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To: EDGES Group

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Subject: Estimate of EDGES-2 Antenna loss

An estimate of the antenna lost requires 3 parts. First the loss of the antenna itself is estimated using FEKO by including the following card:

SK:0:3::::0.001:1:3.5eo7

Which uses the current distribution to estimate the resistive loss in the skin depth. The sum of losses is reported in the output as an efficiency. Second the effect of the balun shunt inductance needs to be included then the loss of the transmission line needs to be included. The combined loss is given by

$$L_T = L_{cab} L_{ant} \left(1 - \Gamma^2 / L_{cab}^2\right) \Big/ \left(1 - \Gamma^2\right) = L_{cab} L_{ant} R$$

Where L_T, L_{cab} and L_{ant} are the efficiency factors ($L \leq 1, L = 1$ for zero loss) for the total combination transmission line and antenna respectively.

Γ is the reflection coefficient measured at the far end of the transmission line. The dependence of the loss on the reflection coefficient is from equation 25 of Rogers and Bowman (2012) and can be shown to hold for any length of uniform cable from the expression in equation 19. Combining the FEKO measurement of loss with the measured reflection coefficient of the prototype antenna the preliminary results are shown in the table.

Frequency (MHz)	L_{ant} (dB)	L_{balun} (dB)	L_{cab} (dB)	R (dB)	L_T (dB)
100	-0.0041	-0.0008	-0.0094	-0.0010	-0.0153
125	-0.0019	-0.0009	-0.0105	-0.0005	-0.0138
150	-0.0028	-0.0010	-0.0115	-0.0008	-0.0160
175	-0.0054	-0.0011	-0.0124	-0.0009	-0.0198
190	-0.0077	-0.0011	-0.0129	-0.0005	-0.0222

Table Antenna Loss

These results do not include the antenna ground plane loss and are only intended to provide an indication of the magnitude of the loss which needs to be included in the data analysis software.

Equivalence of loss expressions

The correction for cable loss can be made using the relation

$$T_{rec} = \left[T_{sky} \left(1 - |\Gamma|^2 \right) L + T_{amb} \left((1-L) L |\Gamma|^2 + (1-L) \right) \right] |F|^2 \qquad [1]$$

Where Γ is the reflection coefficient of the antenna at the antenna end of the cable and

$$F = \left(1 - |\Gamma_\ell|^2 \right)^{1/2} \Big/ \left(1 - \Gamma \Gamma_\ell L \right) \qquad [2]$$

From equation 19 of Rogers, Bowman (2012)

If we define $L_0 = L\left(1 - |\Gamma_0|\right)^2 \big/ \left(1 - |\Gamma_0|\right)^2$ and $\Gamma_0 = \Gamma L$

Equation [1] with some algebraic manipulation becomes

$$\left[T_{sky} L_0 + T_{amb} (1 - L_0) \right] \left(1 - |\Gamma_0|^2 \right) |F_0|^2 \qquad [3]$$

Where $F_0 = \left(1 - |\Gamma_\ell|^2 \right)^{1/2} \Big/ \left(1 - \Gamma_0 \Gamma_\ell \right)$ [4]

The correction for the cable loss is given by

$$T_{effective} = T_{sky} L_0 + T_{amb} (1 - L_0)$$

Where $L_0 = L\left(1 - |\Gamma_0|^2 / L^2 \right) \Big/ \left(1 - |\Gamma_0|^2 \right)$

And the antenna reflection Γ_0 is measured at the reference plane looking back through the cable to the antenna and L is the reflection magnitude with the cable disconnected from the antenna and left open.