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Subject: Stability measurements of VNA, coaxial cable, and antenna with Roberts balun

1 Description

This document presents some of the measurements performed so far on the roof top of the SESE building. All of them were conducted with the R&S ZVL3 VNA (up to 3 GHz) with the following settings:

- frequency range: 10 - 500 MHz
- frequency resolution: 1 MHz
- power level: 0 dBm
- trace averaging: 10 traces
- bandwidth: 100 Hz
- time resolution: 2 min

2 VNA-Only Measurements

In these measurements the VNA is located outside, exposed to changes in air temperature of more than 10 degrees between day and night. Different loads were connected directly to the VNA port without using a cable. Each measurement lasted two days or more.

The loads are: open standard (*open* device used for calibration, instead of actually leaving the port open), short standard (same as open), attenuators of 150 and 83.5 Ω input resistance (open ended), and one 50.45 Ω terminator.

On the following pages, figures 1 to 5 summarize the results for each load:

1. Plots on row 1 correspond to the first trace of s_{11} after calibration.
2. Plots on row 2 correspond to the evolution of traces with time. A checkered pattern is evident in most cases.
3. Plots on row 3 correspond to the traces sorted by ambient temperature. There are empty lines because the temperature domain is not evenly mapped.
4. Plots on row 4 correspond to the scatter of traces for 1-degree drift in temperature. The scatter is quantified as the largest difference between traces within 1 degree at each frequency, minus the white noise. Green lines come from all the 1-degree divisions and the black line is the median.

Table 1 summarizes the results of the plots for the scatter of s_{11}. The temperature coefficient for the attenuators is $\sim$ 10 mΩ/K and for the 50 Ω load it is $\sim$ 5.5 mΩ/K. At their average level of reflection coefficient this is equivalent to a change in reflection coefficient of $<$ 0.002 dB for the attenuators and 0.07 dB for the 50 Ω load. This is roughly 10% or less of the drift reported in the table, so we can say that the drift is primarily due to the instrument and not the loads.

Table 1: Scatter in s_{11} for changes of 1 degree in ambient temperature where the VNA is located. White noise has been removed from scatter. Results are valid for frequencies above 50 MHz. Measurements were conducted with no cable. Contribution to the scatter due to temperature coefficient of loads is 10$\%$ or less.

load	average $\|s_{11}\|$ [dB]	scatter $\|s_{11}\|$ [dB]	scatter phase(s_{11}) [deg]
open	0	0.010	0.10
short	0	0.015	0.10
attn1	-6.05	0.010	0.05
attn2	-11.55	0.020	0.15
50 Ω	-44.7	1	7

OPEN STANDARD

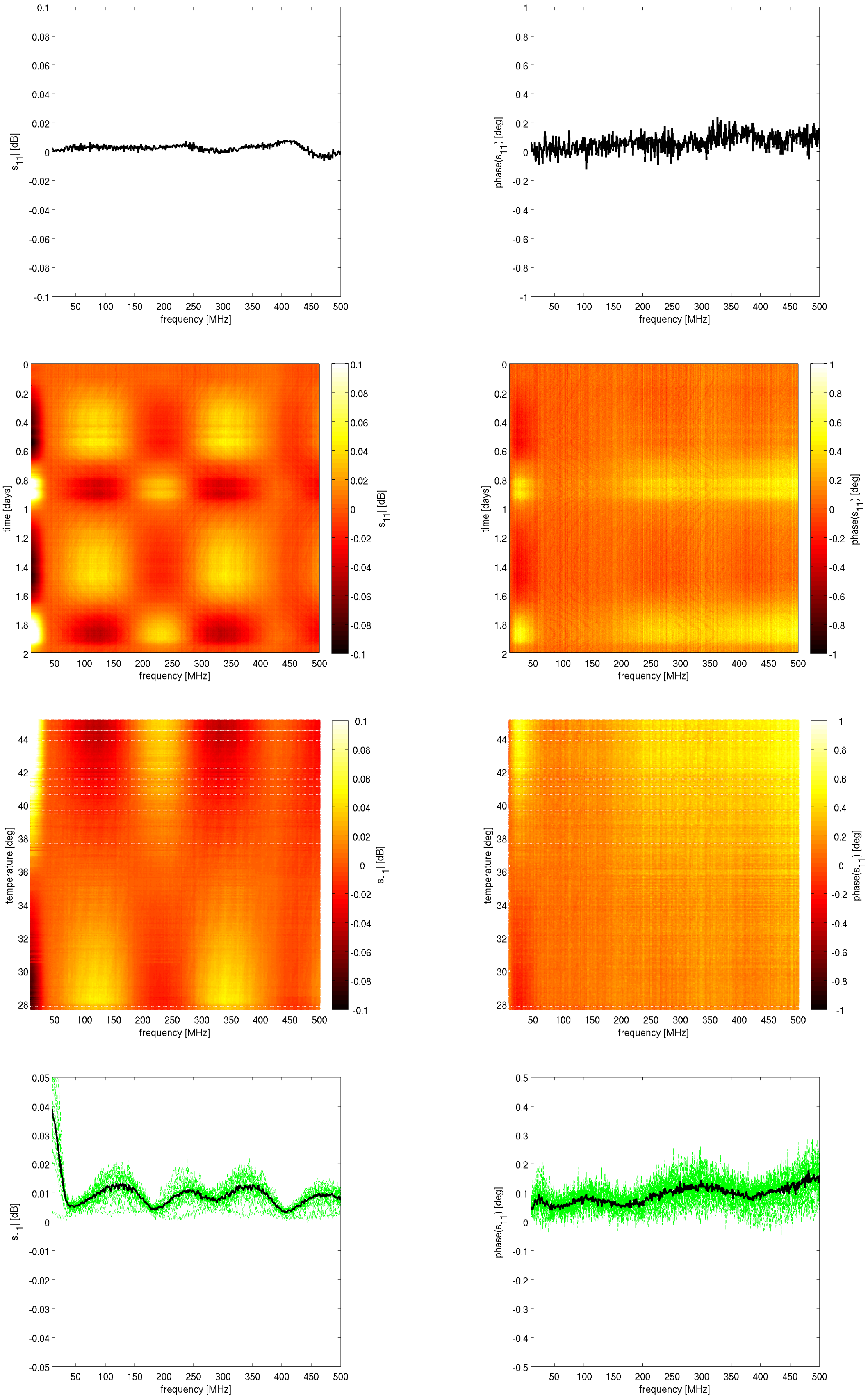

Figure 1:

SHORT STANDARD

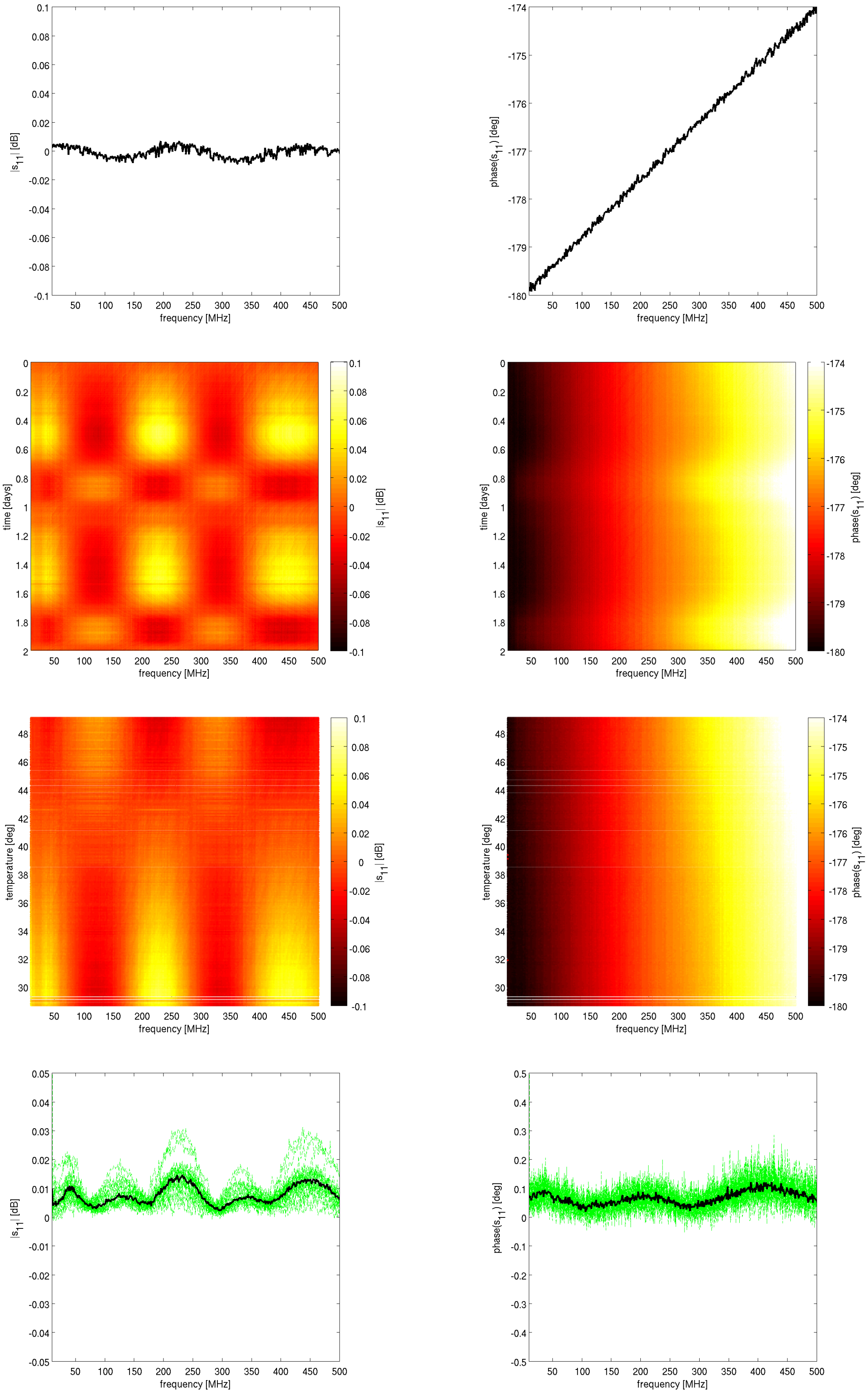

Figure 2:

ATTN 150 Ohm (open ended)

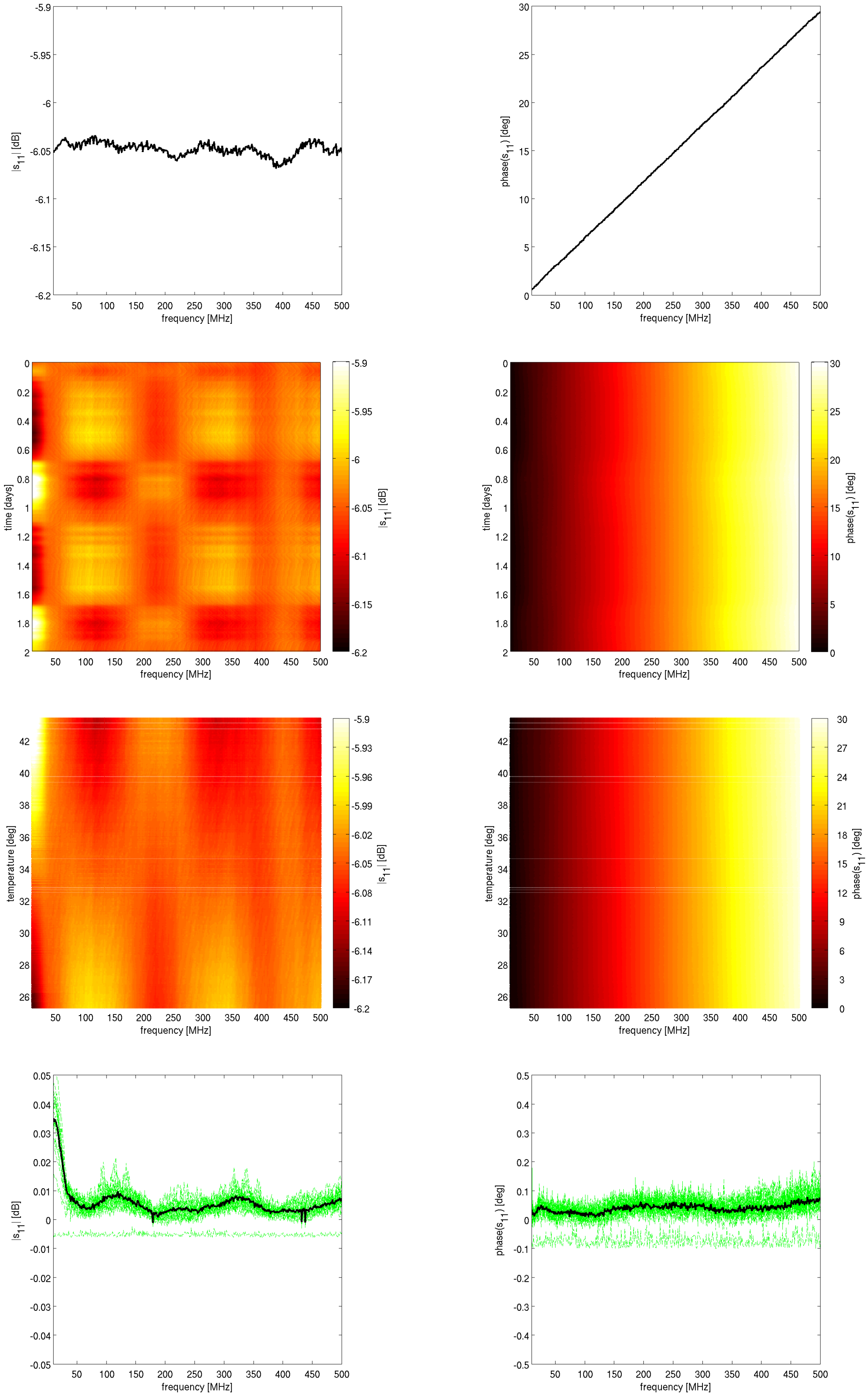

Figure 3:

ATTN 83.5 Ohm (open ended)

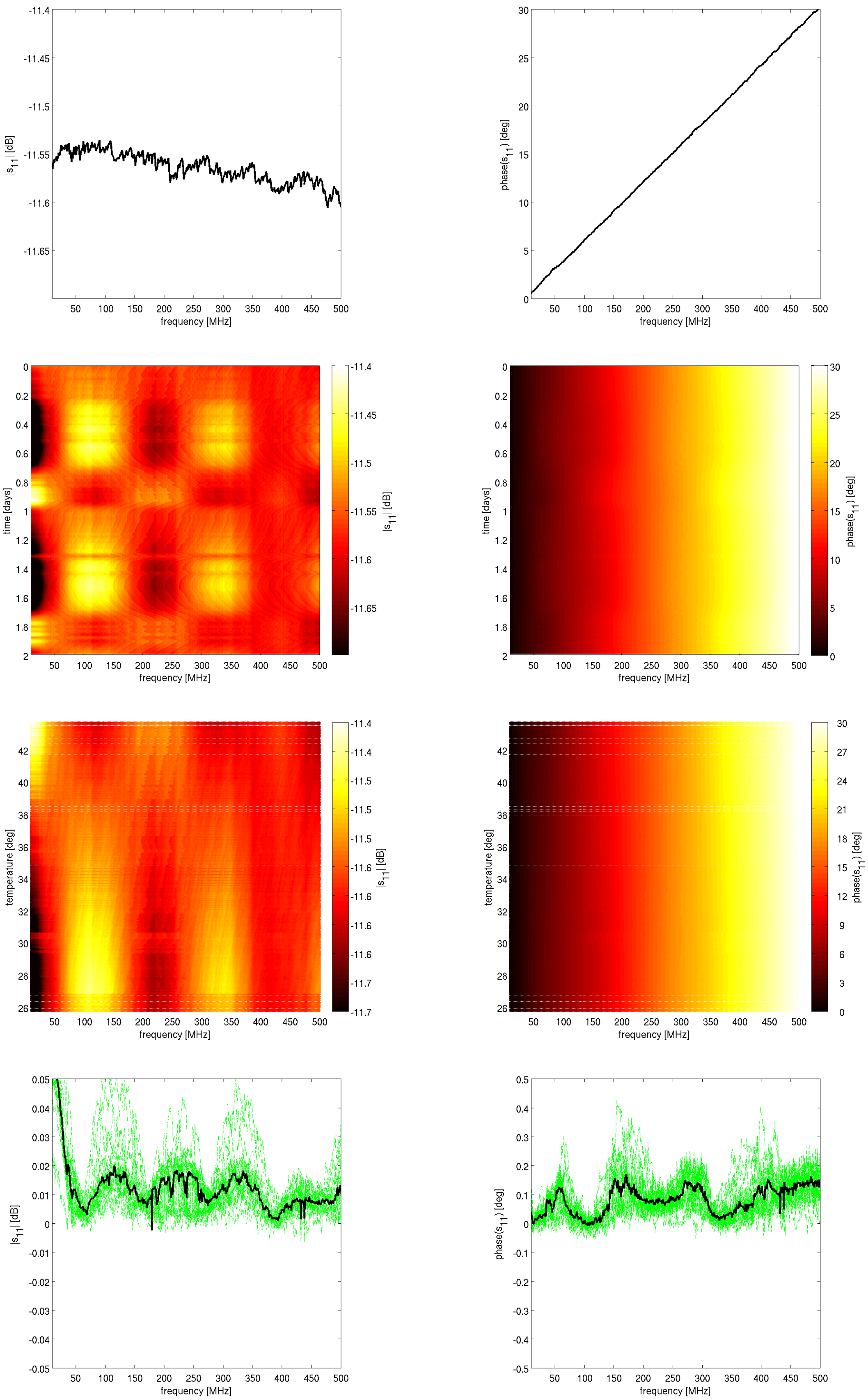

Figure 4:

50 Ω LOAD

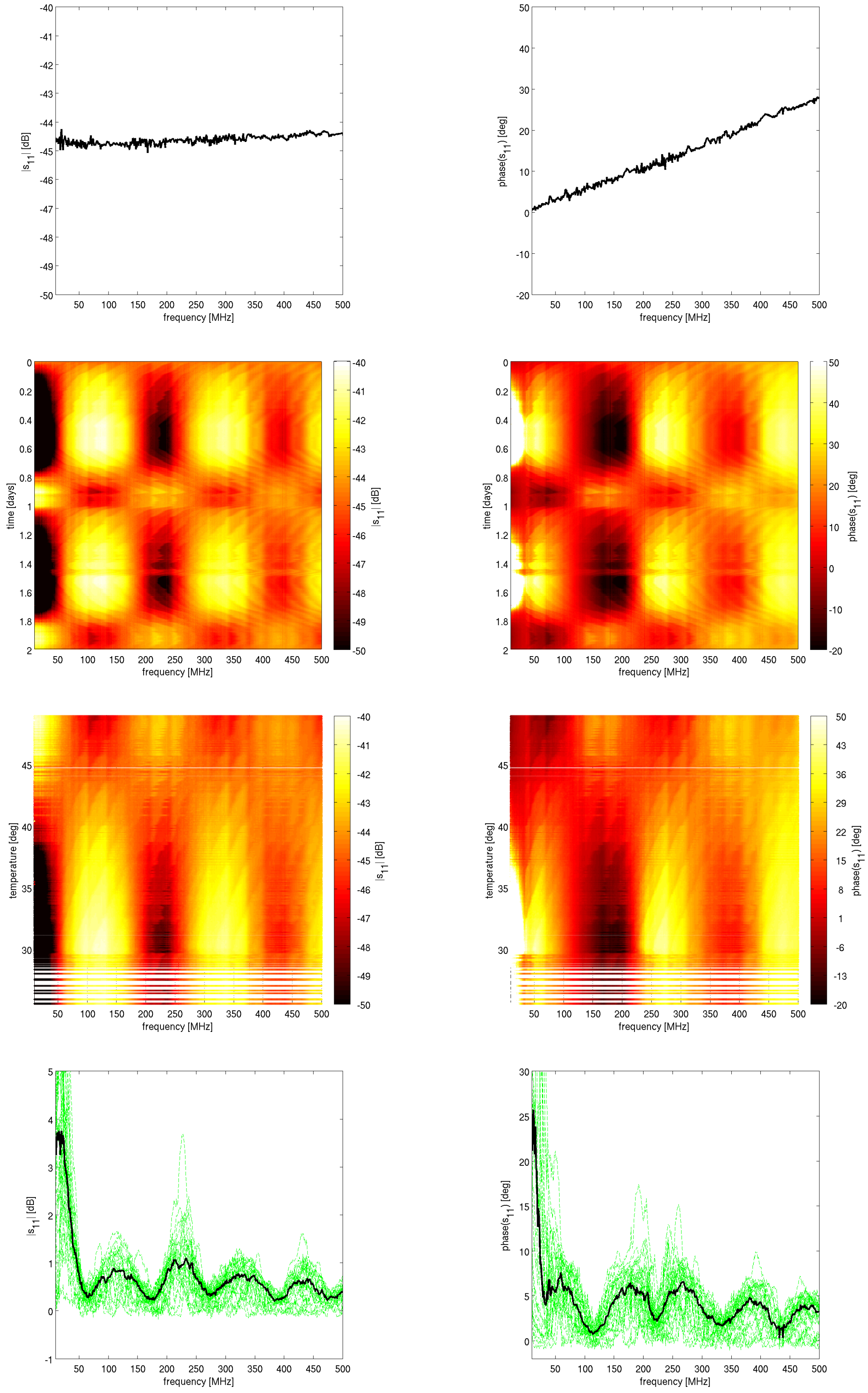

Figure 5:

3 VNA + Cable

Two other measurements were conducted after calibrating at the end of a 4 m KLMR100 cable. Most of the cable was exposed to the environment while the VNA was inside a room whose temperature changed less than 1°C. The loads used here were the open standard and a 50 Ω termination. The measurements also lasted more than two days.

After calibration, the reflection coefficient immediately shows ripples in frequency. This is depicted in figure 6, which shows the magnitude of s_{11} for both loads in linear scale after subtracting the mean. The cable used in both occasions was the same. The amplitude of the ripple is very close, and the frequency response is similar but not equal.

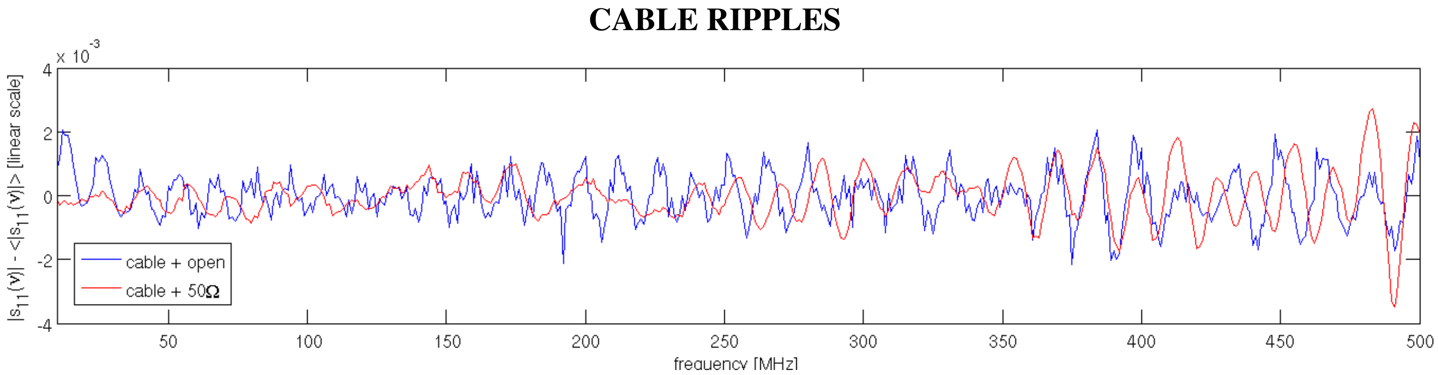

Figure 6: Magnitude of reflection coefficient minus their mean. The ripple is due to the cable and has a similar amplitude and frequency in both cases, although not equal. This makes it difficult to remove from measurements of loads whose s_{11} is unknown.

The ripples remain throughout the measurements but they are also subject to changes due to temperature. This is evidenced in figures 7 and 8, in particular in the fourth rows which show the scatter for temperature differences within 1°C. This scatter is also presented in table 2.

The scatter naturally includes the one due to the VNA dependence on temperature, since the VNA was also in an environment whose temperature was controlled to within 1 degree. The two temperature variations are not necessarily correlated.

It is worth noting that when calibrating after the cable, ambient temperature changes create a uniform pattern across frequencies and not a checkered pattern as in the VNA-Only case. If the ripples were attenuated as much as possible, it could be realistic to think of characterizing the cable dependence on temperature and then calibrate out its effect.

Table 2: Scatter in s_{11} for changes of 1 degree in ambient temperature where the VNA is located AND also 1 degree where the cable is located (both variations not necessarily correlated). White noise has been removed from scatter. Results are valid for frequencies below 200 MHz. Calibration was performed after the cable. Contribution to the scatter due to temperature coefficient of load is 10% or less.

load	average $\|s_{11}\|$ [dB]	scatter $\|s_{11}\|$ [dB]	scatter phase(s_{11}) [deg]
open	0	0.030	0.15
50 Ω	-42.5	1	6

CABLE + OPEN

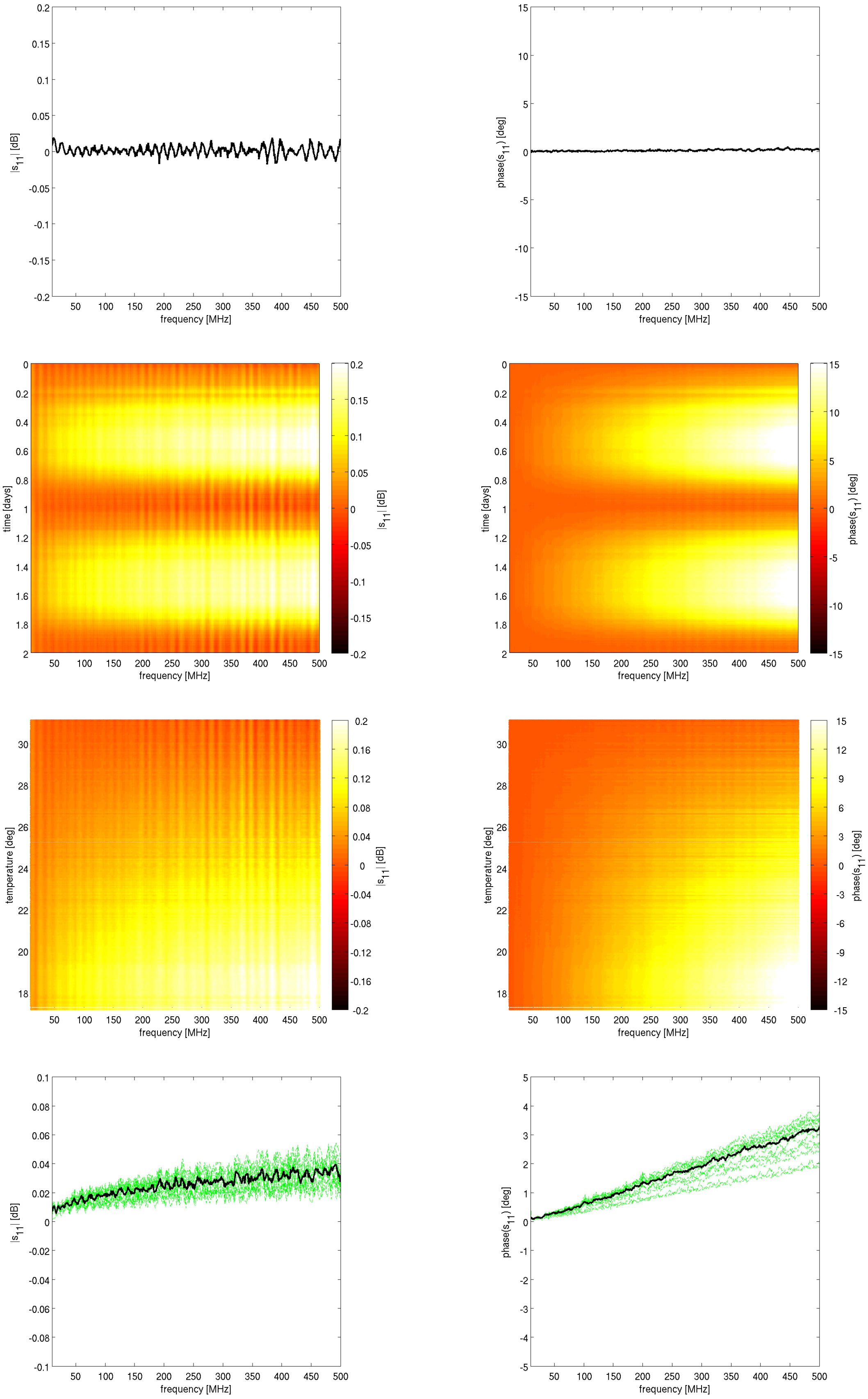

Figure 7:

CABLE + 50 Ω

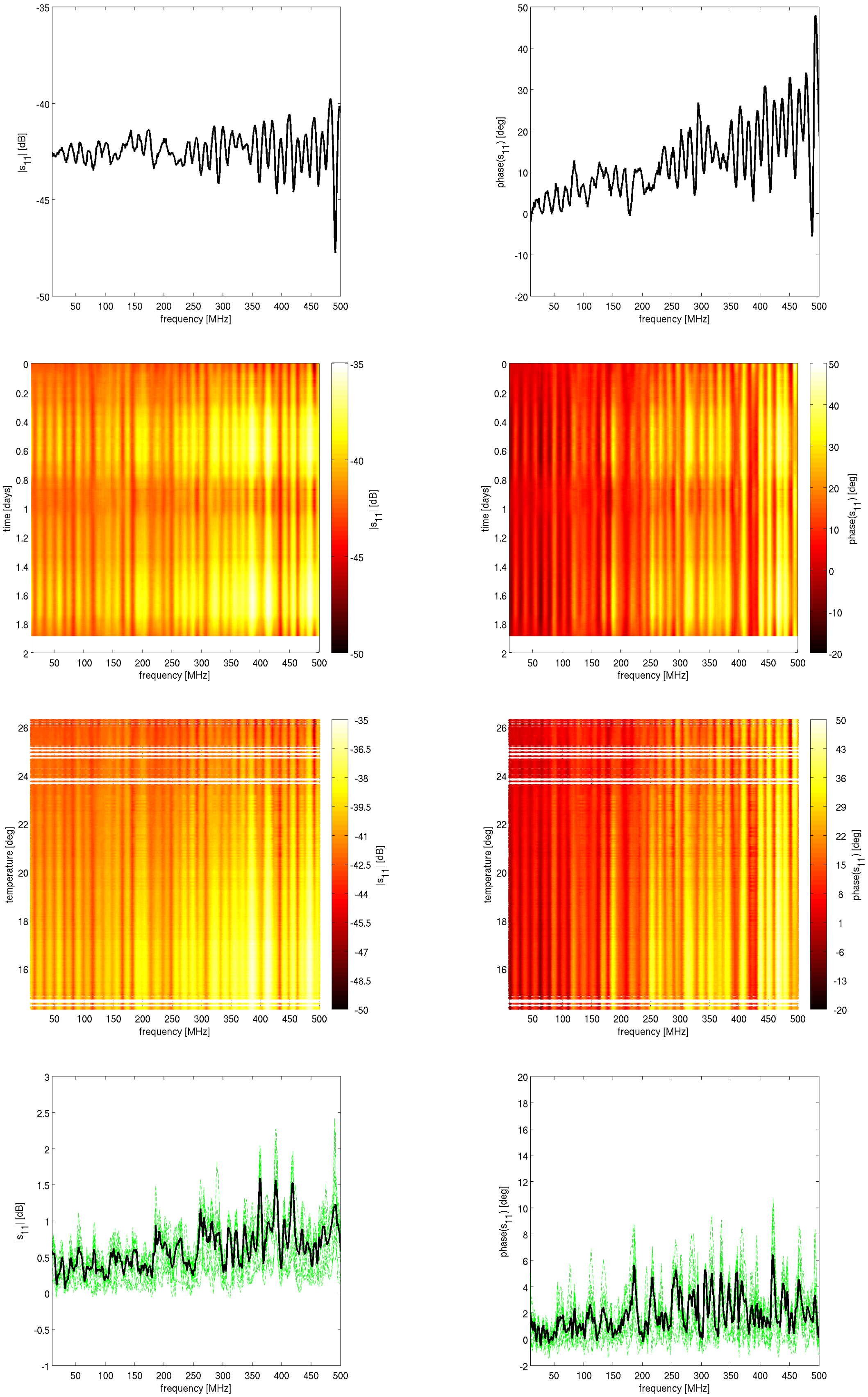

Figure 8:

4 EXTRA – New Antenna Results

Figure 9 shows the measurements of the antenna + roberts balun + KLMR100 cable.

The first row shows s_{11} right after calibration. It doesn't follow the measurement and modeling done by Alan, presented in Memo 89, especially for frequencies between 150 and 200 MHz. This is most likely a tuning problem so we will keep experimenting with that.

Row four shows the scatter for 1-degree temperature change. Given the levels of reflection coefficient of the antenna, from figures 7 and 8 it is expected that a significant fraction of that scatter is due to the cable and not the antenna. Again, if we could minimize the ripple of the cable, then its temperature dependence could be better characterized and removed from the antenna measurements.

ANTENNA ROBERTS BALUN

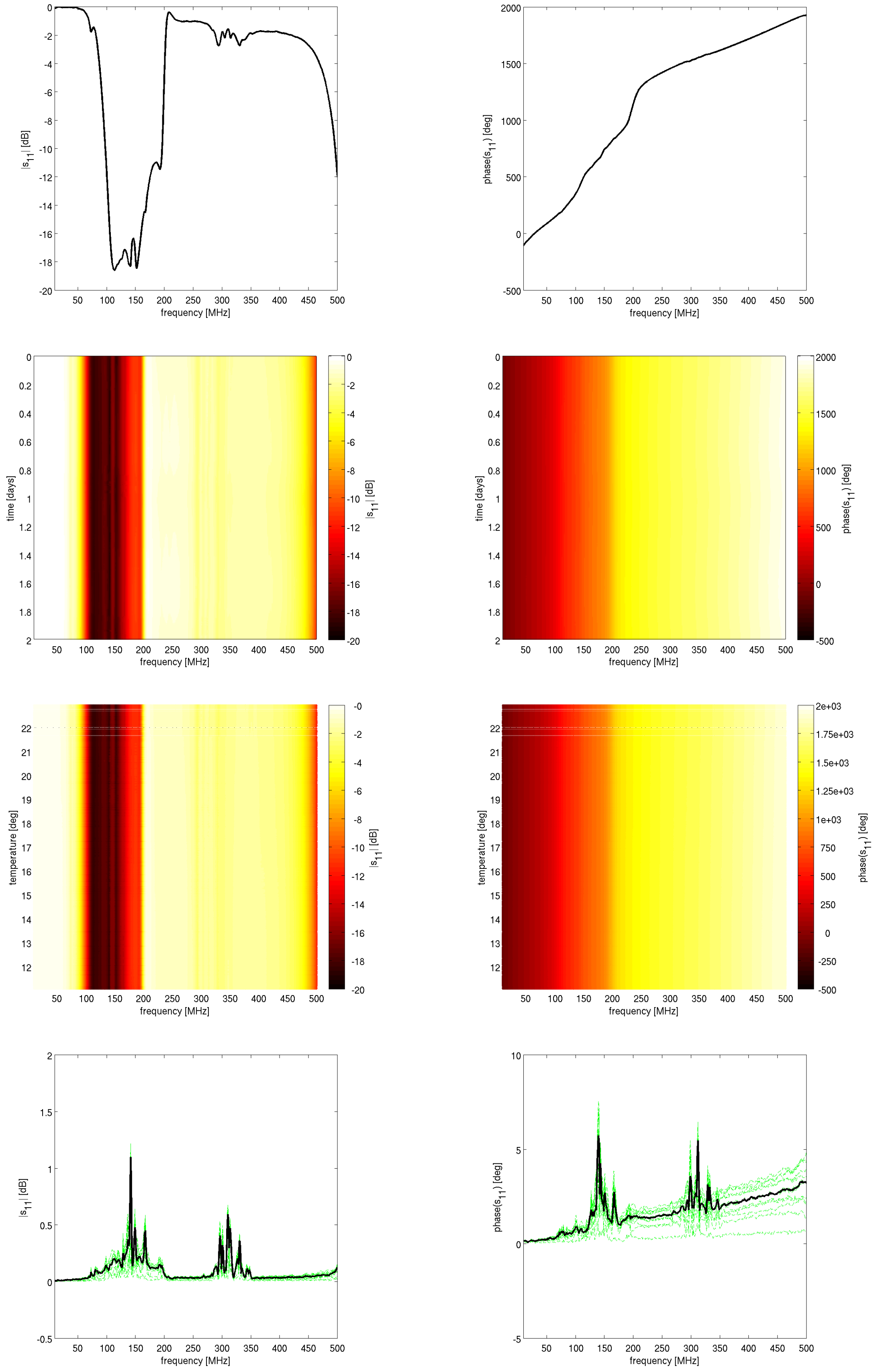

Figure 9: