EDGES MEMO #180

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Subject: Simulations of the sensitivity to errors in balun loss parameters.

Currently the balun loss is modeled using two transmission lines in series. The portion closest to the antenna is a coax line and next is a connector which terminates at the receiver reference plane. These two lines are modeled using coaxial transmission lines from which the S-parameters are derived from theory. The combination is derived using 2-port network theory. In the future the loss in the topcap connection might be added as a third 2-port section.

While several comparisons between the coaxial transmission line model and its S-parameters the only test of the Roberts balun loss is described in memo #148. The key parameters for each section are the center conductor diameter, the outer conductor internal diameter, the conductivity, of each conductor, the dielectric constant of the space between conductors and the section lengths. In most cases the center conductors are plated and currently one value of conductivity is assumed to represent the two layer combination. At this time no measurements of the low band balun has been made so the following tests are suggested:

1] Make S11 measurements with the topcap removed.
2] Extend S11 measurements below 50 MHz and use a CST or FEKO model of the antenna impedance along with a search for the best fit values of conductivity needed to match the S11 measurements.
3] Construct a duplicate and measure as in memo #148.

Table 1 gives the sensitivities for high band 105-195 MHz for changes in the 4 conductivities. Values are relative to copper whose value is one. 10% changes in dimensions and dielectric are smaller than the changes in conductivity. The values for the changes are given as residuals to 1,2,3,4 and 5 term fits where the fitted functions are scale, spectral index, gamma, ionospheric absorption, ionospheric emission. The sky signal is Galaxy down with 300 K at 150 MHz and spectral index of -2.5. Making a change to the more accurate cable model of LeSurf

Item	Conductivity		1	2	3	4	5
Balun tube inner	1	0.24	286	105	41	27	5
Balun tube outer	0.24	1	120	44	17	11	2
Connector Inner	0.05	0.24	121	71	24	18	16
Connector Outer	0.024	0.24	69	40	13	10	9

Table 1. Sensitivity of changes to high band balun model as residual to fits in mK.

(see memo 126) has little effect producing residuals of 6,3,1,1,0 mK.

Number of terms	Total balun	Just the connector	All copper connector
1	1030	441	784
2	435	229	302
3	85	54	104
4	61	54	46
5	55	45	20

Table 2. Residuals which result from the addition of the balun or just the addition of the connector or the use of copper for connector.

If the balun is not modelled and there are no other errors the balun is expected to produce the residuals shown in Table 2. Most of the frequency dependence is in the connector. This could be reduced if a gold plated copper center conductor and body were available.

The sensitivity to errors in the balun model, which assumes the measured S11 of the high blade, can be reduced by a factor of about 2 when the antenna S11 is lowered by 10 dB. For example the third entry of residuals in table 1 become 126, 48, 6, 6, 5 mK.

Comments on other balun designs.

The balun used in EDGES-1 used ferrite cores which result in much higher loss. Placing the receiver under the antenna as in EDGES-1 would eliminate the balun tubes but whatever type of balun is used there are connectors involved which would need to be measured or modelled.

Comment on "in place" measurement of the balun loss

A S11 measurement with the topcap shorted is not sensitive to changes in conductivities. On the other hand a S11 measurement with the topcap removed maximizes the sensitivity to conductivities. For example changing the conductivity of BeCu from 0.24 to 0.12 in center conductor of the connector makes a 20% change in the loss. Extending the range of S11 measurement without any temporary change to antenna provides some information on the balun at frequencies for which the antenna S11 is accurately known. For example at frequencies below about 30 MHz for the high band antenna the antenna S11 drops below -0.001 dB S11 and the antenna impedance is determined by the inductance of the transmission line formed by the balun tubes which is shorted at the ground plane. However the balun loss is under 0.02 dB below 30 MHz so measuring a 20% change is beyond the capability of a VNA.

Condition	Frequency MHz	|S11| dB
No change	5	-0.020
No change	10	-0.021
No change	20	-0.010
No change	30	-0.002
Topcap removed	5	-0.001
Topcap removed	10	-0.001
Topcap removed	20	-0.002
Topcap removed	30	-0.004
Topcap removed	150	-0.080
Topcap removed	200	-0.076

Table 3. |S11| values for balun at low frequencies without changing antenna and at several frequencies for topcap removed.

Sensitivity of low band balun

Table 4 shows the corresponding sensitivities of the low band balun to conductivity changes. As with the high band results in Table 1 the connector model is more critical than the model for the balun tubes. The frequency range is 51 to 95 MHz.

Item	Conductivity		1	2	3	4	5
Balun tube inner	1	0.24	710	490	480	153	11
Balun tube outer	0.29	1	243	167	164	52	4
Connector inner	0.24	0.05	310	284	111	98	15
Connector outer	0.024	0.24	158	146	57	58	8

Table 4. Sensitivity of low band 51-95 MHz balun to changes in conductivity.