RFI MEMO #004

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To: RFI Group

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Subject: Calibration and Sensitivity limits of RFI monitor

A] Calibration method

If spectra are taken with a load so, the load plus added noise S_1 and the antenna S_2.

$$S_0 = (T_R + T_L)\, g$$
$$S_1 = (T_R + T_L + T_{cal})\, g$$
$$S_2 = (T_R + T_{ant})\, g$$

where g is the receiver gain, T_R is the receiver noise and T_L is the load temperature. In this case

$$T_{ant} = \frac{(S_2 - S_0)T_{cal}}{(S_1 - S_0)} + T_L$$

This method works, even if the spectrum analyzer is uncalibrated as the gain cancels, but the calibration noise, T_{cal}, must be known.

Alternately, if the spectrum analyzer is well calibrated (i.e. reads the signal strength in dBm with only a small error) it is only necessary to measure the spectrum on the antenna and another on the load. In this case the spectra can be converted to temperature, since g is known and hence

$$T_{ant} = (S_2 - S_0) + T_L$$

B] Sensitivity limits

The noise in the determination of T_{ant}, assuming the antenna temperature is close to that of the load, is

$$\Delta T = 2(T_R + T_L)(B\tau)^{-1/2}$$

where B = resolution bandwidth (Hz)
τ = is the integration time (sec)

The Tektronix RSA3303A acquires about 800 microseconds in about 100 seconds so that τ about 30 ms in an hour. The receiver noise is about 700 K so that the system temperature looking at the load is about 1000 K and hence $\Delta T \approx 10K$ rms in an hour.

C] Systematic limits

It turns out that systematic errors are more of a problem. For example if the preamp emits T_{out} in the direction of the antenna and $\Gamma\, T_{out}$ is reflected back from the antenna the peak to peak baseline ripple will be $2\Gamma T_{out}\rho$

Where Γ = refection coefficient
ρ = correlation coefficient between outgoing and ingoing noise

If $\Gamma = 0.2$, $\rho = 0.5$ and T_{out} = 300 K the peak to ripple is 30 K.

This shows that systematic errors are likely to dominate, despite the poor spectral efficiency of the RSA 3303A. The systematic errors can be minimized by using a preamplifier which emits very little noise and by using a very well matched antenna. Both of these improvements may be needed to reach our goal. The basic problem is that the method of measuring the difference between the antenna and the load (known as load switching in radio astronomy) easily leads to large systematic spectral errors. Ideally one would like to switch between the antenna looking at the RFI and antenna which doesn't see the RFI. One possibility might be using another antenna in a box with absorbing walls connected with the same cable length as a reference. Another possibility could be to add and subtract the output of 2 discone antennas, one on top of the other. This would be equivalent to beam switching as the RFI from the horizon would only appear in the sum, while the difference would act as the reference. Yet another possibility would be to assume the antenna refection induced spectral baseline is a constant and to measure the ripple spectrum with the antenna in an absorbing box or anechoic chamber. Then apply a corrected based on the measured ripple spectrum.