EDGES MEMO #087

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To: EDGES Group

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Subject: The "Roberts" balun

The "Roberts" balun was described by Robers in the paper "A new wide-band balun" Proc. IRE pp 1624-1628, Dec. 1957. This balun, also called the "Collins" balun, converts a balanced antenna output to an unbalanced output and in addition can be used to extend the bandwidth of the antenna match. Figure 1 shows the equivalent transmission line circuit of the balun.

The antenna impedance, Z_a, is in parallel with the shorted balanced line, B, which is also used to support the antenna above the ground plane. The unbalanced port enters through a transmission line, A, which connects to the antenna via na open ended line, C, in series with the antenna. While the mechanical length of A and B are constrained to be no longer than the height of the antenna above the ground plane they can be shortened with the shorting bar, D. The electrical length and transmission line impedance of A,B and C can be adjusted within the mechanical constraints. In practice the impedance of B is in the range 300 to 500 ohms.

And its length is close to a quarter wavelength so the impedance across, Z_a, is very large. Since the antenna impedance is likely to be in the range 100 to 200 ohms the transmission line, A, is around 70 ohms to act as a quarter-wave transformer. Open line, c, also around quarter-wave the center frequency of the antenna to provide a low impedance with a transition from capacitive to inductive reactance. In all the transmission line impedance and electrical length of A,B and C provide 6 free parameters which can be used to optimize the bandwidth of the antenna match.

The impedance of the shorted balanced line ZB

$$ZB = R_b \left(1+\Gamma\right)/\left(1-\Gamma\right)$$

Where $\Gamma = -e^{i\phi_b}$

R_b is the line impedance

$\phi_b = -4\pi \ell \in^{1/2} f/c$

ℓ = length, f = frequency, c= velocity, $\in$= dielectric

and the impedance of the stub, c is a similar expression with $\Gamma = e^{i\phi_c}$ since the end is open. The impedance seen by the end of the input line A is

$$Z = ZC + \left(Z_a^{-1} + ZB^{-1} \right)^{-1}$$

and the reflection coefficient is

$$\Gamma = (Z - R_a)/(Z + R_a)$$

and the impedance at the un-balanced port is

$$Z = R_a \left(1 + \Gamma e^{i\phi_a}\right) \Big/ \left(1 - \Gamma e^{i\phi_a}\right)$$

An example is shown in Figure 2. Where the thin and thick curves show the S11 for the antenna and the antenna with balun. For this example the EDGES antenna parameters were

Gap = 0.02

Diag = 0.6

Hgt = 0.48

Start of Teflon = 0.14

With a 0.29 m square plate 0.12 m below the panels. The Roberts balun parameters were

$R_a = 66.8 \quad \Omega, \quad \ell = 0.4 \quad m$

$R_b = 226 \quad \Omega, \quad \ell = 0.48 \quad m$

$R_c = 65 \quad \Omega, \quad \ell = 0.34 \quad m$

$\in = 1.1$ (to accommodate some air spacers).

The ratio of maximum to minimum frequency over which the reflection coefficient is below -16 dB in Figure 2 is 1.7:1. The antenna gain ranges from 8.4 dB at 100 MHz dropping to 6.8 dB at 220 MHz. The drop in gain at 220 MHz is ameliorated at 220 MHz by the square plate below the panels which reduces the effective antenna height.

While an antenna impedance of about 100 ohms appears to optimize the VSWR bandwidth and width of constant antenna pattern a lower impedance of about 50 ohms has the advantage of not requiring an impedance transformation in the balun.

A search through parameter space was made with FEKO to find a design with acceptable gain flatness without "tuning" plate. The following parameters result in a frequency range from 110 MHz to 196 MHz with S11 better than -15 dB and gin from 8.4 to 7.0 dBi:

Side	0.3713
Lip	0.015435
Gap	0.0082
Diag	0.68
Hgt	0.52
Start of Teflon	0.21

The side and Lip were rescaled to move the frequency range down by about 20%. Figure 3 shows the S11 for the 50Ω ohm EDGES antenna with simplified Roberts balun without impedance transformation and open stub C.

Figure 4. shows the details of a EDGES-2 prototype with built-in Roberts balun. Estimated loss in the balun is 0.01 dB at 200 MHz. In this balun the coax impedance is 50 ohm and the balanced stub, B, across the antenna has impedance of 186 ohms.

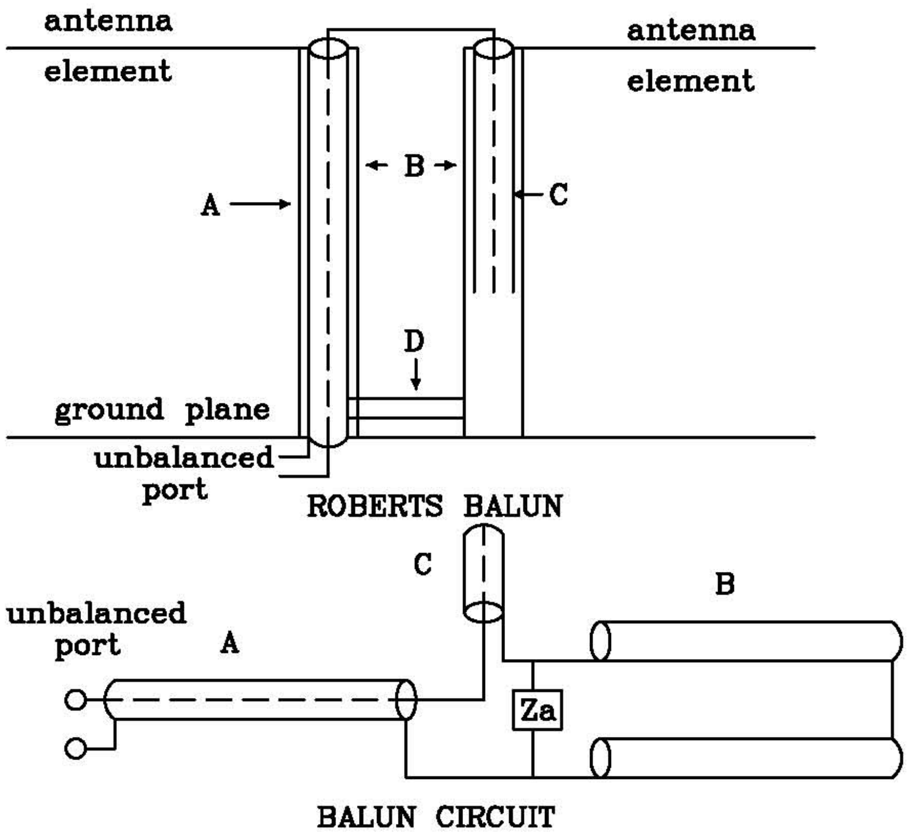

Figure 1. Schematic of Roberts balun. A is a quarter wave transformer. B is a balanced line which also acts as a support structure for the antenna. C is an open “stub” line which aids in the antenna match.

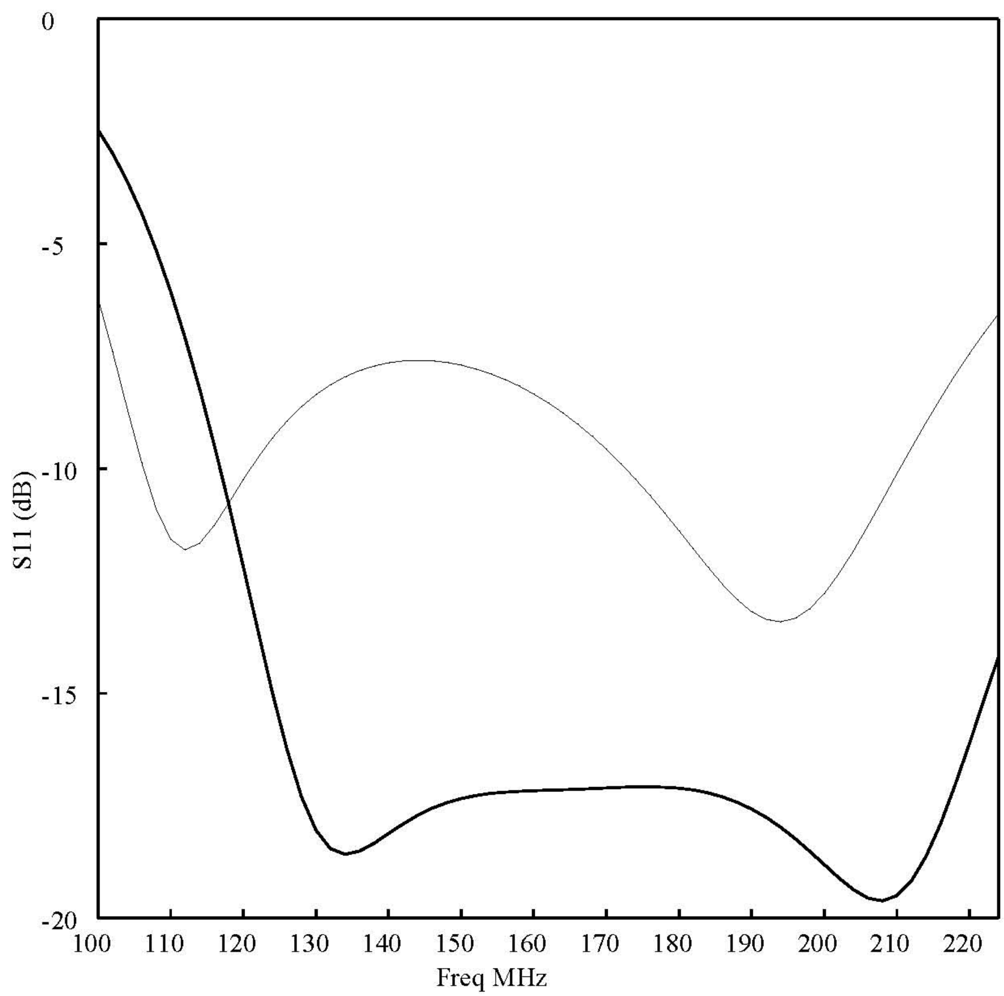

Figure 2. The thin curve is the S11 for a variant of the EDGES antenna alone without balun. The thick curve is the S11 at the 50Ω unbalanced input port.

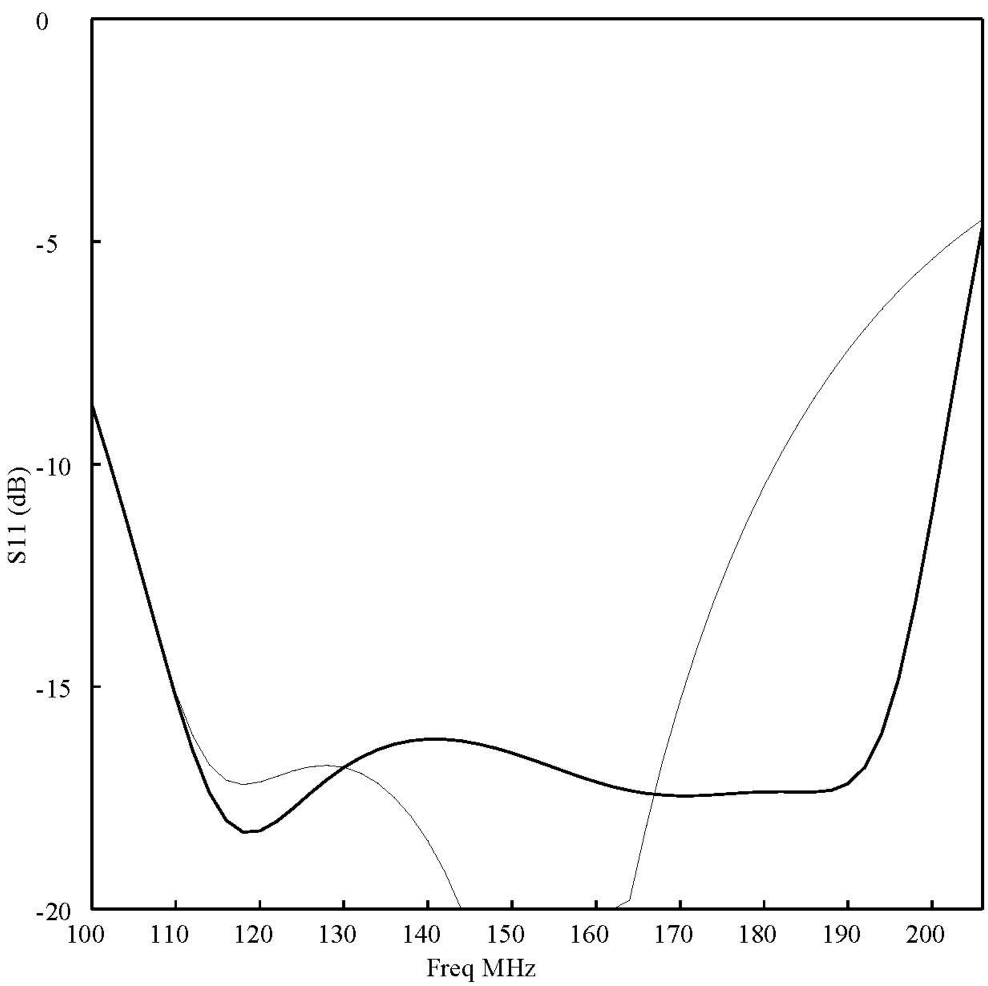

Figure 3. S11 magnitude in dB for simplified Fourpoint and simplified Roberts balun.

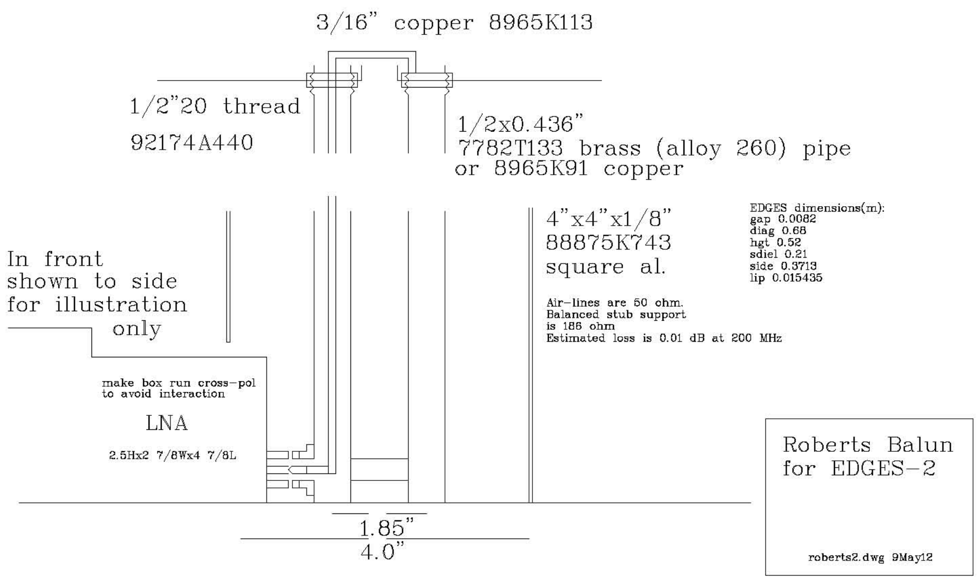

Figure 4. Proposed simplified balun for EDGES 2.