Estimating the Accuracy of the Antenna S11 Measurements at the MRO

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Description

We test the accuracy of the field setup for measurement of the antenna S_{11} with a similar setup in the lab at ASU. It consists of an S_{11} *verification box* containing a 4-position switch with inputs connected to generic Open, Short, and $50 - \Omega$ Load standards, and the fourth input connected to the DUT input of the box. The output of the box is connected through an LMR-250 cable to a Fieldfox VNA. The switching can be controlled either manually or from a computer.

The calibration of the DUT measurements consists of an initial calibration at the switch assuming reflection values of 1, -1, and 0 for the internal standards. Then, the calibration plane is shifted to the input of the verification box using the S-parameters of the path between the switch and the box input.

The S-parameters of the initial path of the box are obtained from a one-time measurement of the internal standards at the switch and the absolute calibration standards from the Keysight/Agilent 85033E kit at the box input. These absolute standards are modeled accurately using all their known parameters and DC resistance.

In summary, after doing measurements with a long (100-m) and a short (3-ft) cable between the verification box and the VNA, the estimated accuracy in magnitude is of ~ 0.02 dB and ~ 0.05 dB at reference levels of ~ -11.7 dB and ~ -20.2 dB, respectively. This applies to the setup in the ASU lab, not necessarily to the one in the field which uses a different Fieldfox VNA. These numbers are given relative to measurements at the port of a benchtop Agilent E5061b VNA. Finally, these numbers are at 200 MHz. At lower frequencies the differences are smaller. For the phase, the agreement with the benchtop VNA is within 0.1° for a magnitude ~ -20.2 dB, and better at ~ -11.7 dB.

Going from a long to a significantly shorter cable did not improve dramatically the measurement accuracy. Thus, some of the residual errors can be attributed to the Fieldfox VNA itself. Thus, it would be important to characterize the Fieldfox VNA, in particular the one in the field, relative to the benchtop unit.

S-parameters of input internal path

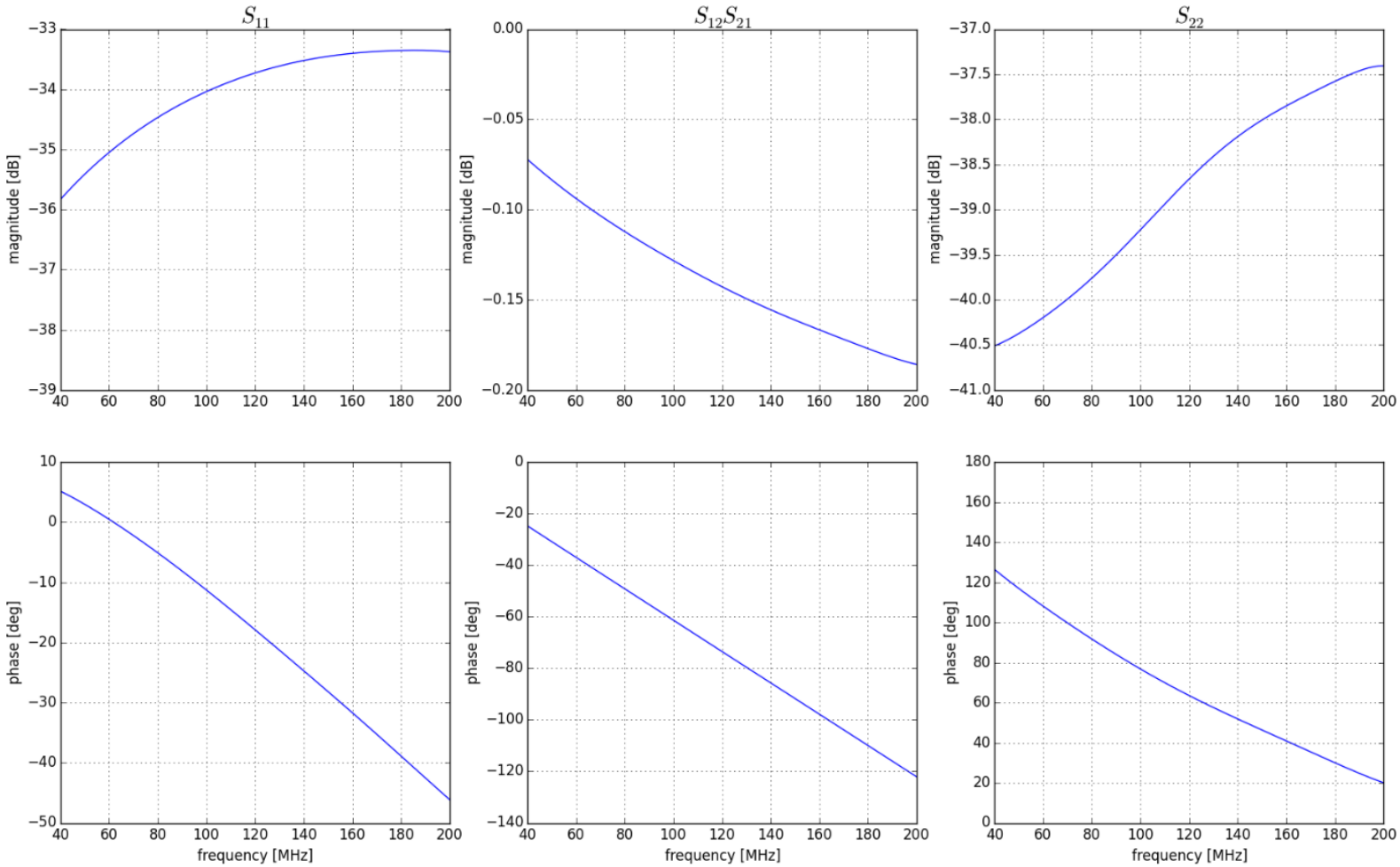

Figure : (1): These S-parameters were obtained from measurements of the internal reference standards and the external absolute reflection standards from the Keysight 85033E calkit. In this nomenclature, port 1 faces the internal switch, and port 2 faces the DUT input.

Initial Performance Verification (Magnitude)

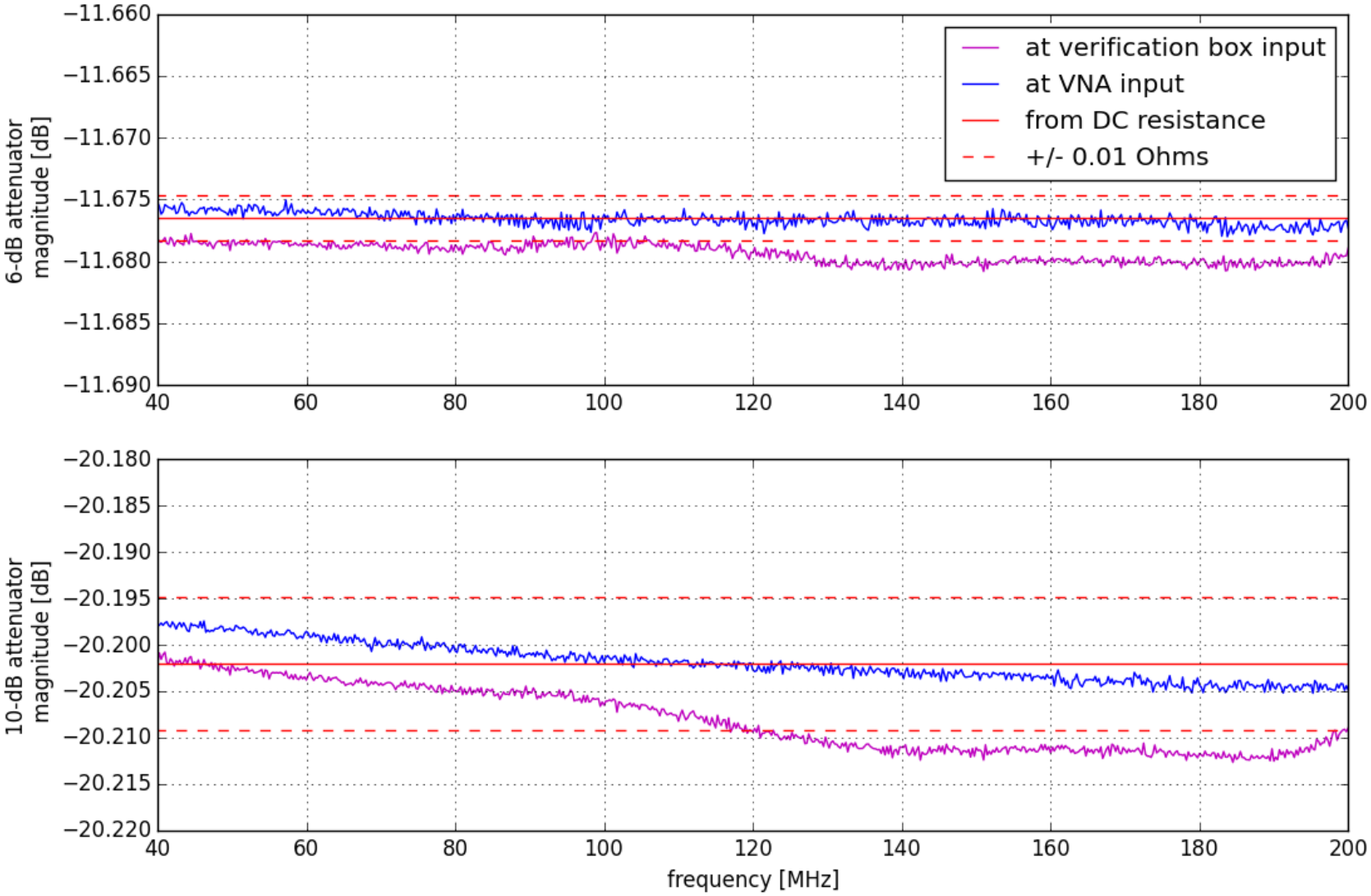

Figure : (2): Two attenuators, of 6-dB and 10-dB, are measured at two locations. First (magenta line) at the input of the verification box and using a 3-ft cable between the box and the benchtop E5061b VNA (NOT THE FIELDFOX VNA), and second (blue line) directly at the input of the benchtop E5061b VNA. Overall, results from the VNA input agree better with projections from the DC resistance. Disagreements for the results using the verification box are at the $\sim$ 0.01-dB level.

Initial Performance Verification (Phase)

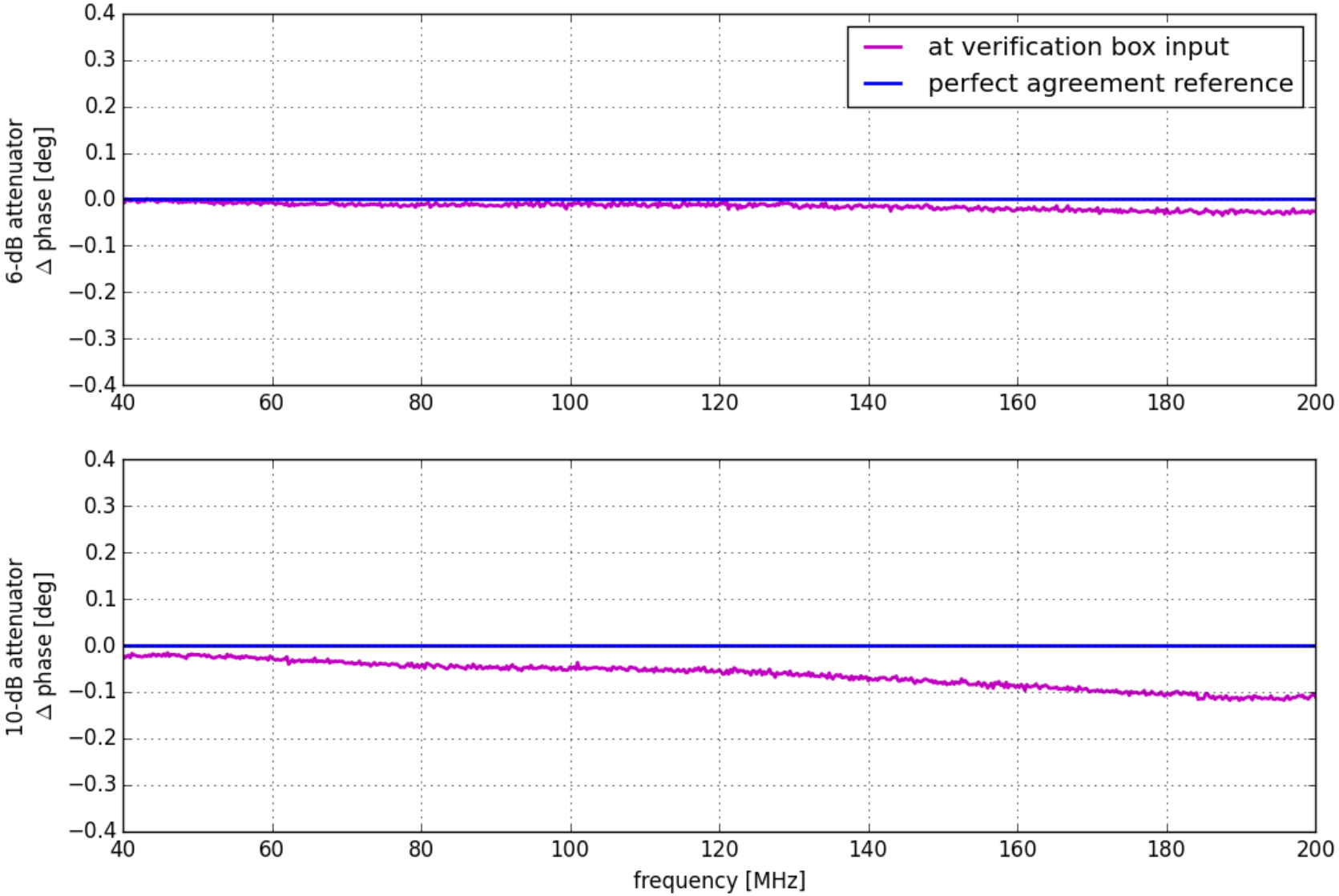

Figure : (3): Same as Figure 2 but for the phase. Results (magenta line) are presented as differences between measurements at the input of the verification box and the VNA input. Disagreements are within $\sim 0.03^\circ$ for a magnitude of ~ -11.7 dB, and $\sim 0.1^\circ$ at ~ -20.2 dB.

Long Cable Measurement with Fieldfox VNA (Magnitude)

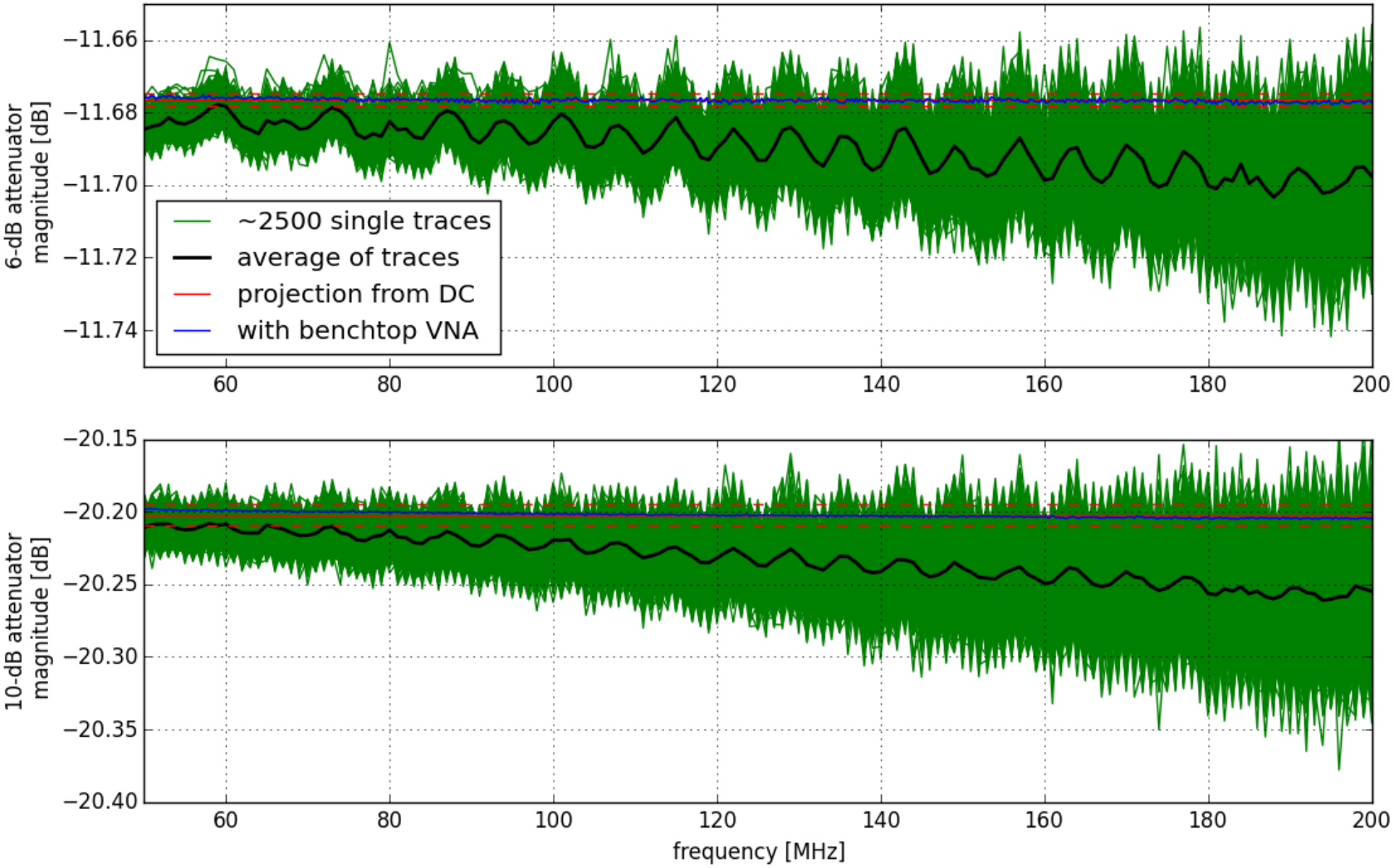

Figure : (4): Measurement of the attenuators with a long (100-m) cable between the verification box and the Fieldfox VNA. The green lines correspond to the thousands of measurements, and the black line is their average. In the original single traces there are frequency ripples on $\sim$ 1-MHz and $\sim$ 10-MHz scales. When averaged (black lines), only the 10-MHz ripples remain. At 200 MHz, the differences between the averages and the DC predictions (red lines) or direct measurements with the benchtop VNA (blue lines) are at the level of $\sim$ 0.02 dB and $\sim$ 0.05 dB for reference levels of ~ -11.7 dB and ~ -20.2 dB, respectively.

Long Cable Measurement with Fieldfox VNA (Phase)

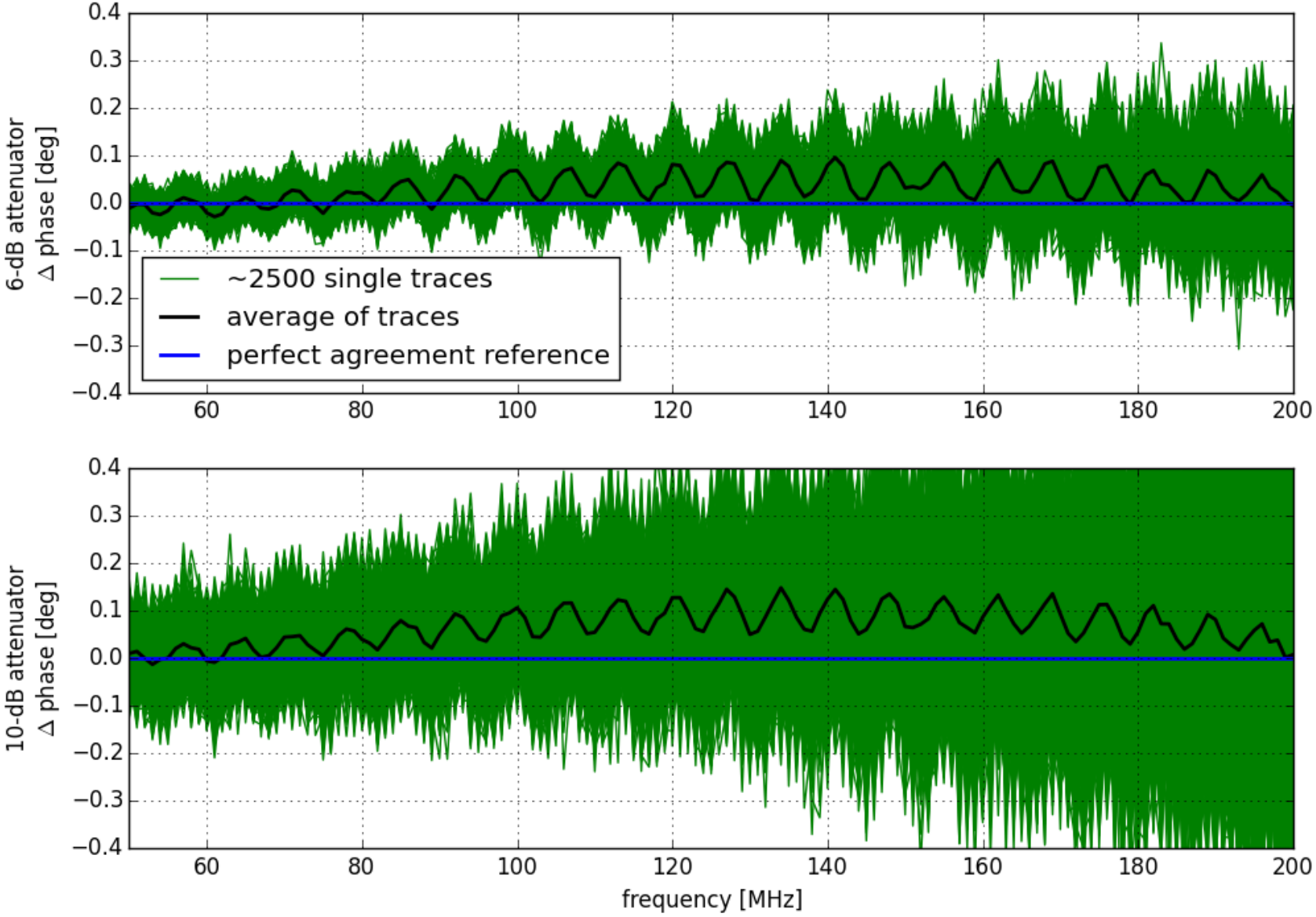

Figure : (5): Same as Figure 4 but for the phase, presented as differences with respect to the measurement at the input of the benchtop VNA. The differences between the averages (black lines) and the reference are within $\sim 0.1^\circ$.

Short Cable Measurement with Fieldfox VNA (Magnitude)

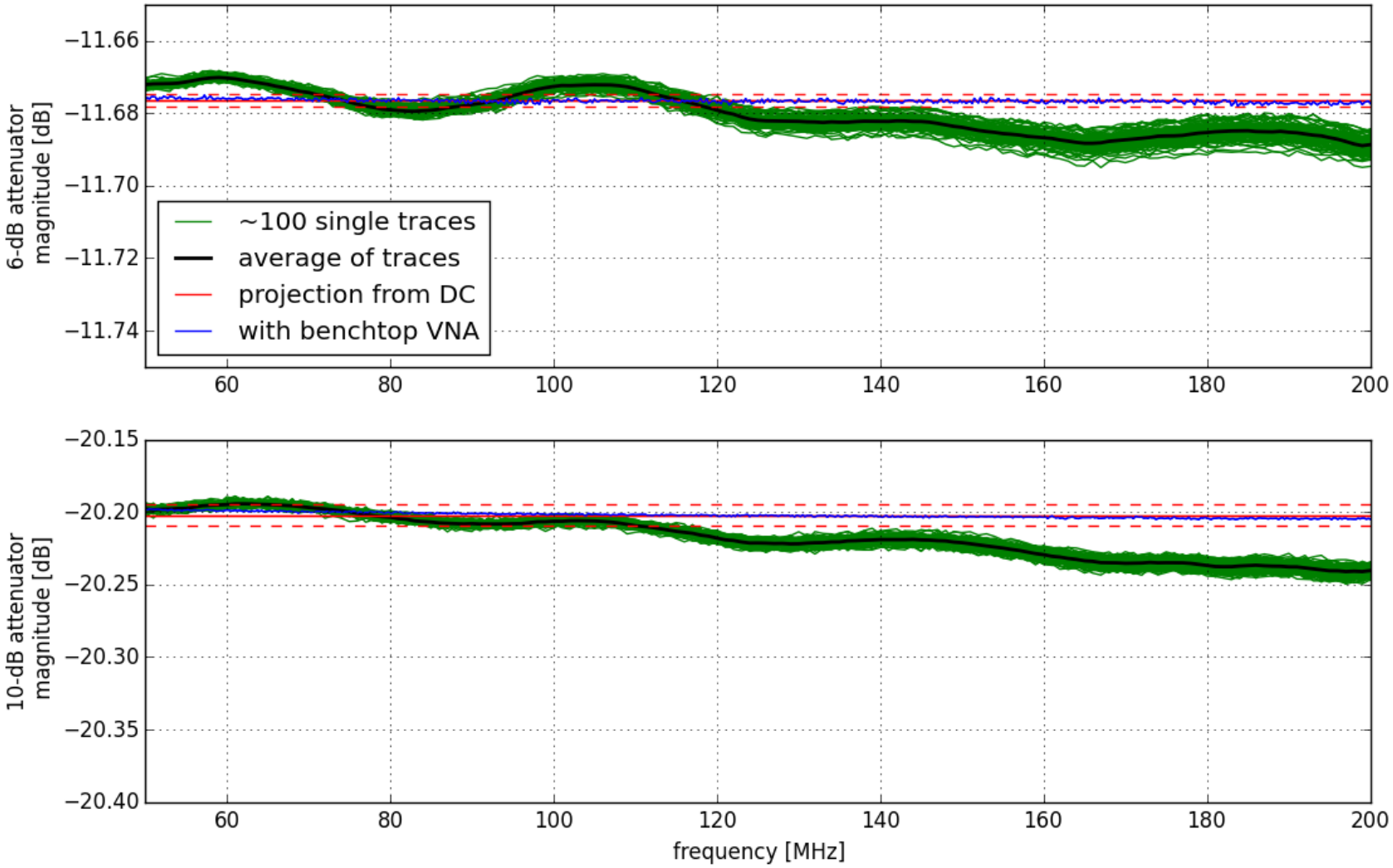

Figure : (6): Measurement of the attenuators with a short (3-ft) cable between the verification box and the Fieldfox VNA. The green lines correspond to the one hundred measurements, and the black line is their average. There are frequency ripples on a $\sim$ 50-MHz scale. At 200 MHz, the differences between the averages and the DC predictions (red lines) or direct measurements with the benchtop VNA (blue lines) are at the level of $\sim$ 0.02 dB and $\sim$ 0.05 dB for reference levels of ~ -11.7 dB and ~ -20.2 dB, respectively.

Short Cable Measurement with Fieldfox VNA (Phase)

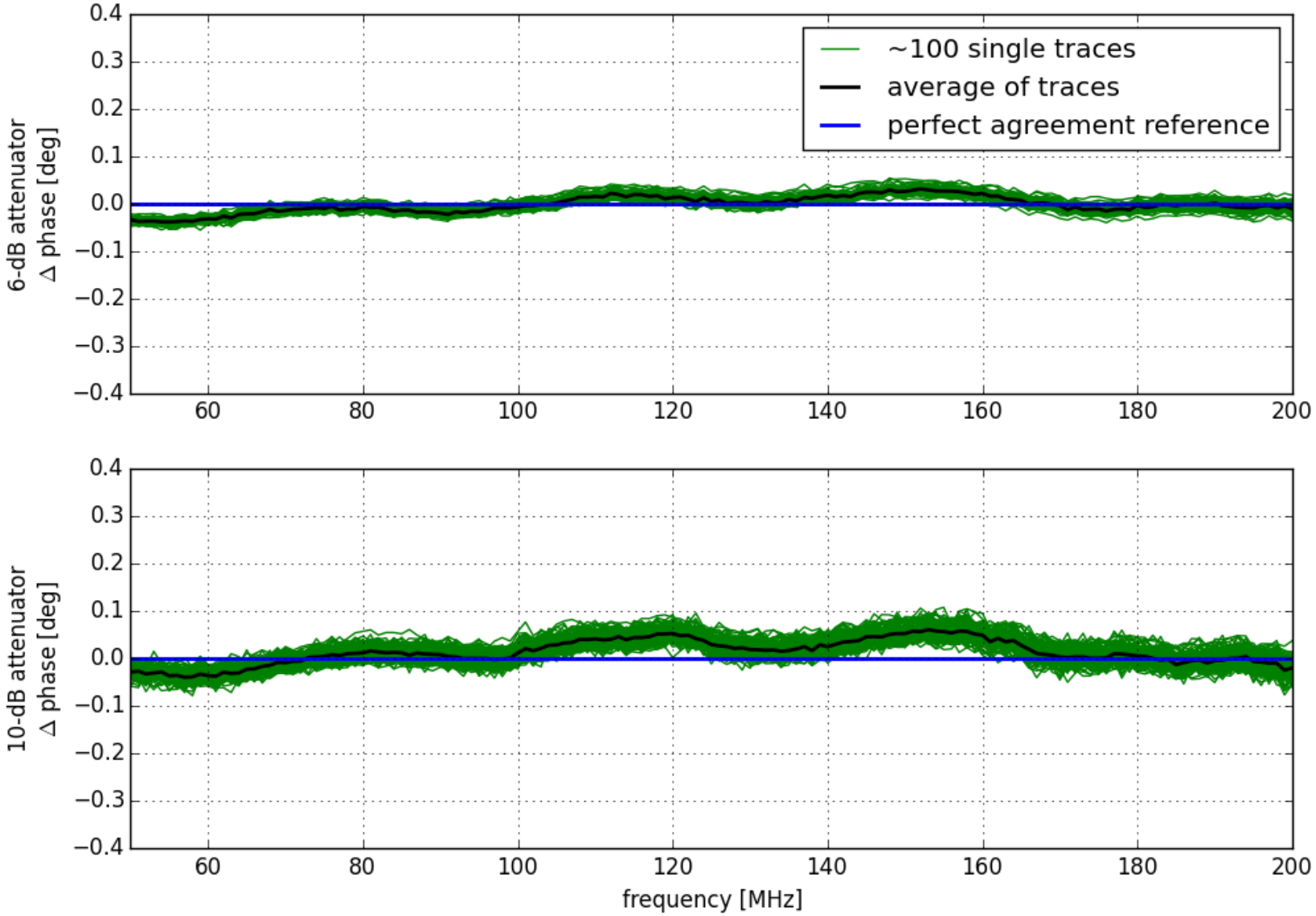

Figure : (7): Same as Figure 6 but for the phase, presented as differences with respect to the measurement at the input of the benchtop VNA. The differences between the averages (black lines) and the reference are within $\sim 0.05^{\circ}$.

Comparison Summary (Magnitude)

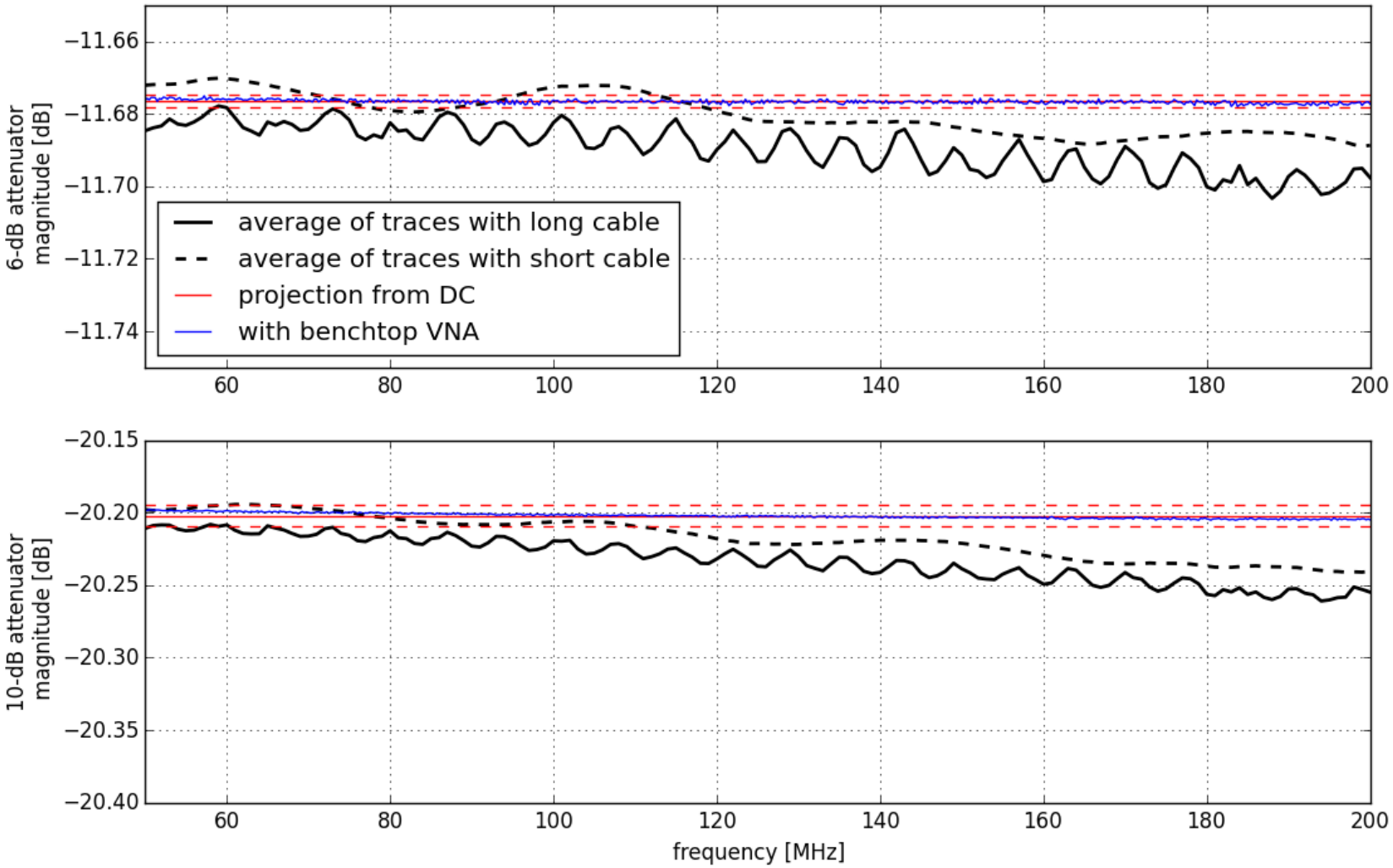

Figure : (8): The average of traces with the long cable (solid black line) has a larger RMS difference with the DC prediction (solid red line) than that for the short cable (dashed black line). The frequency slope is similar in both cases, which at higher frequencies makes them depart from the significantly flatter measurements at the input of the benchtop VNA (blue line).

Comparison Summary (Phase)

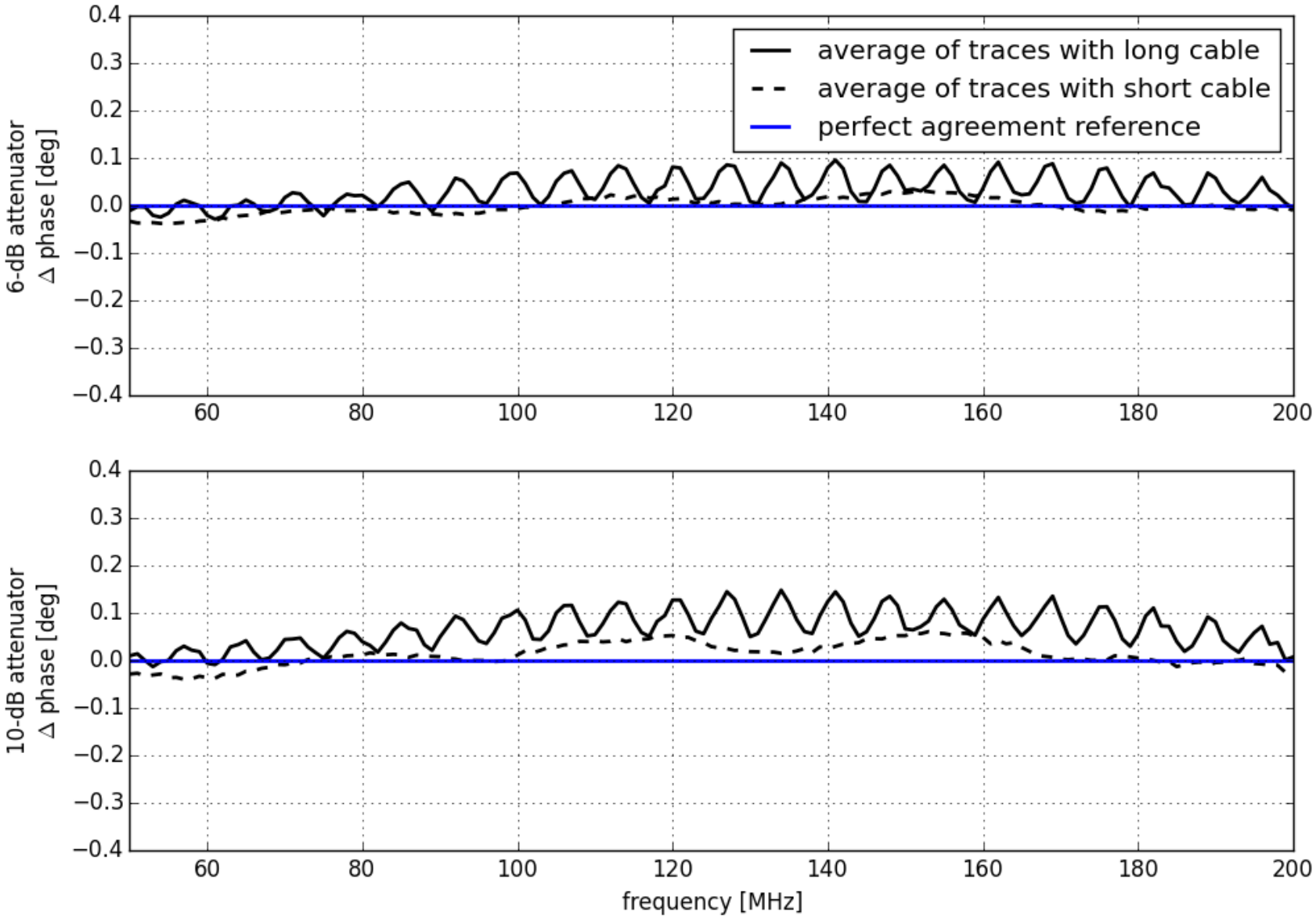

Figure : (9): Same as Figure 8 but for the phase. Differences with respect to the reference are within $\sim 0.1^\circ$, but slightly better ($\lesssim 0.05^\circ$) for the short cable.

Stability of the Long Cable Measurements (Magnitude)

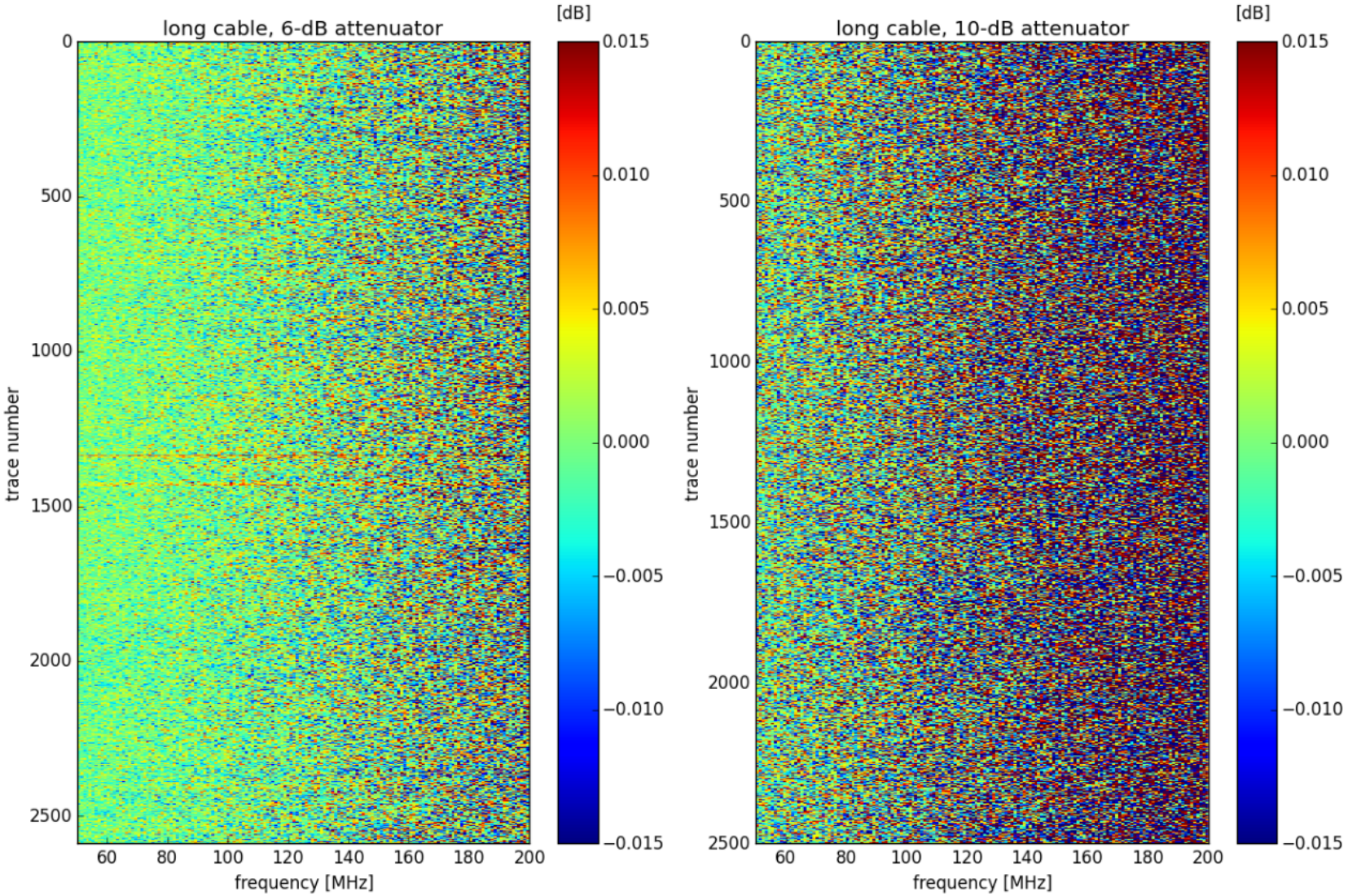

Figure : (10): Differences between the average of the long measurements and the individual traces. They are dominated by noise, suggesting that the setup was very stable during the long measurements.

Stability of the Short Cable Measurements (Magnitude)

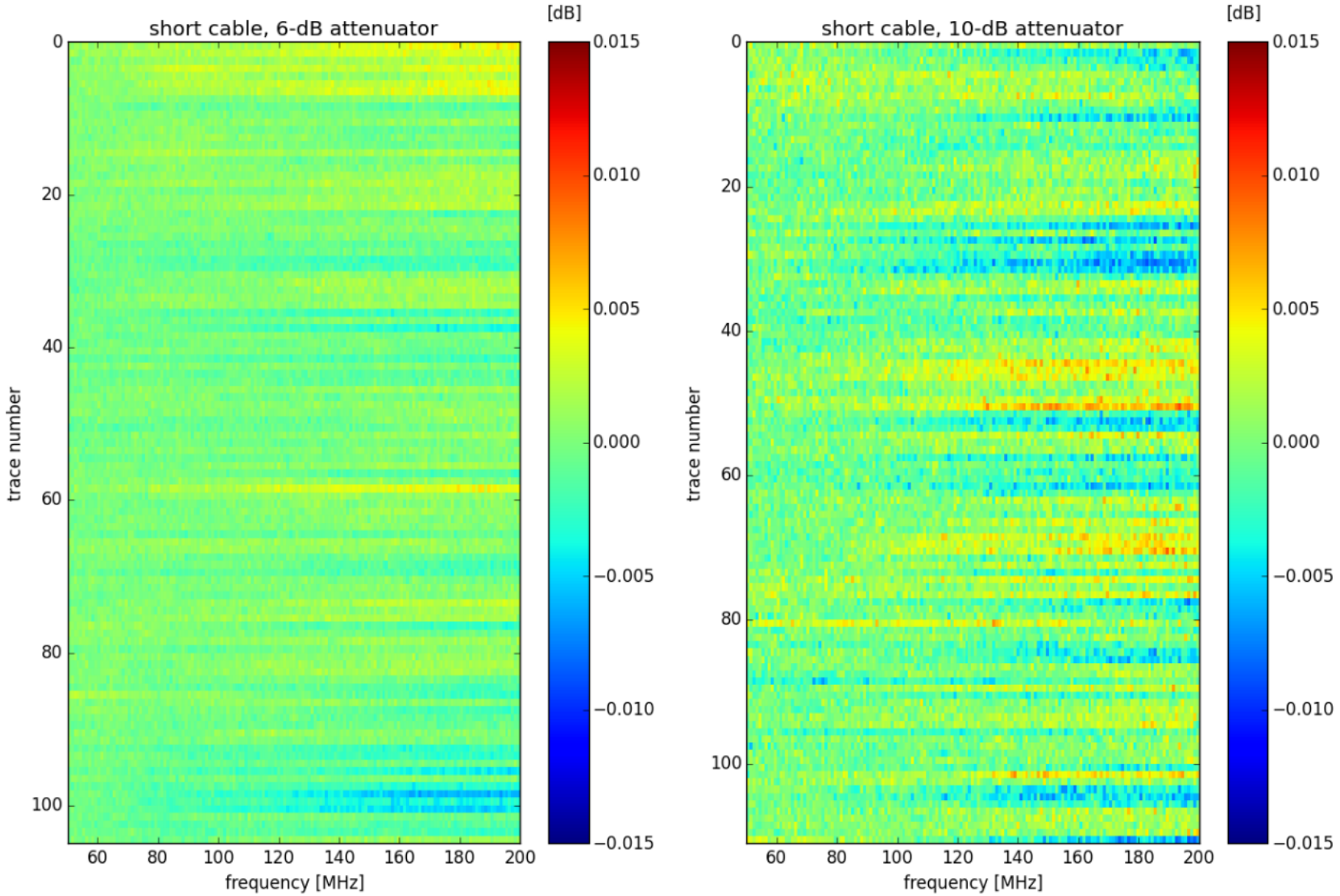

Figure : (11): Differences between the average of the long measurements and the individual traces. They are within ± 0.01 dB, not following any systematic trend.