To: EDGES Group  
From: Alan E.E. Rogers  
Subject: Noise model for balun, antenna loss and ground pickup

Memo #76 gives a wave model for the antenna, LNA and any 50\(\Omega\) attenuation between the antenna and the LNA. The loss in the balun can be approximated by making \(L\) equal to the balun loss but a more accurate model is to consider the balun as part of the antenna since the VNA measurements of antenna impedance use the same balun. In this model the balun adds a parallel impedance across the antenna and a short length of 50\(\Omega\) coax. If the parallel impedance \(Z_f\) than the “true antenna impedance,” \(Z_a\), is

\[
Z_a = 1.0 / \left(1/Z_{ant} - 1/Z_f \right)
\]

Where \(Z_f\) is the ferrite core impedance and \(Z_{ant}\) is the impedance measured by the VNA and moved by rotation of the reflection coefficient so that

\[
\Gamma_{ant} = \Gamma_{vna} e^{2\pi i r L^{-1}}
\]

Where \(r = \) balun coax 2-way delay times frequency  
and \(L = \) balun coax one-way power loss

The noise fraction \(B\) from the sky is given by

\[
B = \text{Re} \left( Z_f Z_f^* \right) / \left( \text{Re} \left( Z_f Z_f^* \right) + \text{Re} \left( Z_a Z_a^* \right) \right)
\]

and \(T = T_{sky} B + T_{amb} (1 - B)\)

where \(T_{sky}\) is the beam weighted sky temperature.

If the antenna resistive loss and ground pickup are included the expression becomes

\[
T = T_{sky} \alpha B + T_{amb} (1 - \alpha B)
\]

\[
B = \left( \text{Re} \left( Z_a - rloss \right) Z_f Z_f^* \right) / \left( \text{Re} \left( Z_a Z_f Z_f^* \right) + \text{Re} \left( Z_f Z_a Z_a^* \right) \right)
\]

where \(\alpha\) = fraction of antenna pattern which illuminates the sky.  
\(1 - \alpha\) = ground loss  
rloss = resistive loss in ohms
Measurement of $Z_f$

If the balun is disconnected from the antenna $\Gamma_{\text{vna}}$ now measure

$$\Gamma_{\text{open}} = e^{-2\pi i\tau} L \left( Z_f - 50 \right) / \left( Z_f + 50 \right)$$

which can be inverted to obtain $z_f$

$$Z_f = \frac{50 (\Gamma + 1)}{(1 - \Gamma)}$$

where $\Gamma = \Gamma_{\text{open}} e^{2\pi i\tau} L^{-1}$