

DEUTERIUM ARRAY MEMO #010

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To: Deuterium Array Group

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Subject: Measurement of the active antenna noise temperature from the sidereal variation of sky noise

The power from an active antenna is given by

$$p = g (T_{sky} \otimes D + T_{amp}) \quad (1)$$

where g = gain

$T_{sky}(az, el)$ = sky noise vs angle

$D(az, el)$ = antenna directivity

T_{amp} = amplifier noise

\otimes = convolution

$$T_{sky} \otimes D = \iint T_{sky}(z, el) D(az, el) \cos(el) da_z del \quad (2)$$

The sky temperature as a function of azimuth and elevation can be obtained from a sky map by coordinate conversion to right ascension and declination. The sky map used was that of R.E. Taylor [Proc. IEEE letters, page 469, April 1973]. For high accuracy a horizon mask should be used and

$$T_{sky} \approx T_{ambient}$$

for any elevations below the horizon.

For a given site, frequency and antenna pattern

$$T_{sky} \otimes D = T(t)$$

where t = sidereal time.

At low frequencies some account may have to be taken of the Sun whose output can influence $T(t)$. For example with an antenna whose on axis gain is 8 dBi the sensitivity is

$$1.5 \times 10^{-4} \text{ K / Jy}$$

so that with the Sun on axis at 250,000 J there will be a contribution of 40 K. If the gain is constant the amplifier temperature could be calculated from the “Y” factor ratio

$$Y = P_{\max} / P_{\min} = (T_{\max} + T_{\text{amp}}) / (T_{\min} + T_{\text{amp}})$$

$$T_{\text{amp}} = (T_{\max} - YT_{\min}) / (Y - 1)$$

Calibration

Since the gain is often a function of temperature and consequently a function of time the system needs to be calibrated. Calibration can be accomplished with dipole connected to a noise diode close enough to the active antenna to provide a reliable path free of multipath. If the calibration is stable the calibrated power is given by

$$P_{\text{cal}} = P / (P_{\text{on}} - P_{\text{off}})$$

where p_{on} = power with calibration on
 p_{off} = power with calibration off

Measurements

Figure 1 shows the calibrated antenna temperature at 327.4 MHz vs sidereal time along with the modeled temperature (large dots). The daytime data (22 to 10 hrs LST) is corrupted by noise from the sun (which was in an active state) and various sources of RFI. A best fit to the model is (using only the night time data)

$$T_{\text{amplifier}} = 12 \pm 10 \text{ K}$$

$$T_{\text{calibration}} = 60 \pm 10 \text{ K}$$

This data was obtained using a prototype active antenna from Eric Kratzenberg.

Appendix

Beam of dipole above ground plane

$$B(\alpha, \epsilon) = \left[\cos((\pi/2) \cos \theta) / \sin \theta \right] \sin(2\pi d \sin \phi) \text{ for } \phi \geq 0$$

$$= 0 \text{ for } \phi < 0$$

where d = height above ground plane in wavelengths

θ = angle relative to line of dipole

ϕ = elevation relative to ground plane

θ and ϕ can be obtained using the following coordinate conversions:

$$\begin{aligned} \text{zen} &= \sin(\text{el}); \text{north} = \cos(\text{el}) \cos(\text{az}); \text{east} = \cos(\text{el}) \sin(\text{az}) \\ \sin\phi &= \text{zen} \sin(\text{elb}) - \text{north} \cos(\text{elb}) \\ \text{nb} &= \text{north} \sin(\text{elb}) + \text{zen} \cos(\text{elb}) \\ \cos\theta &= \text{nb} \cos(\text{azd}) + \text{east} \sin(\text{azd}) \end{aligned}$$

where elb is the elevation of the beam maximum (assuming a ground plane tilted to the south)
 azd is the azimuth of the line of the dipole.

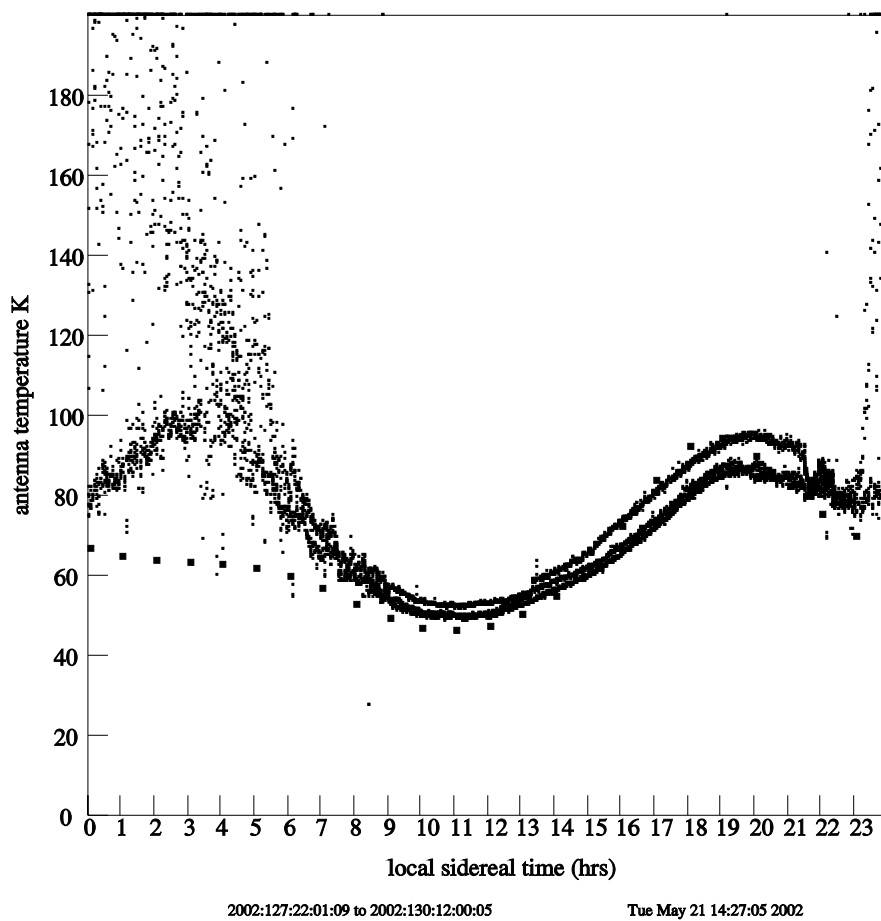


Figure 1- Calibrated antenna temperature and sky brightness model vs LST.