EDGES MEMO #363

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To: EDGES Group

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Subject: Automated tests of VNA warm-up needed for highest accuracy

A simple test of the Agilent N9923A VNA warm-up time was made using EDGES-3 to automatically measure the calibration SOL on the 8-position switch. The cycle using 100 traces per measurement was repeated over and over covering a total of an hour. The calibrated s11 of load which equals the assumed s11 value of the load is perfectly estimated for each SOL cycle as required by the equations. For a check the s11 value of the load is then calculated using the calibration of an adjacent SOL cycle.

If the VNA is in an idle state for the start of the cycling the accuracy check results in an error in s11 of about 1e-3 fractional parts for a VNA power level of -30 dBm which improves to about 2e-4 after about 30 minutes. If the VNA has been off for several hours and the cycling is started from "cold" the initial fractional error can be as high as about 1e-2. It approaches 1e-3 in 30 minutes and 2e-4 in one hour. Similar results are obtained using the VNA power level set to full power.

Table 1 shows how the VNA measurement of the load s11 approaches the true value using the calibration from the last SOL cycle.

Cycle number	Time 16 June 2021 EDT	Fractional error
1	21:12	2.1e-3
2	21:25	1.4e-3
3	21:39	9.3e-4
4	21:52	6.0e-4
5	22:05	4.0e-4
6	22:18	2.4e-4
7	22:32	1.3e-4
8	22:45	6.6e-5
9	22:58	6.5e-5
10	23:11	0

Table 1. The difference of the calibration load s11 calculated using the VNA s-parameters determined using the last cycle in the series of 10 SOL cycles started from the VNA in an idle state following powering up at about 18 hours EDT.

Similar s11 errors when expressed in fractional units were obtained for the open and short and for the errors measuring an attenuator in a separate test.

The current plan for EDGES-3 is to only power up the VNA for the measurements needed for calibration and antenna s11. The s11 measurements only require about 100 traces to achieve low enough noise so that the time to perform the entire set of s11 data is dominated to the warm-up time of about one hour. The proposed sequence is to turn on the VNA and start it running creating start-up data which will not be used for a total EDGES power consumption for frontend and backend, Nuvo not running fastspec, nominal thermal power, fans etc. of 14 + 5.6 + 25 + 15 = ~ 60w and run the s11 for an hour following the one hour warm-up for total of 2 hours. Following the S11 data turn off the VNA and run the calibration spectra for a power consumption of 5.6 + 25 + 72 = ~ 105w. Leaving the VNA on in an idle state would only add about 2w but the VNA generates some RFI and since it is not in the inner shielded box this could leak into the antenna as discussed and quantified in memo 299 but tests could be made in the field to see if leaving the VNA turned on has any advantage.

In summary the Fieldfox VNA requires a "warm-up" time during which it is taking traces in order to achieve an accuracy of 1e-4 fractional units. The reason the VNA needs to stabilize while running is the result of the large increase in power consumption from about 2 to 14 watts which presumably increases the temperature of the internal electronics and results in a change of it's calibration. While the need for time to warm-up is mentioned in VNA data sheets the dependence on operating state is not mentioned. Ninety minutes warm-up is mentioned in the Fieldfox data sheets.

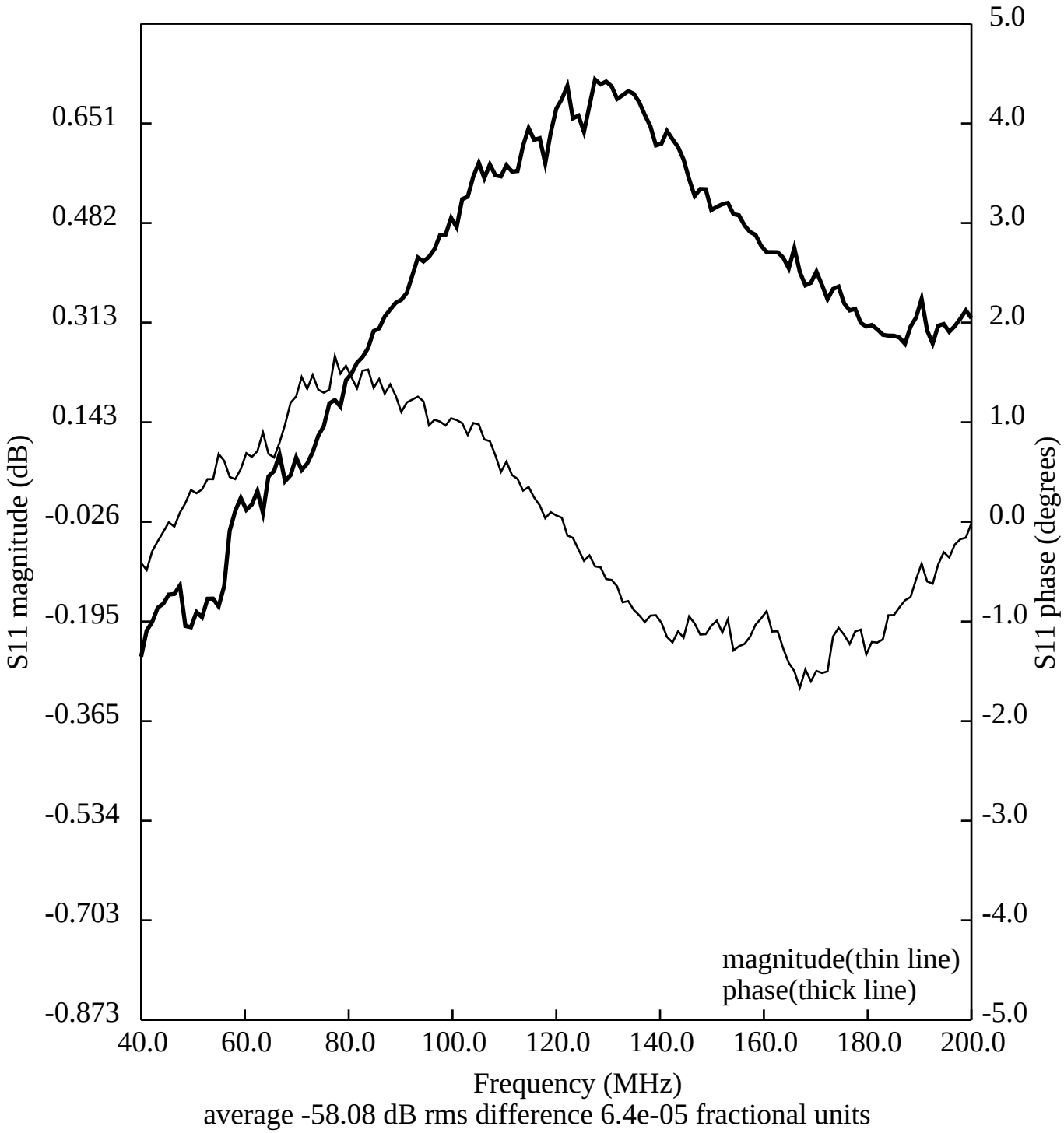

Figure 1. Plot of VNA error for cycle 9 using the calibration of cycle 10