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To: EDGES Group

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Subject: Noise model for balun, antenna loss and ground pickup

Memo #76 gives a wave model for the antenna, LNA and any 50Ω 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 50Ω coax. If the parallel impedance $Z_f$ than the "true antenna impedance," $Z_a$, is

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

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

$$\Gamma_{ant} = \Gamma_{vna} e^{+2\pi i \tau} L^{-1}$$

Where $\tau$ = 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

$$B = \operatorname{Re} Za \left( Z_f Z_f^* \right) \Big/ \left( \operatorname{Re} Za \left( Z_f Z_f^* \right) + \operatorname{Re} Z_f \left( Z_a Z_a^* \right) \right)$$

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

where $T_{sky}$ is the beam weighted sky temperature.

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

$$T = T_{sky} \alpha B + T_{amb} \left( 1 - \alpha B \right)$$

$$B = \left( \operatorname{Re} Z_a - rloss \right) Z_f Z_f^* \Big/ \left( \operatorname{Re} Z_a \left( Z_f Z_f^* \right) + \operatorname{Re} Z_f \left( Z_a Z_a^* \right) \right)$$

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 $\Gamma_{vna}$ now measure

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

which can be inverted to obtain $z_f$

$$Z_f = 50\left(\Gamma + 1\right)/\left(1 - \Gamma\right)$$

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