Interoffice

NATIONAL RADIO ASTRONOMY OBSERVATORY

TUCSON, ARIZONA

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To: 36-Foot Observers

From: B. L. Ulich

Subject: Spectral line calibration with Cassegrain receivers

The corrected antenna temperature T_A^* of a spectral line is equal to

$$T_A^* = \frac{\Delta T_{source}}{\Delta T_{Cal}} T_C \qquad (1)$$

The equivalent calibration temperature T_C is different in the Cassegrain configuration than at prime focus. This is because the antenna couples to the sky differently than to the source. In particular the spillover is directed toward the sky rather than mainly toward the ground. Taking this into consideration, the calibration temperature T_C is

$$\begin{aligned} T_C \simeq\ & (1 + G_i/G_s) \left(\frac{\eta_{sky}}{\eta_{source}}\right) [J(T_M) - J(T_{bg})] \\ & + (1 + G_i/G_s) \left(\frac{\eta_{sky}}{\eta_{source}}\right) (e^{\tau sA}) [J(T_{sbr}) - J(T_M)] \\ & + (G_i/G_s) \left(\frac{\eta_{sky}}{\eta_{source}}\right) (e^{(\tau s - \tau i) A} - 1) [J(T_M) - J(T_{bg})] \\ & + (1 + G_i/G_s) (e^{\tau sA}/\eta_{source}) [J(T_{amb}) - J(T_{sbr})] \end{aligned} \qquad (2)$$

where $$J(T) = \frac{\frac{h\nu}{k}}{e^{\frac{h\nu}{kt}} - 1} \qquad (3)$$

A = air mass

For the NRAO 36-foot telescope I have calculated (and measured) the following losses:

	Prime Focus	Cassegrain
Ohmic Loss Efficiency	0.99	0.99
Edge Diffraction Efficiency	1.00	0.97
Blockage Efficiency	0.88	0.88
Spillover Efficiency	0.83	0.73
η_{source}	0.72	0.62

In the prime focus case the antenna coupling efficiency to the sky is the same as to an extended source; i.e., η_{sky} = 0.72. However, for Cassegrain receivers the spillover is toward the sky (and only a few degrees off the electrical axis of the antenna) and thus η_{sky} is the product of only the first three efficiencies in the table above (which = 0.85).

For the NRAO 36-foot telescope and 80-120 GHz cryogenic Cassegrain receiver I have measured typical values for the following parameters in the frequency range 85-105 GHz:

$$T_{amb} = 290 \text{ K}$$

$$T_M = 280 \text{ K}$$

$$T_{bg} = 2.7 \text{ K}$$

$$T_{sbr} = 280 \text{ K}$$

$$\tau_s \simeq \tau_i \simeq 0.08 \text{ (in clear weather)}$$

Thus equation (2) reduces to

$$T_C = (380 + 16\ e^{.08A})\ (1 + G_i/G_s)$$

In the Cassegrain mode the equivalent calibration temperature T_C is considerably larger than typical prime focus values because:

(1) The calibration signal is larger since η_{sky} is larger, and

(2) The source signal is smaller since for the 80-120 GHz Cassegrain receiver η_{source} is smaller (due to increased spillover).

With the image rejection filter $G_i/G_s \simeq 0$ and one should set T_C to 400 in order to obtain the correct $T_A{}^*$.