EDGES MEMO #148

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Subject: Measurements of EDGES-2 high band balun loss

Figure 1 shows the balun transmission line dimensions. The loss from the reference plane at the input to the 90 degree bend through the bend on to the connector and through the tube leaving to the "topplate" of the antenna is modeled as 3 parts

a. Fairview Microwave 90 bend SM5283
b. Fairview Microwave connector SC7121
c. Balun brass pipe with Cu

S11 measurements were made by connecting to the HP 8713 VNA as shown in Figure 5B. The VNA was calibrated at the female port 2 input. Initially the joint between connector and the center conductor was shorted with copper tape as shown in Figure 5B. This provided a check of the loss of the loss to this point. The S11 was -0.06 dB at 200 MHz. Figure 2 shows the S11 with the balun shorted by copper tape as shown in Figure 5E. A measurement of S11 with the balun open at the end is shown in Figure 3. In order to have the balun open at the end the balun pipe was extended to cover the end as shown in Figure 5A. Since the balun has a connector on only one end it is not possible to measure the scattering parameters using the SOL procedure. Instead the balun is modeled as 2 transmission lines using the component dimensions and materials. The bend connector and balun tube are modeled with parameters in the table below:

Section	Inner ID	Material	Outer ID	Material	dielectric	Length
Bend	0.05	BeCu	0.16	Stain less steel	2.05	0.83
Connector	0.05	BeCu	0.16	Stainless steel	2.05	0.47
Balun tube open	0.156	Cu	0.37	Brass	1.07	21.9
Balun tube short	0.156	Cu	0.37	Brass	1.07	20.95

While the bend and connector are gold plated its thickness is not sufficient for frequencies below about 1 GHz. The Cu conductivity is 5.96×10^{7}. BeCu, Nickel or brass and stainless steel were assumed to be 0.29 and 0.024 times that of Cu respectively. At 100 MHz the skin depth for Cu is 256 micro inches.

Figure 4 shows the thermal noise contribution of the balun for an antenna S11 of -14 dB and a 20 ns delay using the model. The top curve is for the bend, connector and balun tube. The bottom curve is the contribution from the balun tube alone.

The ripple is the result of the loss being sensitive to the phase of the antenna S11 as a result of the development of a complex impedance in transmission lines at low frequencies. See EDGES memos 115, 126, 133.

The relative loss of various different bends is hard to understand since all the details of the materials are unpublished. Measurements made the S11 in dB of 3 different 90° bends terminated with a Maury Calibration short with 16.68 ps one-way delay and 1.3 GΩ/s loss in dB were as follows:

Bend	50 MHz	100 MHz	200 MHz
Short alone	-0.003	-0.003	-0.006
Carlisle	-0.018	-0.029	-0.052
Gold	-0.034	-0.062	-0.097
Stainless	-0.017	-0.023	-0.032

The bends are shown in Figure 5C Carlisle, gold, stainless from left to right. The stainless is shown with calibration short attached.

Those tests were very repeatable and not dependent on the specific tightness of the connectors so it is reasonable to assume that the surprisingly large differences are the result of the internal conductive materials. In all cases the open S11 is zero within the VNA noise so the dielectric loss is not significant. Checks of the DC resistance were 2,5 and 50 milliohms for the Carlisle, gold and stainless bends. Also S11 measurements at 300 kHz gave S11 values of zero within 0.002 dB. The conclusion is that the lower loss of the "stainless" bend is most likely the result of this bend having a thicker gold plating on the center conductor. A check was made of the balun terminated in a 47 Ω resistor shown in Figure 5D. The S11 was about -29 dB.

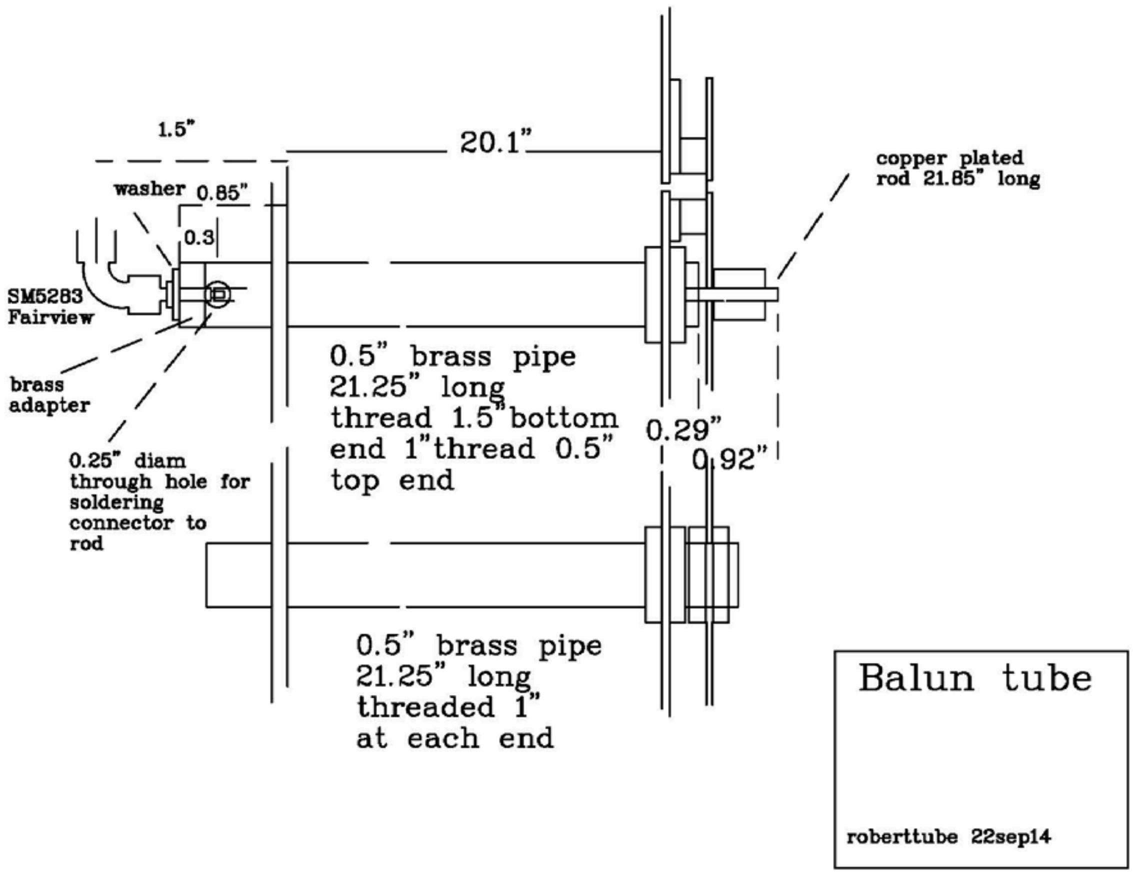

Figure 1. The balun coax line is copper plated brass of 0.156” diameter inside a brass tube of 0.37” I.D.

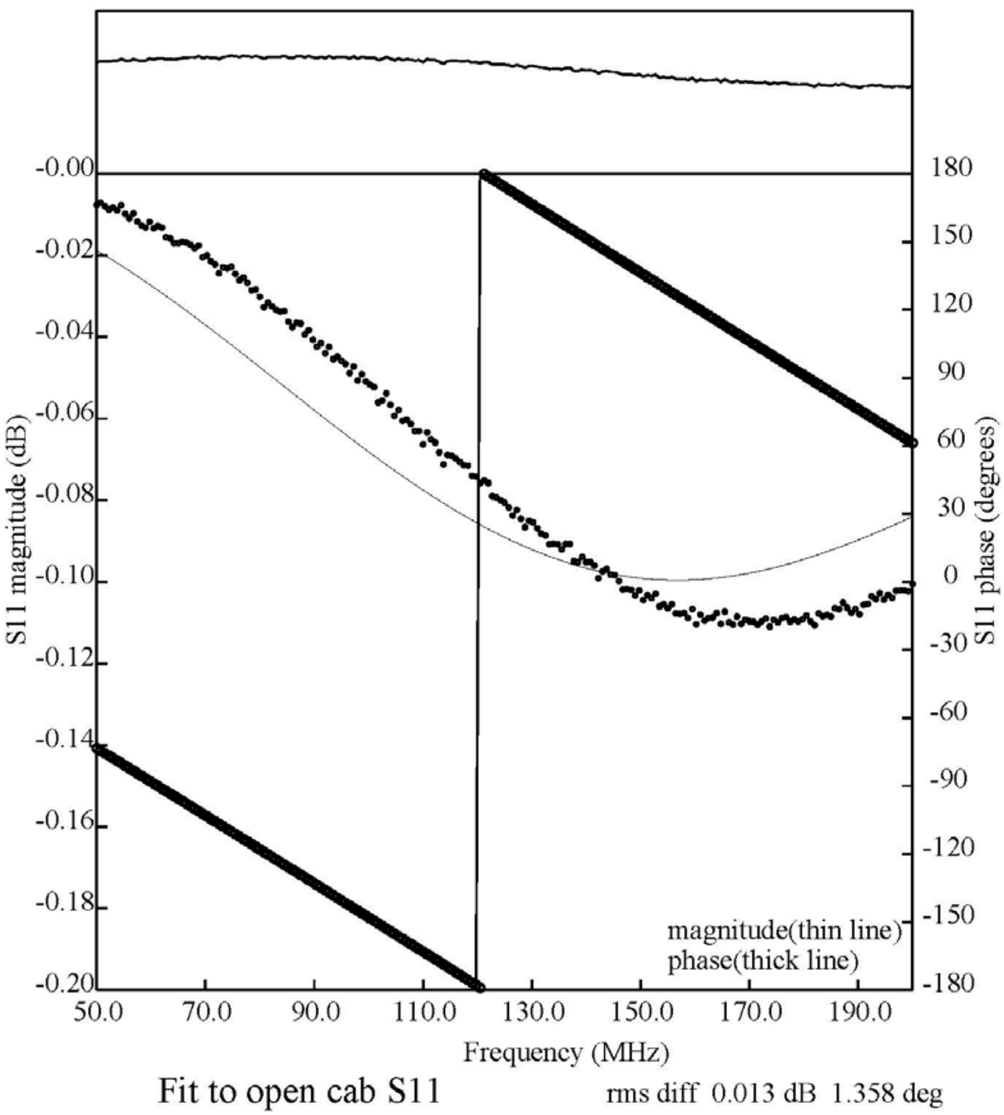

Figure 2. S11 data and model (thin line) for balun transmission line open at the end.

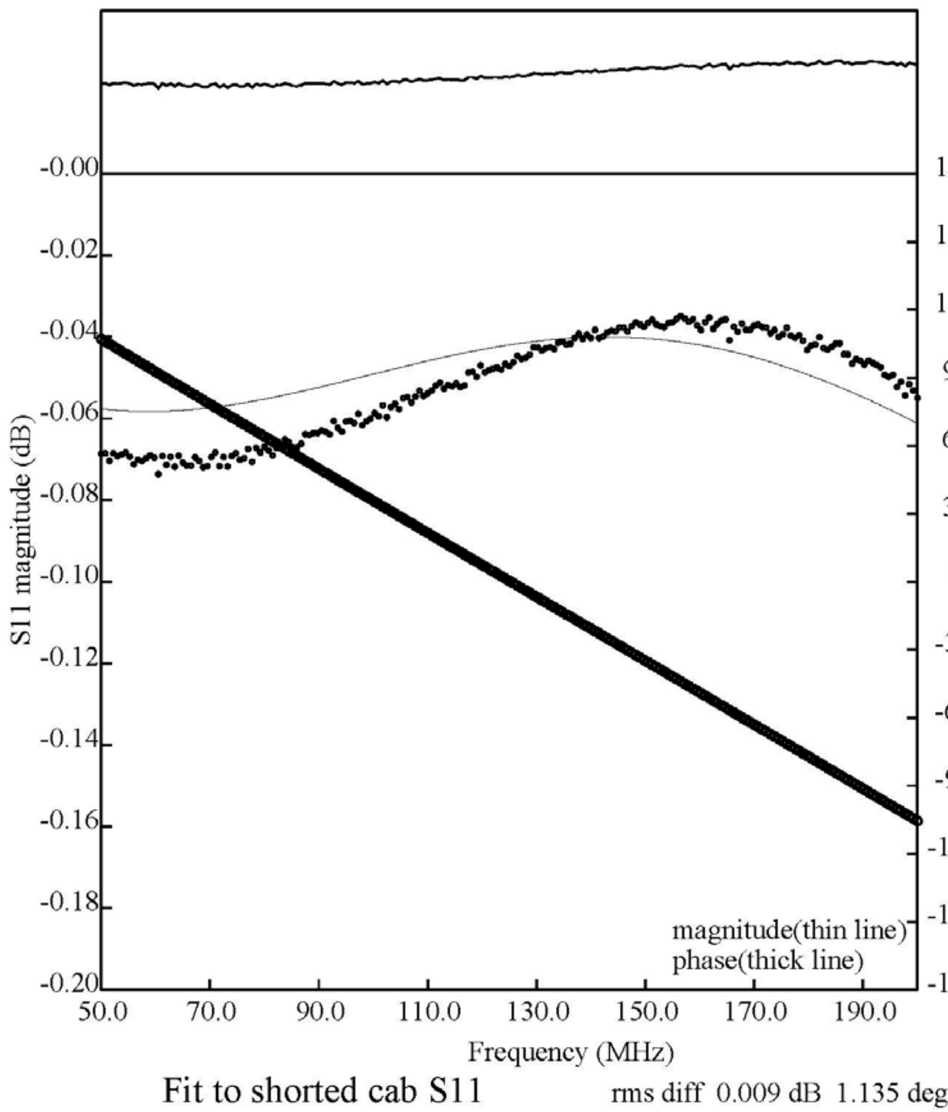

Figure 3. Balun tube end shorted

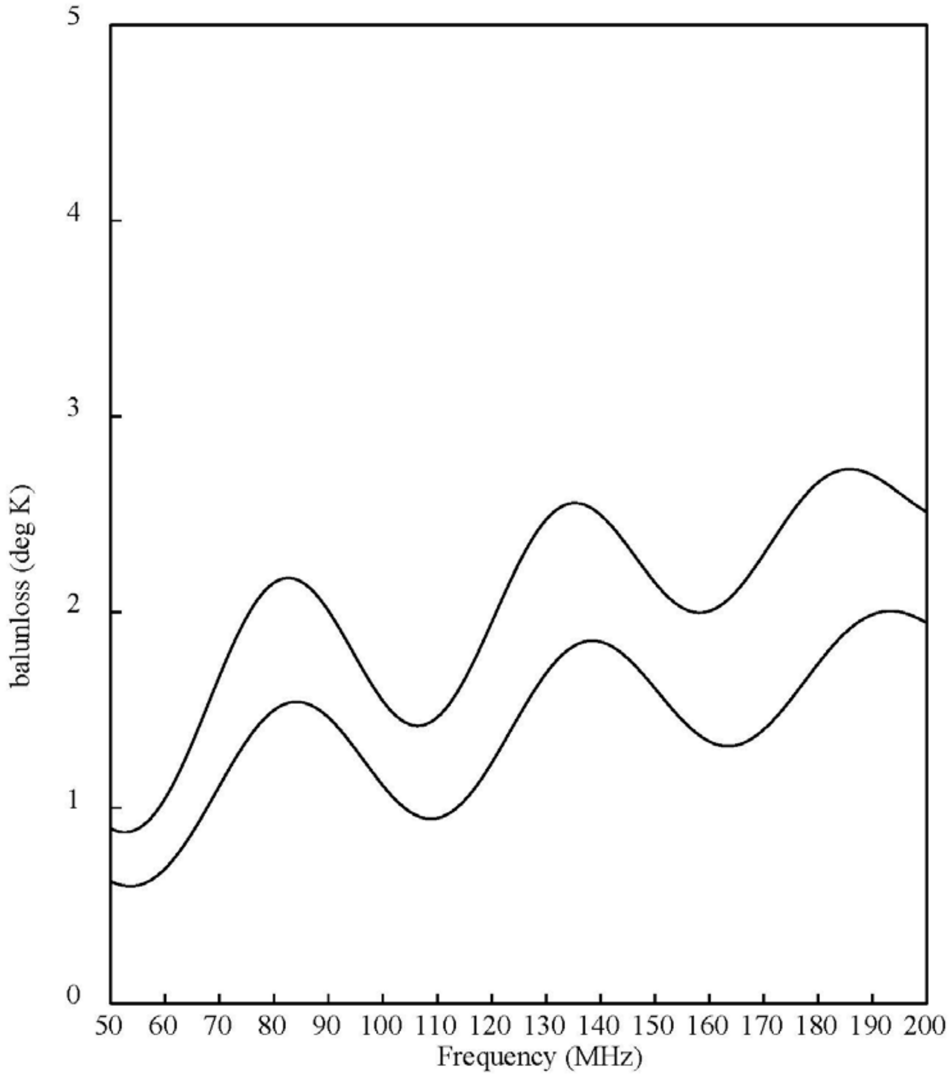

Figure 4. Thermal noise contribution from balun for antenna reflection coefficient -14 dB and 20 ns delay. Lower curve is for balun with connector or bend.

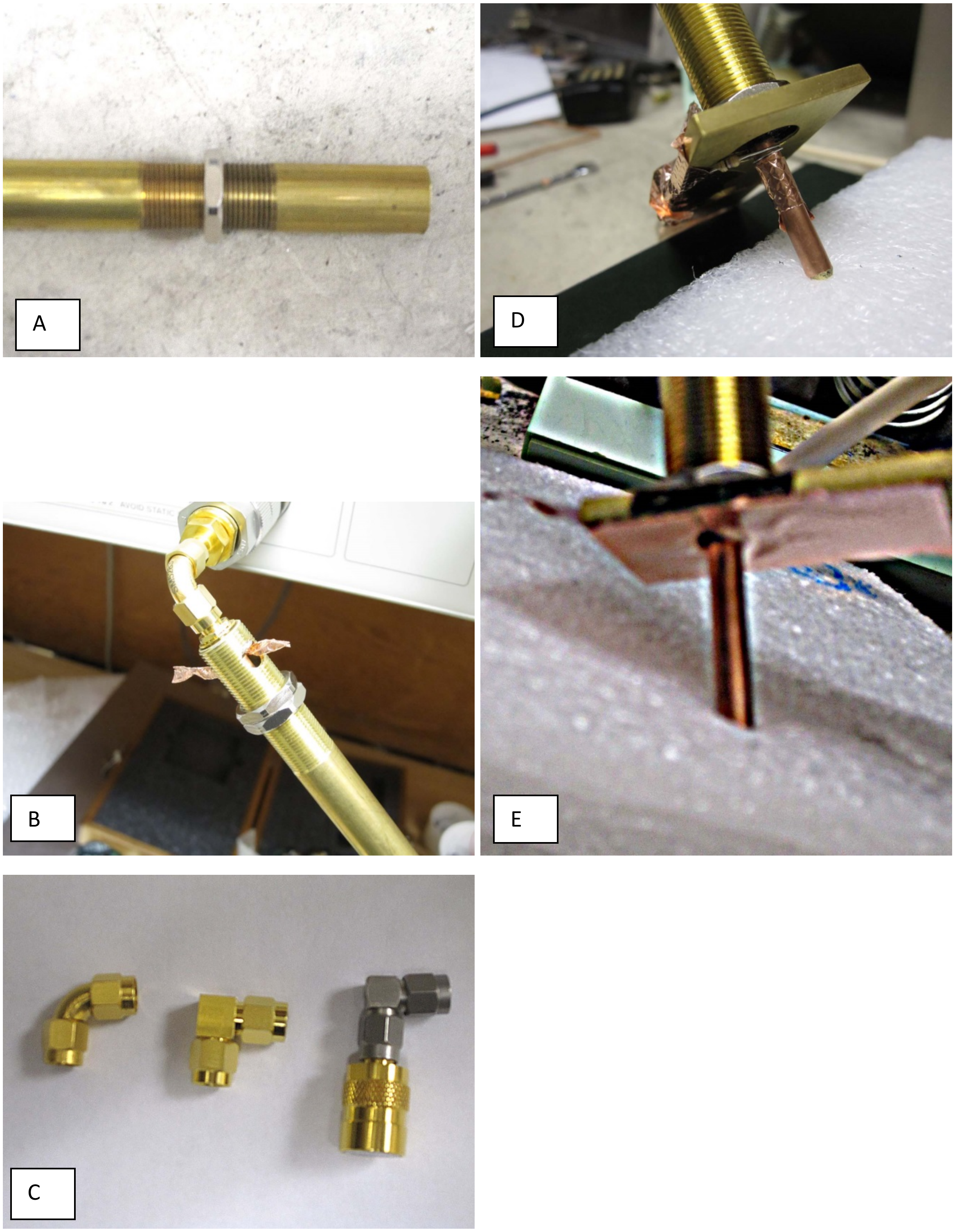

Figure 5. A extension to shield open end,
B: Balun with bends attached to VNA and shorted,
C: SMA bends tested,
D: Balun terminated with 47Ω resistor,
E: Balun shorted