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To: EDGES Group

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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/Reserve 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.

Material	Part Number	ID	OD
330 brass	1705T32	0.75	1.00
360 brass	8953K47	-	5/16
Polystyrene	8720K36	-	-

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.

Model error	rms error dB
Air dielectric	10^{-5}
1mm length	4×10^{-4}
1 percent dimensional	7×10^{-4}
1 percent conductivity	5×10^{-4}
1 percent outer conductivity	1.5×10^{-4}
1 percent inner conductivity	3.4×10^{-4}

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:

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Roberts, Tom H., and Yeou-Song Lee. "A superior solution to control the connection repeatability of Coaxial Airline Impedance standards used for network analyzer verification." In Microwave Measurement Conference (ARFTG), 2011 77th ARFTG, pp. 1-6. IEEE, 2011.

Juroshek, John R., and George M. Free. "Measurements of the characteristic impedance of coaxial air line standards." Microwave Theory and Techniques, IEEE Transactions on 42, no. 2 (1994): 186-191.

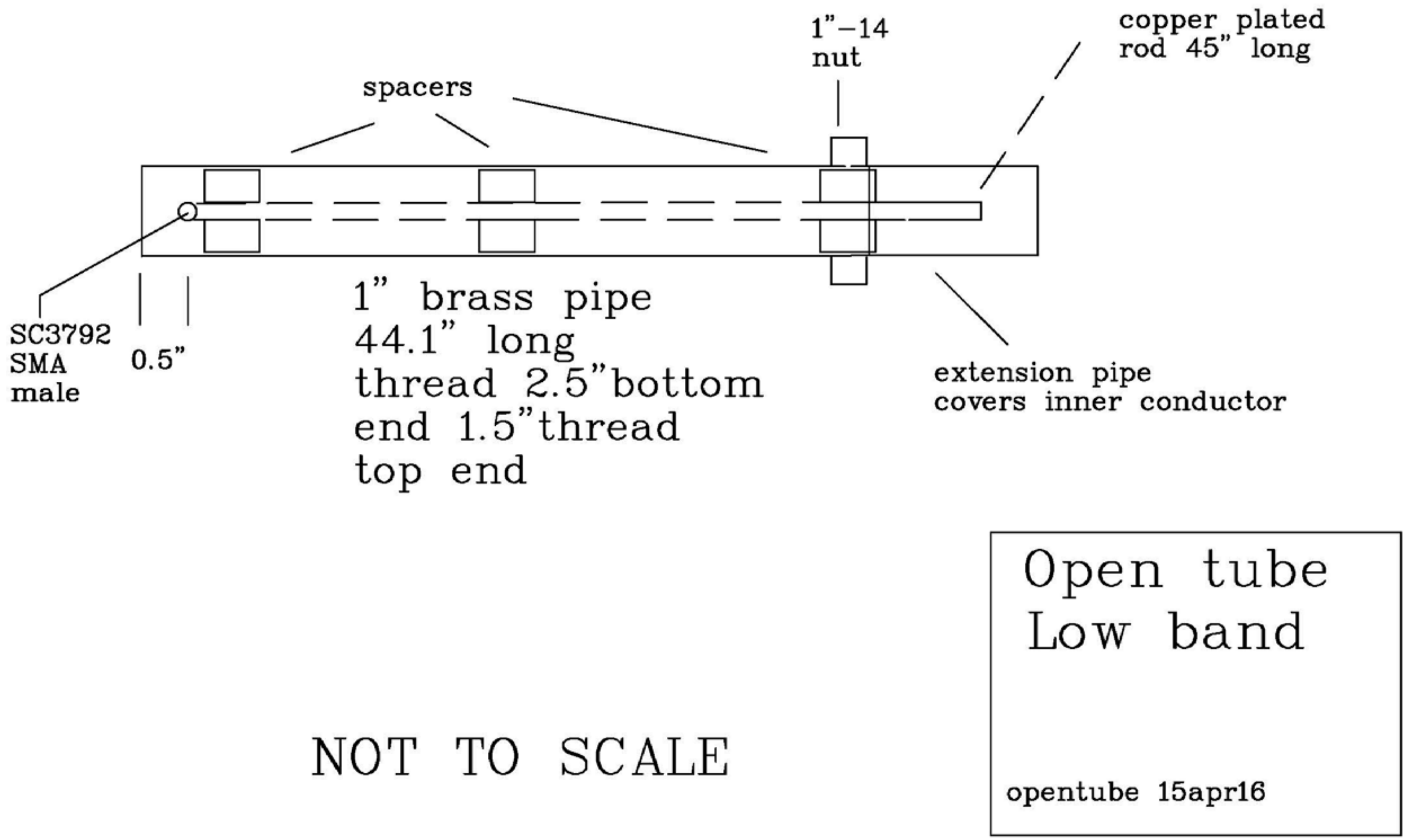
1"–14
nut
copper plated
rod 45" long
spacers
SC3792
SMA
male
0.5"
1" brass pipe
44.1" long
thread 2.5"bottom
end 1.5"thread
top end
extension pipe
covers inner conductor
Open tube
Low band
opentube 15apr16
NOT TO SCALE

Figure 1.

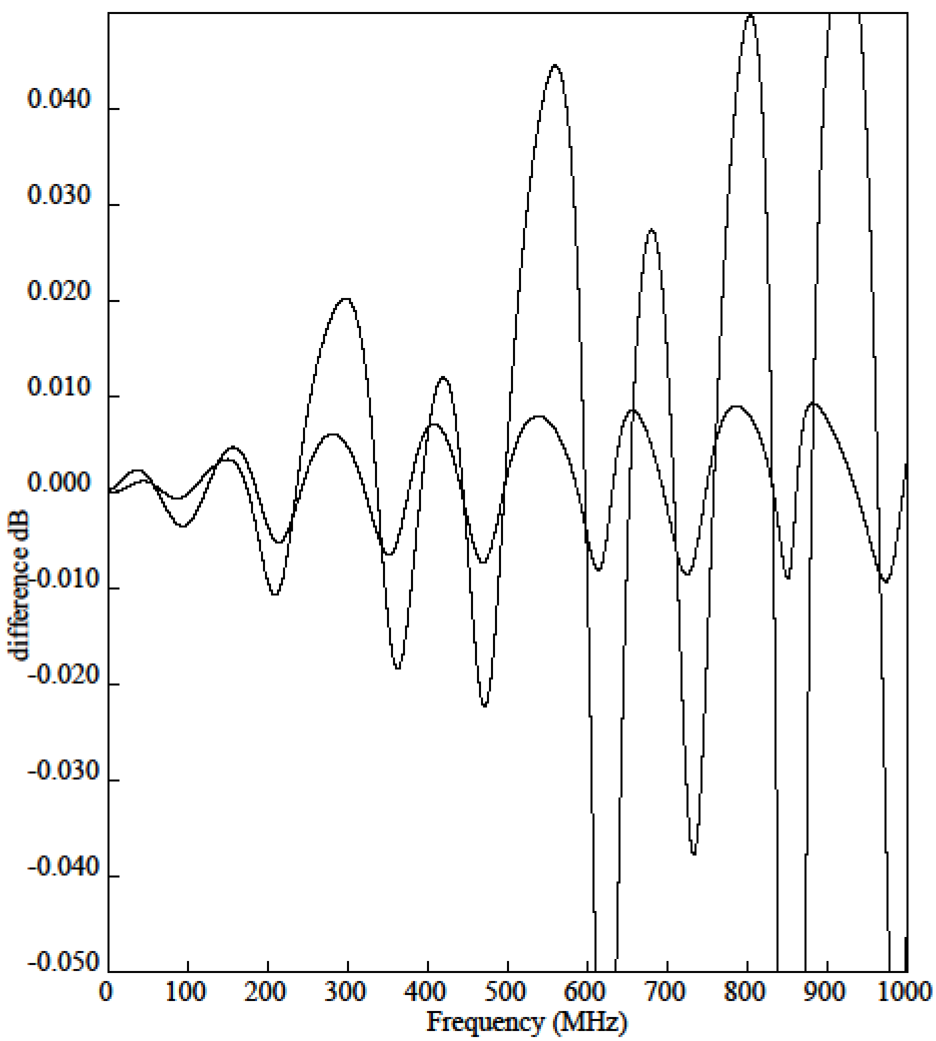

Figure 2. Simulation of S11 error for assuming perfect 50 ohm calibration load. The thin line curve is for end effects of the dielectric spacers.

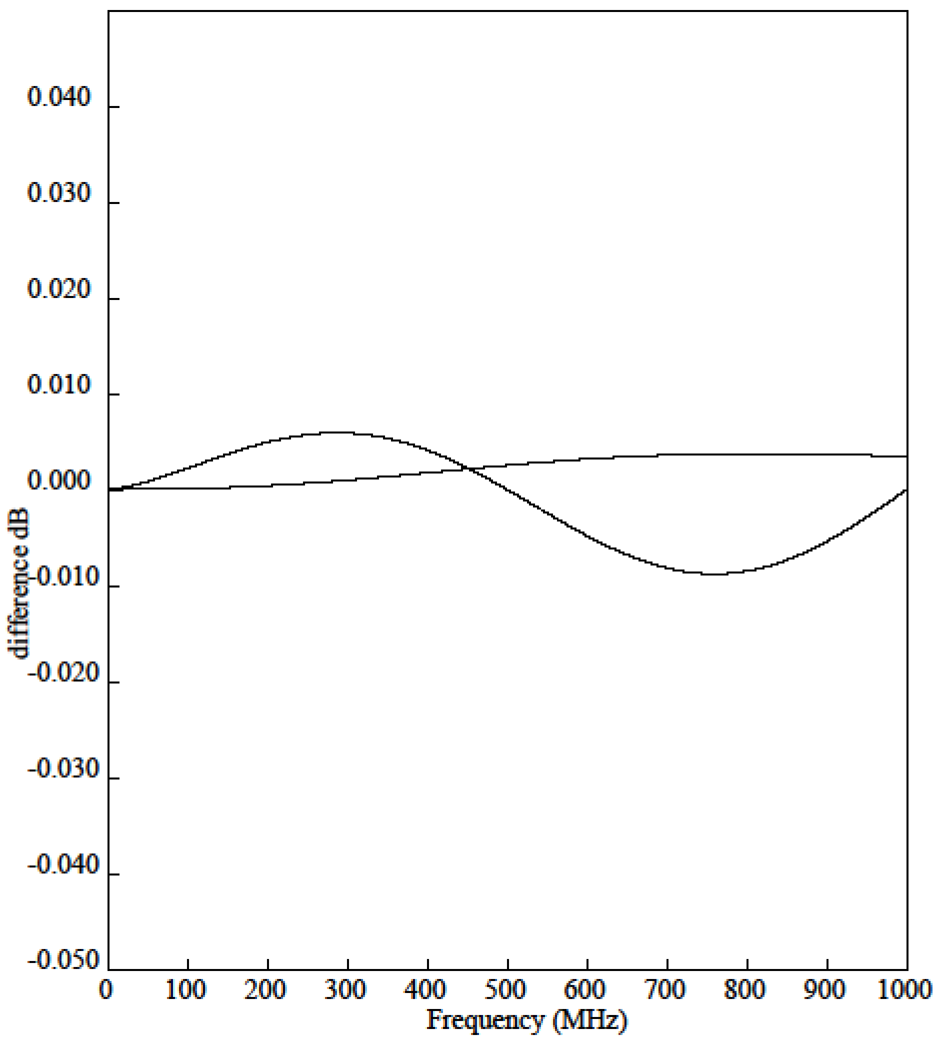

Figure 3. Simulation of S11 error for open airline assuming perfect 50 ohm calibration load. Thin line curve is for 5% error in conductivity.

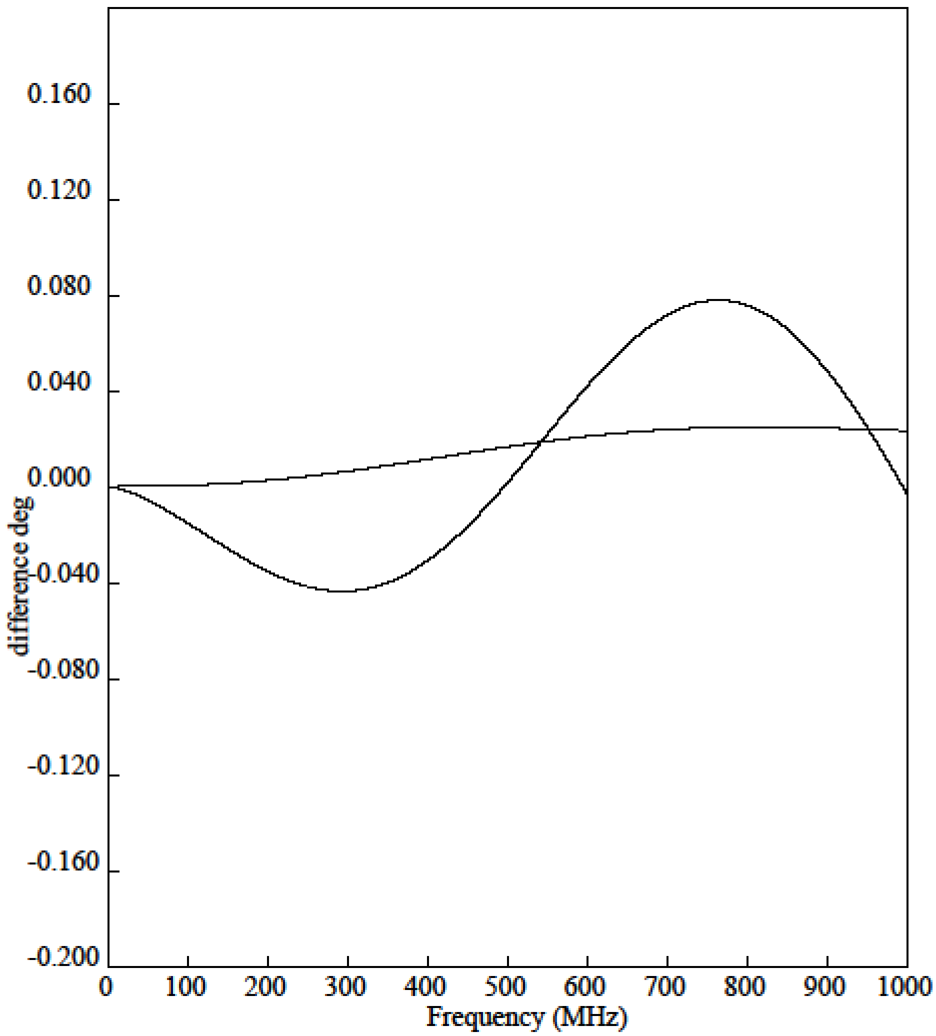

Figure 4. Effect of S11 error on phase.