# LoCo Lab EDGES Memo 143
# Evaluation of the Keysight P9370A USB VNA

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## 1 Introduction

Here we show the measurements of three open-ended attenuators with the portable Keysight P9370A USB VNA. We compare these VNA measurements with the reflections derived from the DC resistance of the same attenuators. This was done to evaluate the performance and accuracy of this VNA.

Specifically, we measured a 3-, 6-, and 10-dB attenuator. The three attenuators were measured twice, once at each of the two ports of the VNA, in order to determine the consistency of the ports as well as the measurement repeatability. At both ports we also measured an open, short, and 50-Ω load. These measurements were used to manually calibrate offline the VNA ports and attenuator measurements.

The settings of the VNA were:

- Power: 0 dBm
- Frequency range: 1-300 MHz
- Frequency resolution: 1 MHz
- IF Bandwidth: 10 Hz
- Trace averaging: No

We did not have a proper calibration kit available, such as the Keysight 85033E calkit typically used in EDGES. Therefore, for calibration we used generic OSL devices. In the analysis we modeled these devices with the models for the Keysight 85033E OSL devices, but with the DC resistance of the actual 50-Ω load used. This approach provides enough accuracy for an initial evaluation of the reflection measurements with this VNA.

## 2 Results and Discussion

The results are shown in Figure 1. We note the following main features in the measurements.

1. The agreement between the VNA reflection measurements and the predictions from the DC resistances is good, especially toward low frequencies where the differences are $\lesssim 0.02$ dB.
2. The differences between the measurements with Ports 1 and 2 of the VNA are small and, in magnitude, comparable to the differences with the DC resistance predictions at low frequency. It is interesting to see that, in phase, the results from Port 2 are lower than with Port 1 for the three attenuators.
3. The measurement noise is very low ($< 0.001$ dB in magnitude). This is the result of the low value used for the IF Bandwidth (10 Hz). It is a very good aspect of this instrument, especially considering that no trace averaging was used.

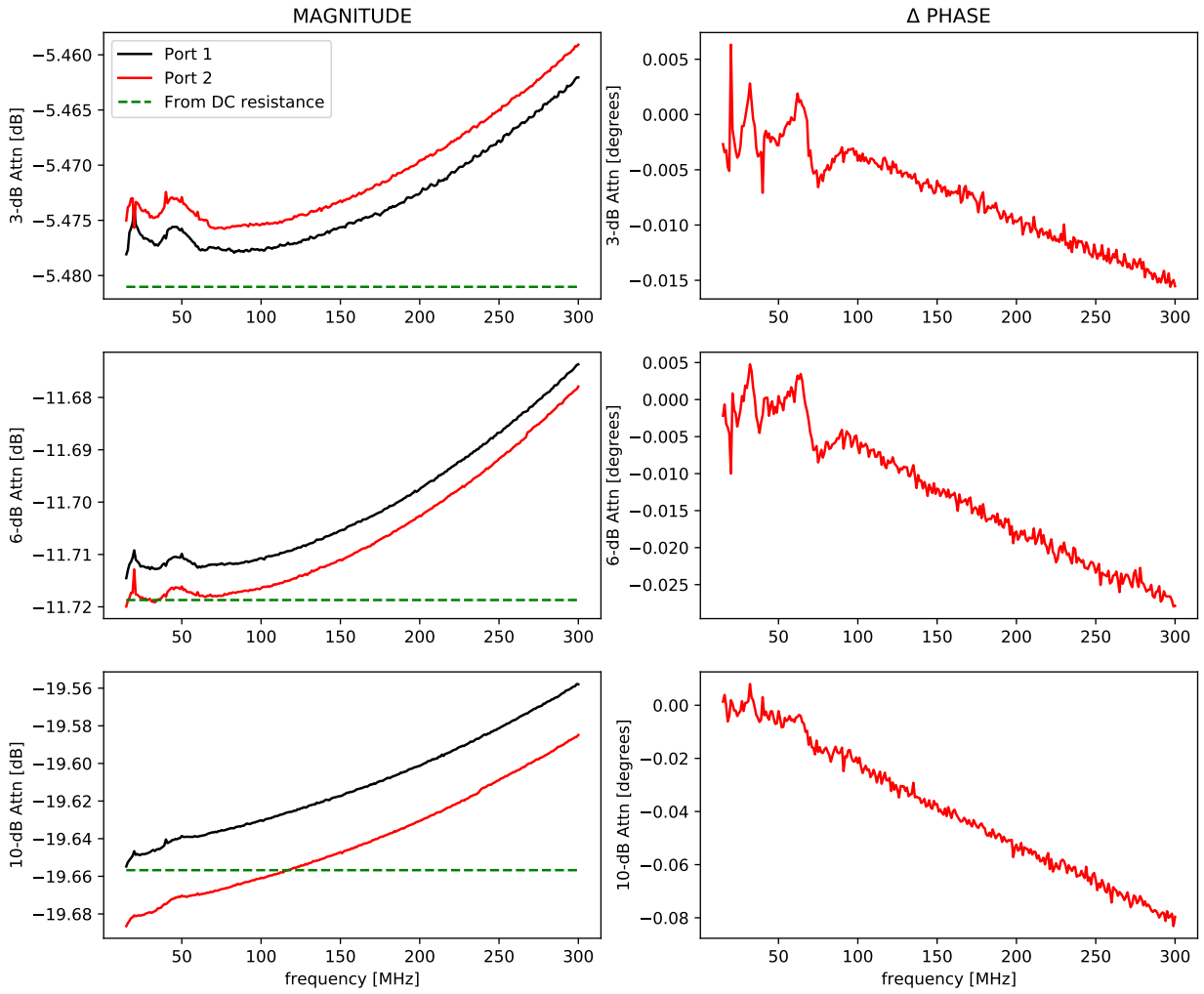


Figure 1: Calibrated measurements with the Keysight P9370A VNA. In the panels of the right column we show the phase difference between the measurements at the two ports for the three attenuators, computed as Port 2 - Port 1.

4. We notice a low-level ($<<$ 0.01 dB) step-like 'jump' at $>$ 200 MHz in the magnitude of the 6- and 10-dB attenuators measured with Port 2 (red line).

5. There is structure in the measurements in the range $15-60$ MHz not consistent with noise or expected from the devices under test. This unwanted structure is seen in magnitude and phase, and with both ports. In magnitude, this structure has an RMS $\approx$ 0.002 dB. Therefore, although unwanted, this structure does not dominate the uncertainty budget at $15-60$ MHz.

6. Although our measurements extended down to $1-15$ MHz, we do not show these data in the figure because they contain even larger structure, most likely due to inferior performance of the VNA. More tests and measurements are necessary to determine the origin of this structure and if it is possible to eliminate. This low-frequency structure is the most negative aspect of the Keysight P9370A VNA we have available.