EDGES MEMO #018
RFI MEMO #033

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To: RFI Group

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Subject: Noise and error sources in 3 position switching

The goals for a 3-position switched LNA amplifier module are as follows:

1. low noise
2. very low input VSWR
3. low level of noise coming out of the input
4. low output VSWR
5. high reverse isolation

As discussed in memo #30 imperfect input match and noise from the input produce errors in the input from a imperfectly matched antenna. The usual solutions of using an input isolator or balanced LNAs with quadrature hybrids are not practical for a wideband system covering an octave or more. These input deficiencies can be ameliorated by using an input cable to rotate the reflections so that with averaging the input loss is reduced to $1-|\Gamma|^2$. The VSWR ripple of the output cable normally cancels because it is equivalent to a gain variation but inadequate reverse isolation can result in the reflected wave being modulated by an unbalance in the input switch.

Noise calculation

$$p_0 = g\left(T_R + T_L\right)\left(1+\Delta_0\right)$$
$$p_1 = g\left(T_R + T_L + T_{cal}\right)\left(1+\Delta_1\right)$$
$$p_2 = \left(T_R + T_A\right)\left(1+\Delta_2\right)$$

where p_0, p_1 and p_2 are the measured power spectrum, g is the gain, and Δ_0, Δ_1 and Δ_2 are the noise terms. The antenna temperature, T_A is given by

$$T_{cal}\left(p_2 - p_0\right)/\left(p_1 - p_0\right) \approx T_A - T_L + \Delta_0\left(T_R + T_L\right) + \Delta_2\left(T_R + T_A\right) - \Delta_1\left(T_R + T_L + T_{cal}\right)\left(T_A - T_L\right)/\left(T_{cal}\right)$$

The noise in T_A is given by

$$\Delta T_A \approx \left(\Delta_0^2 \left(T_L^2 + T_A^2 + 2T_R^2 + \alpha^2 \left(T_A - T_L\right)^2\right)\right)^{1/2} \text{ when } T_{cal} >> T_L$$

where $\Delta_0^2 = \Delta_2^2$ and $\Delta_1^2 = \alpha^2 \Delta_0^2$

This shows that the noise in the calibration position of the switch is only important when there is a substantial unbalance between the antenna and load positions of the switch. For example, for 100 kHz resolution, 1 hour integration in each of the switch positions,

$$T_L = 300K, T_A = 600K, T_R = 40K$$

$$\Delta T_A \sim 40mK$$