathbf{Twarm}))} \\ \exp\left[\dfrac{-(\mathbf{Vcold}\cdot\ln(\mathbf{Thot}) - \mathbf{Vcold}\cdot\ln(\mathbf{Twarm}) - \mathbf{Vwarm}\,\ln(\mathbf{Thot}) + \ln(\mathbf{Twarm})\cdot\mathbf{Vhot})}{(-\mathbf{Vhot} + \mathbf{Vwarm})}\right] - \mathbf{Tcold} \end{bmatrix}$$

Callisto calibration

Final equation for calibration:

$$S_\lambda = \frac{2 \cdot k}{\lambda^2} \cdot \frac{4 \cdot \pi}{G_\lambda} \cdot \left[10^{\frac{(V_\lambda - Vo_\lambda)}{b_\lambda}} K - Trx_\lambda \right]$$

Still without taking into consideration second order effects like:
- Side lobes
- Spill over
- Cable loss (antenna – switch)
- Noise temperature enhancement by physical temperature of cables (antenna – switch)

To improve, do the same on the cold sky and take the difference S = S(sun) – S(sky)

k = Boltzmann constant
K = 1 Kelvin
λ = wavelength = c/f [m]
G = antenna gain
Trx = receiver noise temperature [K]

V = voltage at one frequency on the sky
Vo = offset voltage at the same frequency (a)
b = detector coefficient at the same frequency
S = radio flux of sky/sun at the same frequency [sfu]

Callisto calibration

Example for a calibration file CAL00800.prn:

#,	MHz,	a,	b,	kf,	Tb
0,	870.000,	38.759,	23.167,	0.0039,	1615.1
1,	868.000,	36.265,	23.653,	0.0037,	1768.6
2,	866.375,	38.759,	23.167,	0.0039,	1615.1
3,	861.375,	34.613,	24.170,	0.0044,	1764.5
4,	856.688,	32.961,	24.686,	0.0046,	1760.5
5,	852.625,	34.627,	24.652,	0.0053,	1522.2
6,	848.875,	32.821,	25.303,	0.0056,	1485.9
…					
195,	112.438,	27.912,	24.799,	-0.0018,	3581.1
196,	111.563,	28.722,	24.253,	-0.0012,	3629.7
197,	111.500,	27.636,	24.263,	-0.0007,	5313.3
198,	110.750,	28.076,	24.176,	-0.0001,	18289.2
199,	110.000,	33.005,	23.703,	0.0006,	2895.7