EDGES MEMO #109

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To: EDGES Group

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Subject: Some tests of cable stability for S11 measurements.

1] Simple tests with 10 feet Temp-Flex 19 AWG FEP 50 Ohm cable

a) Applied heat to 10 dB attenuator on end of cable going from 24 to 34 C offsets S11 by -0.1 dB (owing to change of resistance of load). Returns when cooled back to 24 C.
b) Applied heat to cable with fingers about 6” from VNA. 0.1 dB and 0.1° p-p ripple with period of 36 MHz (28 ns) results from temperature change of 24 to 34 C. A similar effect at 18” from VNA. Returns when cooled back to 24 C.
c) Bending produces ripples ≈ 0.1 dB p-p and only returns if the cable returns to its original shape without any permanent deformation.
d) Unwinding and winding back into a coil typically produces 0.15 dB p-p which recovers at the level of ~0.02 dB.
e) Heating the entire cable from 22 to 30 C produces 0.1 dB p-p ripples which recovers upon cooling.

2] Some simulations to gain insight into the mechanisms

Case 1 – VNA has perfect 50 ohm match and cable is 50 ohm.

a) Cable electrical length increases – S11 phase changes by cable 2-way delay.
b) Cable impedance changes owing to a 1000 ppm change in capacitance – S11 ripples in amplitude by 0.05 dB p-p

Non-uniform changes.

c) Cable impedance changes owing to a 1000 ppm change in capacitance for 10% of the cable – S11 ripples in amplitude by 0.09 dB p-p
d) Same as c for 1% of cable – S11 ripples amplitude by 0.01 dB p-p

Case 2 – VNA and cable impedance differ by 5%

Uniform changes

a) Cable electrical length increases by 500 ppm – S11 ripples by 0.02 dB p-p
b) Increased to 0.1 dB p-p

Non-uniform changes

c) Increased to 0.2 dB p-p
d) Increased to 0.02 dB p-p

These simulations indicate that the changes of S11 observed by heating and/or bending a flexible cable arise from a combination of electrical length and cable impedance. A miss-match between the VNA and cable impedance increases the effects of the cable changes. These effects are also reduced by using a shorter cable which suggests that adding a short flexible cable to a longer section of phase stable semi-rigid might minimize changes with the flexing required to go from connecting the VNA to connecting the LNA to the antenna.

Theory of bent coaxial cable

J.J. Krempasky, (IEEE Trans-MIT, V38, no. 6, June 1990), has solved the perturbed electric and magnetic fields in a curved section of coax. From this he estimated the dependence of the propagation constant upon the radius of curvature for 141 cable (see figure 5 of Krempasky.) This result corresponds to a change of delay of

$$10^5 \left(a/R\right)^2 \ ppm$$

Where (a/R) is the ratio of inner radius of the outer conductor to the radians of curvature. This is a very small effect of only 2 ppm for a 0.05" cable bent into a curvature with 12" radius and doesn't explain the large observed change with bending which arises due to a change in impedance or equivalently from an added reflection in the cable

The effect of the perturbed E and H fields on the impedance is also very small and doesn't explain the observed changes. As a consequence we resort to a mechanical explanation. One possibility is a change in eccentricity. EM theory shows that any eccentricity decreases the cable impedance which is the direction of the observed changes.

Summary of cable modeled effects on 0.05" radius cable of 1 ns 2-way delay on S11 measurement of -20 dB reflection at the end of the cable.

Change mode to cable	Δ dB	Mechanism used in model	Note
Change of 10° C FEP dielectric	0.005	Change of dielectric	1
Bending into 12" radius	0.00003	Change of E&H fields	2
Bending into 6" radius	0.0001	Change of E&H fields	2
Bending into 12" radius	0.001	Coax becomes eccentric	3
Bending into 6" radius	0.01	Coax becomes eccentric	3
Bending into 12" radius	0.1	Eccentric with 10% bias	4
Bending into 6" radius	0.3	Eccentric with 10% bias	4

Notes: 1] Assumes 50 ppm/°C

2] Theory of Krempasky

3] Assumes coax develops eccentricity upon bending. Uses EM theory for impedance perturbation

4] Assumes cable is not perfect and has an initial eccentricity of 10%

Tests with other cable types

Some simple tests were done with 6” lengths of RG316DS and 18” lengths of Gore Flex and LMR-240. The effect of bending the Gore Flex and LMR-240 were similar with about 0.1 dB increase in S11 for a bend radius of about 12”. The change of S11 with bending was significantly smaller for the 6” length. Different samples of the 6” cable gave similar results but significantly different in detail indicating that some invisible feature of the cable like its eccentricity or ovality differs from sample to sample. Tests made with a 35” length of micro-coax UFB197C whose phase vs flexure was specified to be at the 1° of phase level at 18 GHz demonstrated that for this cable changes with flexure of under 0.02 dB can be achieved.

Tentative conclusions

For EDGES-2 use SI02-270 quartz semi-rigid cable or airline from the LNA to within about 5 to 12” of the antenna port. Use a 5 to 12” flexible cable to complete the connection. The small radius combined with a length much shorter than a wavelength should minimize the change with flexing in our frequency range.