NATIONAL RADIO ASTRONOMY OBSERVATORY

ELECTRONICS DIVISION TECHNICAL NOTE NO. 106

TITLE: NOISE MEASUREMENT METHODS FOR 140-FT CASSEGRAIN RECEIVERS

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DATE: JANUARY 21, 1982

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NOISE MEASUREMENT METHODS FOR 140-FT CASSEGRAIN RECEIVERS

Charles J. Brockway

Users of the 140-ft Cassegrain system frequently ask how the noise calibration value and receiver temperature are determined. The purpose of this memo is to give the equations used to calculate the calibration signal, receiver noise temperature and system noise temperature, and to describe the measurements method.

Particular attention is given to the general, or non-ideal, case where feed system loss and input reflection are not zero. It will be shown that the measurements method takes the effects of these into account.

The natural boundary between telescope and receiver is the feed aperture. For this reason, the receiver and system noise temperature and calibration value are specified at that point.

1. Method of Measurements

Consider the following feed and input model for the upconverter-maser receiver:

T_R

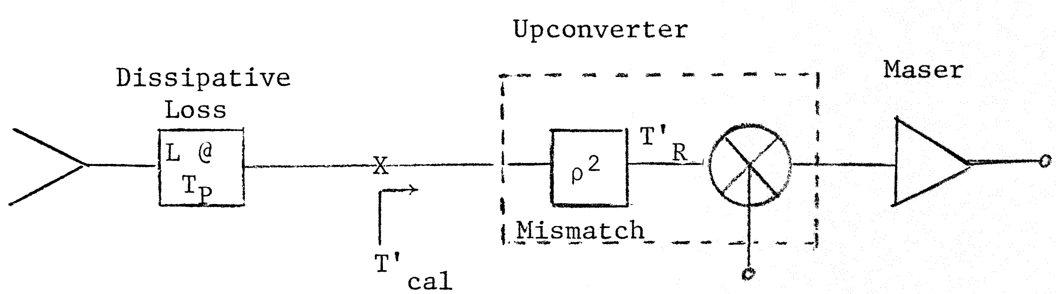
T_A

T_L

T_{sys}

T_{cal}

at feed aperture



T_R = Receiver noise temperature at feed aperture.

T'_R = Receiver noise temperature at upconverter input for $\rho = 0$. Note T'_R inaccessible for direct measurement for $\rho \neq 0$.

T_{cal} = Cal noise temperature at feed aperture.

T'_{cal} = Cal noise temperature at point of injection.

T_A = Noise (including source, T_S) entering feed.

T_L = Hot (T_H) and cold (T_C) absorber loads placed over feed aperture during measurements.

T_{sys} = System noise temperature = $T_R + T_A$.

ρ^2 = Power reflected at upconverter input (ρ = reflection coefficient).

L, T_p = Dissipative loss at physical temperature, T_p, between feed aperture and point of cal injection, X; X is also break point for connection of thermal calibrator.

Assume no feed mismatch and absorbers are perfect, i.e., no multiple reflections. Assume no gain changes.

The equations used to calculate T_R, T_{cal} and T_{sys} are standard. First the Y factor is measured as Y_m, then T_R is calculated from:

$$T_{R_c} = \frac{T_H - Y_m T_C}{Y_m - 1} \tag{1}$$

The ratio of receiver powers with cal on and off is measured as $\left(\frac{P_{on}}{P_{off}}\right)_{m1}$, then T_{cal} is calculated from:

$$T_{cal_c} = \left[\left(\frac{P_{on}}{P_{off}}\right)_{m1} - 1\right]\left[T_{R_c} + T_L\right] \tag{2}$$

T_L can be hot or cold load. Usually, one then the other is used to check for system linearity.

T_{sys} is determined by allowing the feed to look at cold sky and <u>measuring</u> the ratio of receiver powers with cal on and cal off as $\left(P_{on}/P_{off}\right)_{ma}$; then T_{sys} is <u>calculated</u> from:

$$T_{sys_c} = \frac{T_{cal_c}}{\left(\frac{P_{on}}{P_{off}}\right)_{ma} - 1} \qquad (3)$$

For the ideal case, where $L = 1$, $\rho = 0$:

a) $$Y_m = \frac{T_H + T'_R}{T_C + T'_R}$$

Equation (1) becomes:

$$T_{R_c} = T_R = T'_R$$

b) $$\left(\frac{P_{on}}{P_{off}}\right)_{ml} = \frac{T'_R + T_L + T'_{cal}}{T'_R + T_L}$$

Equation (2) becomes:

$$T_{cal_c} = T_{cal} = T'_{cal}$$

c) $$\left(\frac{P_{on}}{P_{off}}\right)_{ma} = \frac{T'_R + T_A + T'_{cal}}{T'_R + T_A}$$

Equation (3) becomes:

$$T_{sys_c} = T_A + T'_R = T_A + T_R$$

2. <u>$L > 1, \quad \rho = 0$</u>

a) $$Y_m = \frac{T'_R + (1 - 1/L)\, T_p + T_H/L}{T'_R + (1 - 1/L)\, T_p + T_C/L} = \frac{LT'_R + (L - 1)\, T_p + T_H}{LT'_R + (L - 1)\, T_p + T_C}$$

$$= \frac{T_R + T_H}{T_R + T_C}$$

Equation (1) becomes:

$$T_{R_c} = LT'_R + (L - 1)\, T_p = T_R$$

= True receiver noise temperature at feed aperture.

There is an excess noise, ΔT_R (due to L) of value:

$$\Delta T_R(L) = (L - 1)\, (T_p + T'_R)$$

b) $$\left(\frac{P_{on}}{P_{off}}\right)_{ml} = \frac{T'_R + (1 - 1/L)\, T_p + T_L/L + T'_{cal}}{T'_R + (1 - 1/L)\, T_p + T_L/L}$$

Equation (2) becomes:

$$T_{cal_c} = LT'_{cal} = T_{cal}$$

c) $$\left(\frac{P_{on}}{P_{off}}\right)_{ma} = \frac{T'_R + (1 - 1/L)\, T_p + T_A/L + T'_{cal}}{T'_R + (1 - 1/L)\, T_p + T_A/L}$$

Equation (3) becomes:

$$T_{sys_c} = T_A + LT'_R + (L - 1)\, T_p = T_A + T_R$$

= True system noise temperature at feed aperture.

3. <u>$L = 1, \rho > 0$</u>

a) $$Y_m = \frac{(1 - \rho^2)\, T_H + T'_R}{(1 - \rho^2)\, T_C + T'_R}$$

Equation (1) becomes:

$$T_{R_c} = \frac{1}{1 - \rho^2}\, T'_R = T_R$$

= true receiver noise temperature at feed aperture.

There is an excess noise, ΔT_R (due to ρ) of value:

$$\Delta T_R(\rho) = \frac{\rho^2}{1 - \rho^2}\, T'_R$$

b) $$\left(\frac{P_{on}}{P_{off}}\right)_{ml} = \frac{T'_R + (1 - \rho^2)\, T_L + (1 - \rho^2)\, T'_{cal}}{T'_R + (1 - \rho^2)\, T_L}$$

Equation (2) becomes:

$$T_{cal_c} = T'_{cal} = T_{cal}$$

c) $$\left(\frac{P_{on}}{P_{off}}\right)_{ma} = \frac{T'_R + (1 - \rho^2)\, T_A + (1 - \rho^2)\, T'_{cal}}{T'_R + (1 - \rho^2)\, T_A}$$

Equation (3) becomes:

$$T_{sys_c} = T_A + \frac{1}{1 - \rho^2}\, T'_R = T_A + T_R$$

= true system noise temperature at feed aperture.

It is seen that the calculated cal value is independent of ρ.