To: EDGES Group
From: Alan E.E. Rogers
Subject: Low band balun tube and Airline as a candidates for “external” validation of VNA Calibration.

In order to obtain the highest accuracy S11 measurements a technique known as “One-port Direct/Reverse method for “Characterizing VNA standards” has been developed to obtain an accurate model for the VNA calibration load. While the open and short are characterized by the company that manufactured the open and short the load is given as a “perfect” 50 ohm load. At low frequencies the transmission line between the resistive material and the reference plane of the connector departs significantly from 50 ohms due to the internal inductance within the skin depth. The use of a transmission line that can be modeled from its physical parameters is examined as a check on the accuracy of the Direct/Reverse method.

The low band balun tube can be accurately modeled from the knowledge of its dimensions and materials. The balun tube is made from the following materials.

<table>
<thead>
<tr>
<th>Material</th>
<th>Part Number</th>
<th>ID</th>
<th>OD</th>
</tr>
</thead>
<tbody>
<tr>
<td>330 brass</td>
<td>1705T32</td>
<td>0.75</td>
<td>1.00</td>
</tr>
<tr>
<td>360 brass</td>
<td>8953K47</td>
<td>-</td>
<td>5/16</td>
</tr>
<tr>
<td>Polystyrene</td>
<td>8720K36</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Table 1.

The “balun tube” consists of a brass tube with inner diameter of 0.75” containing a copper plated brass rod conductor of “5/16” dimeter supported by 3 polystyrene spacers each 1” long. This inner rod is 45” long and is soldered to a SC3792 SMA connector at one end which is located 0.5” from the end of the tube. Figure 1 shows a diagram of the balun tube configured as an “open” load.

Figure 2 shows the simulated difference in S11 measured with a VNA calibrated with calibration load assumed to be a perfect 50 ohms and a VNA calibrated with a model of the calibration load which includes a 30 ps offset and 2.3 Gohm/s loss in the “Offset” transmission line. The thin line curve is an estimate of the level of error in modeling the balun. Unfortunately the modeling errors are likely to be large above 100 MHz owing to the effects of the dielectric spacer and their end effects.

An alternate is to use a commercially available “beadless airline” such as the 8043515 15 cm airline form Maury Microwave. Figure 3 shows the simulated difference as in figure 2. The effect on the phase is shown in Figure 4.
The rms error introduced by various model errors are given in Table 1.

<table>
<thead>
<tr>
<th>Model error</th>
<th>rms error dB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air dielectric</td>
<td>$10^{-5}$</td>
</tr>
<tr>
<td>1mm length</td>
<td>$4\times10^{-4}$</td>
</tr>
<tr>
<td>1 percent dimensional</td>
<td>$7\times10^{-4}$</td>
</tr>
<tr>
<td>1 percent conductivity</td>
<td>$5\times10^{-4}$</td>
</tr>
<tr>
<td>1 percent outer conductivity</td>
<td>$1.5\times10^{-4}$</td>
</tr>
<tr>
<td>1 percent inner conductivity</td>
<td>$3.4\times10^{-4}$</td>
</tr>
</tbody>
</table>

Table 2.

The greatest uncertainty is in the conductivity which will be measured from the DC resistance. This error results mainly in a slope which can be distinguished from a “ripple.” The beadles has no dielectric and the center conductor, which is removable, is supported between the VNA connector and calibration open, short or load.

References:


Figure 1.

1" brass pipe
44.1" long
thread 2.5" bottom end
1.5" thread top end

SC3792 SMA male 0.5"

1"-14 nut
copper plated rod 45" long
extension pipe covers inner conductor

Open tube Low band
open tube 15apr16

NOT TO SCALE
Figure 2. Simulation of S11 error for assuming perfect 50 ohm calibration load. The thin line curve is for end effects of the dielectric spacers.
Figure 3. Simulation of S11 error for open airline assuming perfect 50 ohm calibration load. Thin line curve is for 5% error in conductivity.
Figure 4. Effect of S11 error on phase.