Estimation of the Reflection Magnitude Accuracy with the Agilent E5061A VNA at -30 dBm

Raul Monsalve, Nivedita Mahesh, Thomas Mozdzen
CASA, University of Colorado Boulder
SESE, Arizona State University

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Measuring the reflection coefficient of the EDGES receiver input requires a low VNA power to avoid saturation. Since 2015 we have used between -30 and -35 dBm for the Low- and High-Band receivers. Throughout 2016 and 2017 we have used the Agilent E5061A benchtop VNA for this reflection measurement.

Here we estimate the accuracy of the reflection magnitude at a power of -30 dBm with the same VNA. To estimate the accuracy, we compare the calibrated VNA measurement of four open ended attenuators (3, 6, 10, and 20 dB, with approximate reflection magnitudes of -5.6, -11.6, -20.3, -30 dB, respectively) with the reflection derived from the DC resistance of the attenuators measured with a precision multimeter (Fluke 8845A).

The reflection measurements were done with the same frequency resolution (250 kHz) and averaging (30 traces) as for the receiver input. Three repetitions were done for each attenuator, after disconnection and reconnection at the VNA port.

See Report #74 (`http://loco.lab.asu.edu/loco-memos/edges_reports/report_20160720.pdf`) for a similar accuracy estimation at a VNA power of 0 dB with the same VNA (E5061A), as well as at $+5$ dBm with a portable Agilent Fieldfox VNA, a long cable, and a four-position switch.

The salient points of this test are:

1. Using the DC resistance of the attenuators as a reflection reference is only valid to first order. The frequency-dependence of the reflection is different for each attenuator and, thus, even if the VNA measurement were perfect, the DC reference will be closer to the VNA measurement at different frequencies for each attenuator. With this in mind, the agreement of the calibrated measurements with respect to this reference is, on average across frequency, as follows: (a) 0.004 dB at -5.6 dB, (b) 0.02 dB at -11.6 dB, (c) 0.05 dB at -20.3 dB, and (d) 0.05 dB at -30 dB. These differences cannot be explained only by realistic errors in the DC resistances of the attenuators and the 50-Ω calibration load (whose DC resistance we use in the VNA calibration). Repetitions of this test, as well as more tests at different power levels, are needed to determine with certainty if the accuracy in the VNA measurement is a function of the power level.

2. The connection repeatability at the VNA port is close, to within a factor of a few, to the noise level of these reflection measurements. As an example, at ~ -30-dB reflection, the noise level and the repeatability are both ≈ 0.01 dB.

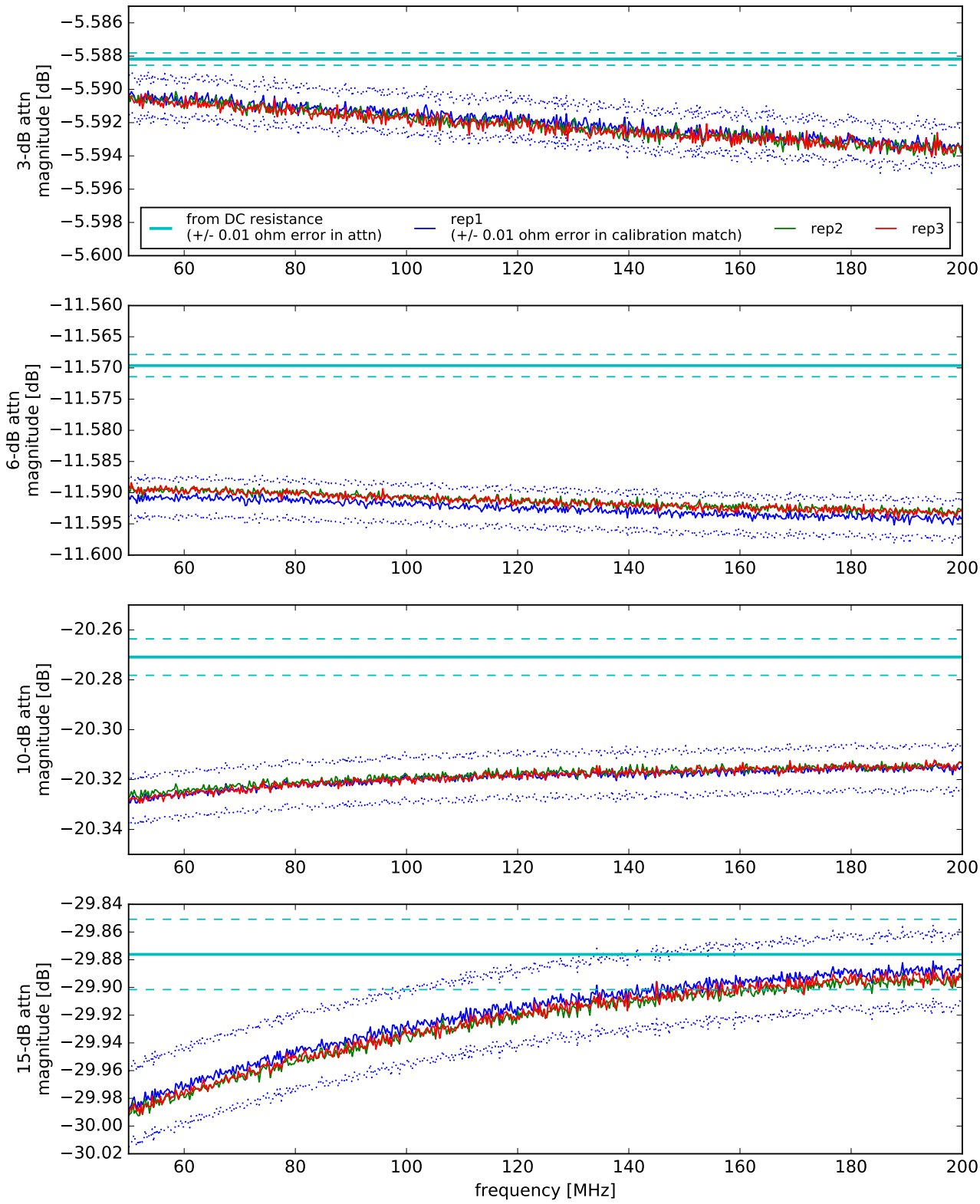

Figure 1: Comparison of the calibrated VNA measurement of four attenuators (3, 6, 10, and 15 dB) at a power of -30 dBm, with the reflection reference from the DC resistance of the attenuators. The VNA used is the Agilent E5061A. Three repetitions were performed for each attenuator. Dashed lines represent uncertainty bands from realistic uncertainties ($\pm 0.01\Omega$) in the measured resistances of the attenuators and the 50-Ω calibration load.