Revisiting the Calibration Method

Raul Monsalve

SESE, Arizona State University

July 13, 2013

Description

The measurements of the Open, Short, and Match are analyzed for two cases: the 20-dB attenuator measurement, and the last antenna measurement. The load itself is not important for this analysis. Instead, the interest focuses on the S-parameters of the setup. This is so because if the measurement of the load (attenuator or antenna) is smooth, then the S-parameters are responsible for the significant variations observed in the *corrected* measurement, which is given by

$$\Gamma = \frac{\Gamma' - S_{11}}{S_{12}S_{21} + S_{22}(\Gamma' - S_{11})}. \tag{1}$$

where Γ' is the raw measurement of the load.

Measurement of Standards, as part of Attenuator Measurement

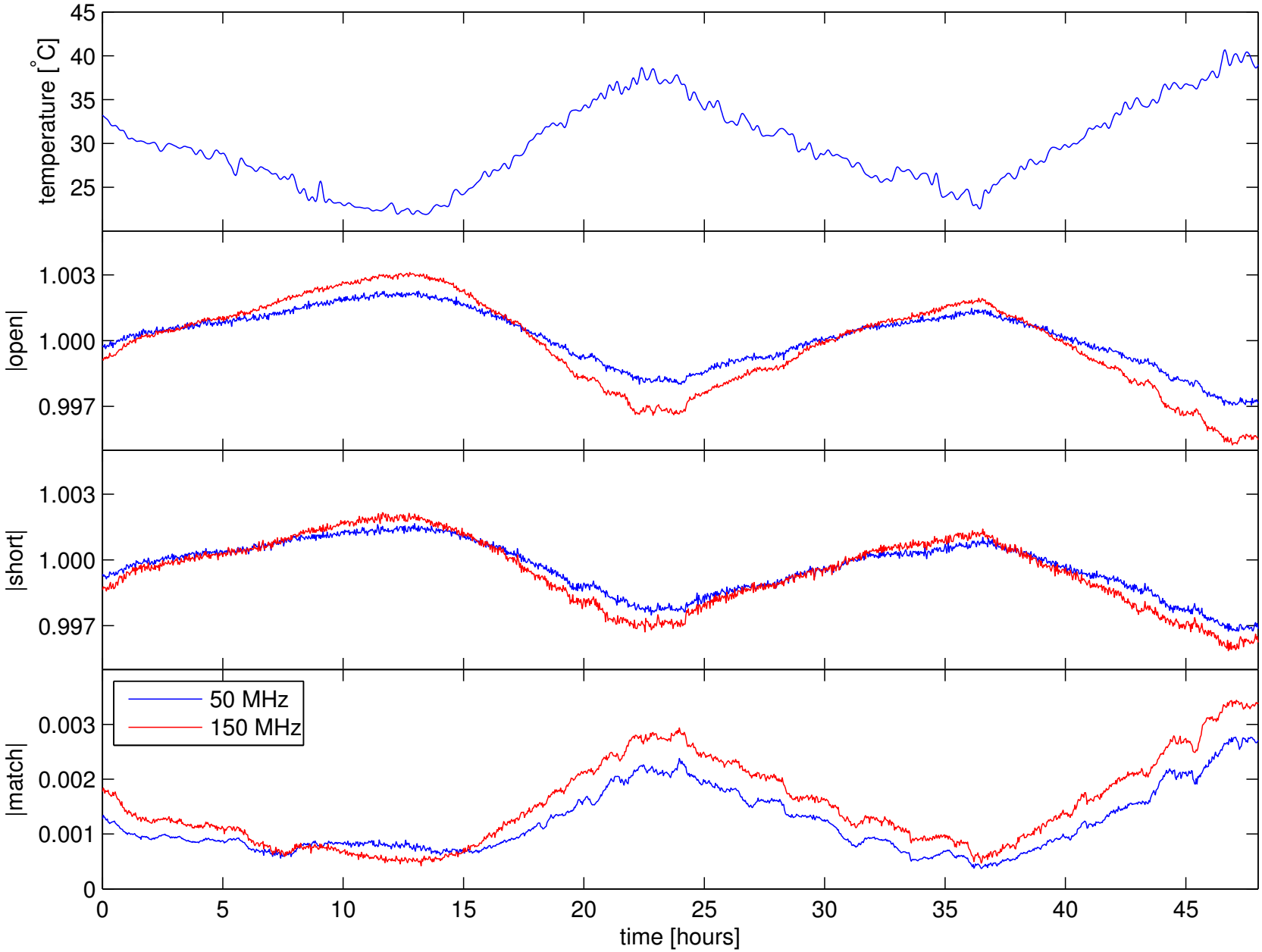

Figure: Magnitude of the *open*, *short*, and *match*. Comments on the next page.

Comments on Previous Figure

- This measurement was conducted during a very windy time, which made the air temperature to oscillate significantly as shown in the top plot.
- From the plots of the *open* and *short* it is evident that the setup (VNA, cable, switch) cannot keep up with rapid temperature changes. Only slower gradients are followed.
- For the *match*, it can be argued that the combination of setup+*match* doesn't follow quick changes either. Even if the *match* alone followed these changes, when connected to the rest of the setup its behavior doesn't directly follow air temperature since the temperature of the setup dampens quick variations.
- If the expected dependence of the *match* with temperature is not occurring in practice, the S-parameters of the setup cannot be recovered successfully.

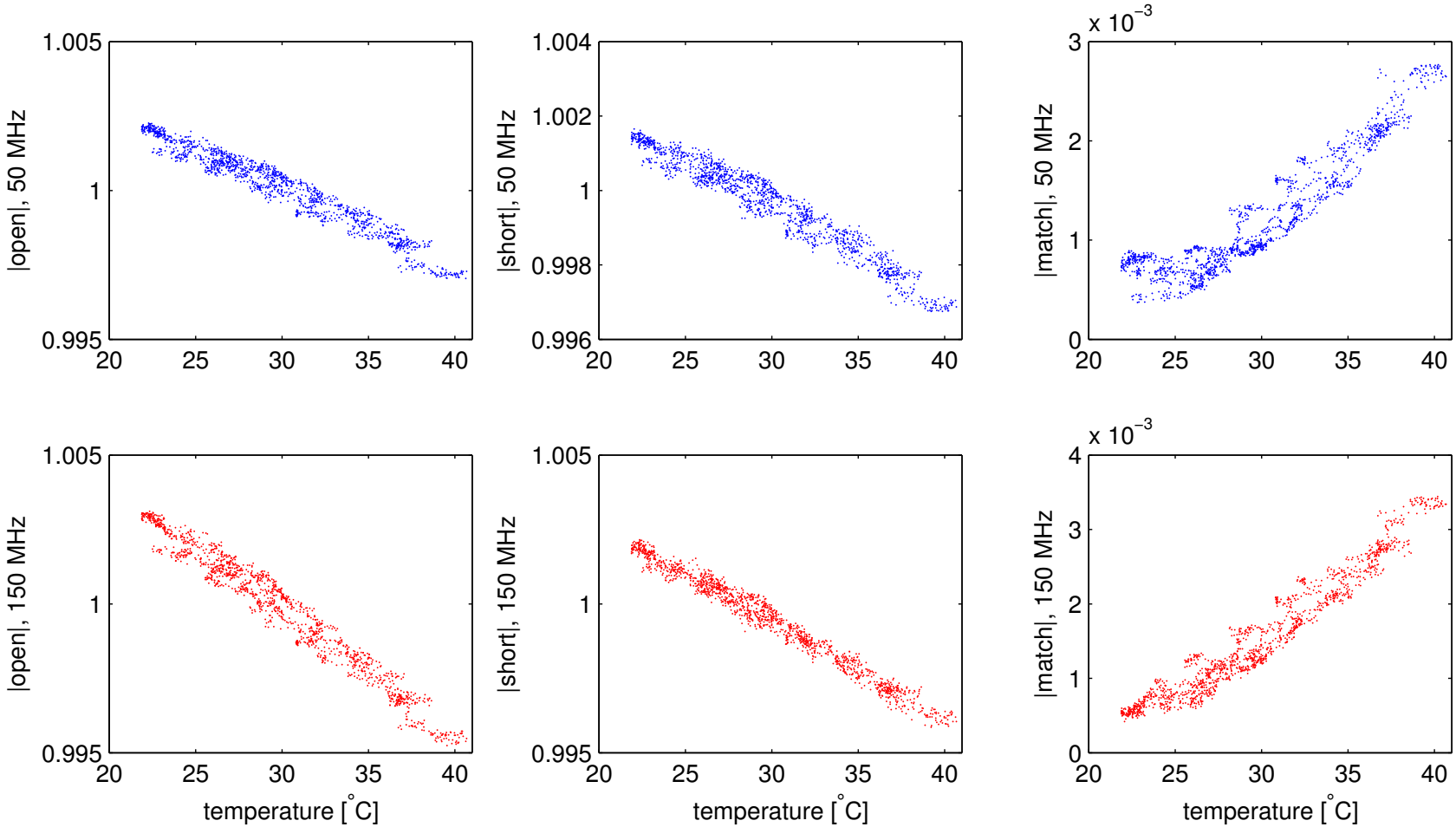

Figure: Correlation of measurements with temperature. There is a subtle step-like component in the correlations, which is a consequence of the lack of sensitivity of the system to quick temperature changes. The case for the *match*, with more scatter than the others, reflect that the *match* is trying to follow air temperature, but when attached to the setup it cannot do it properly.

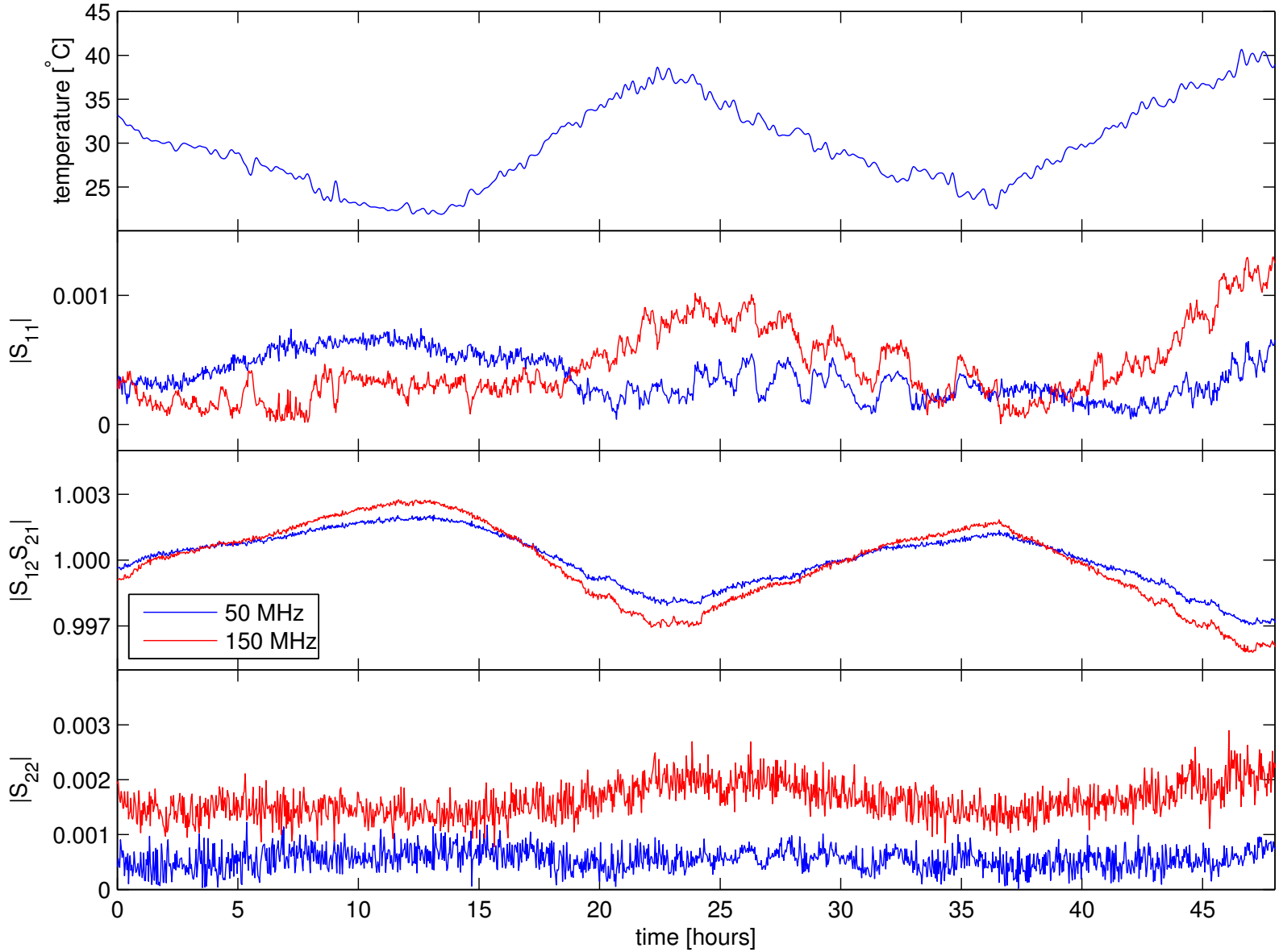

Figure: S-parameters of the setup computed for the measurements presented above. The discrepancies between the expected value of the *match* at a given air temperature T_0, and its true value at its true temperature T_0', are propagated to the S-parameters. S_{11} is the most affected quantity. These *jumps* are then propagated to the load through equation (1).

Measurement of Standards, as part of Last Antenna Measurement

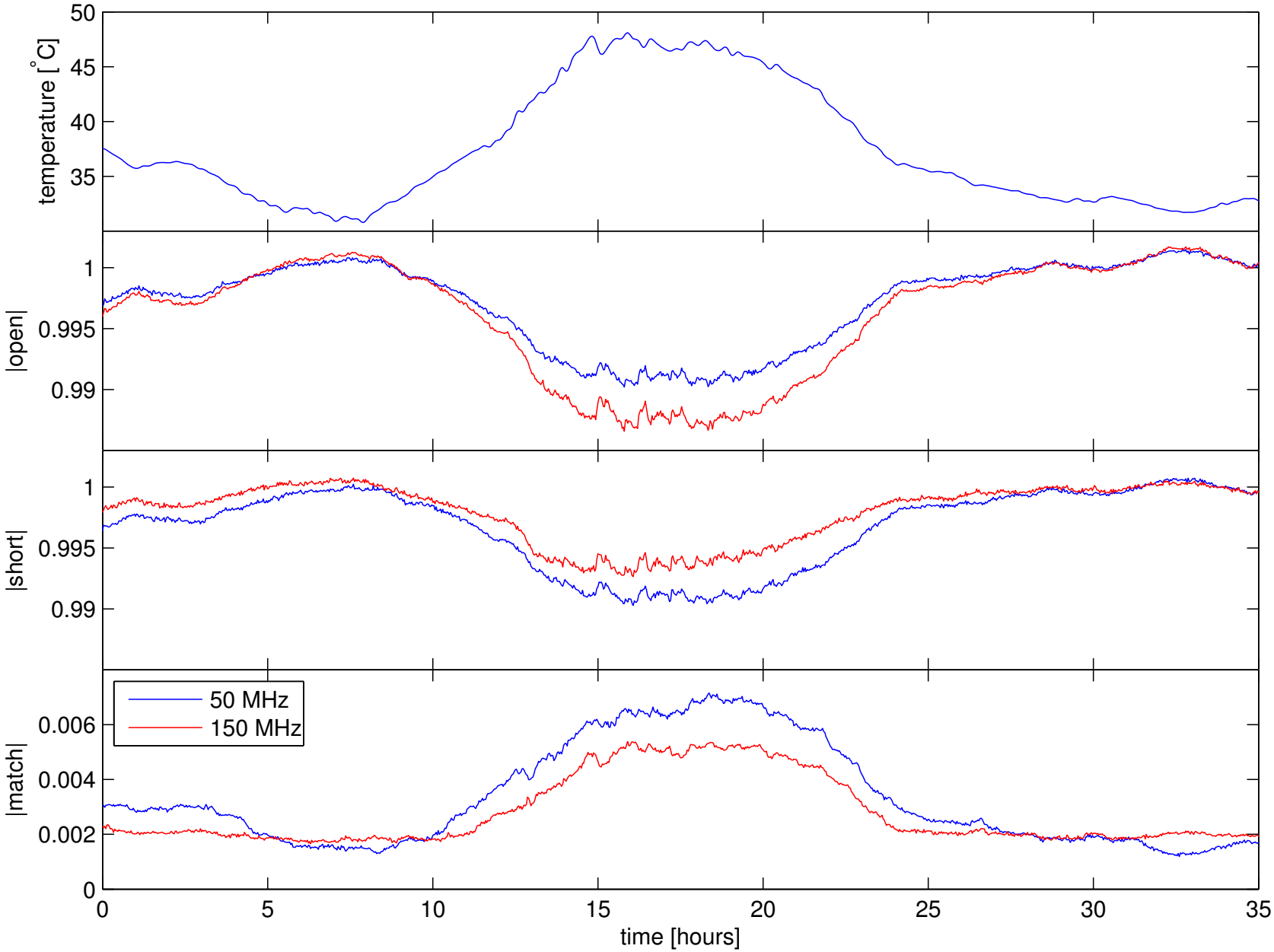

Figure: Magnitude of the *open*, *short*, and *match*. Comments on the next page.

Comments on Previous Figure

- It was not windy during this measurement, and consequently the temperature plot is more stable.
- Although the relationship between the measurements of the standards and air temperature is not linear, the measurements seem capable of reacting to temperature changes on the appropriate time scales.

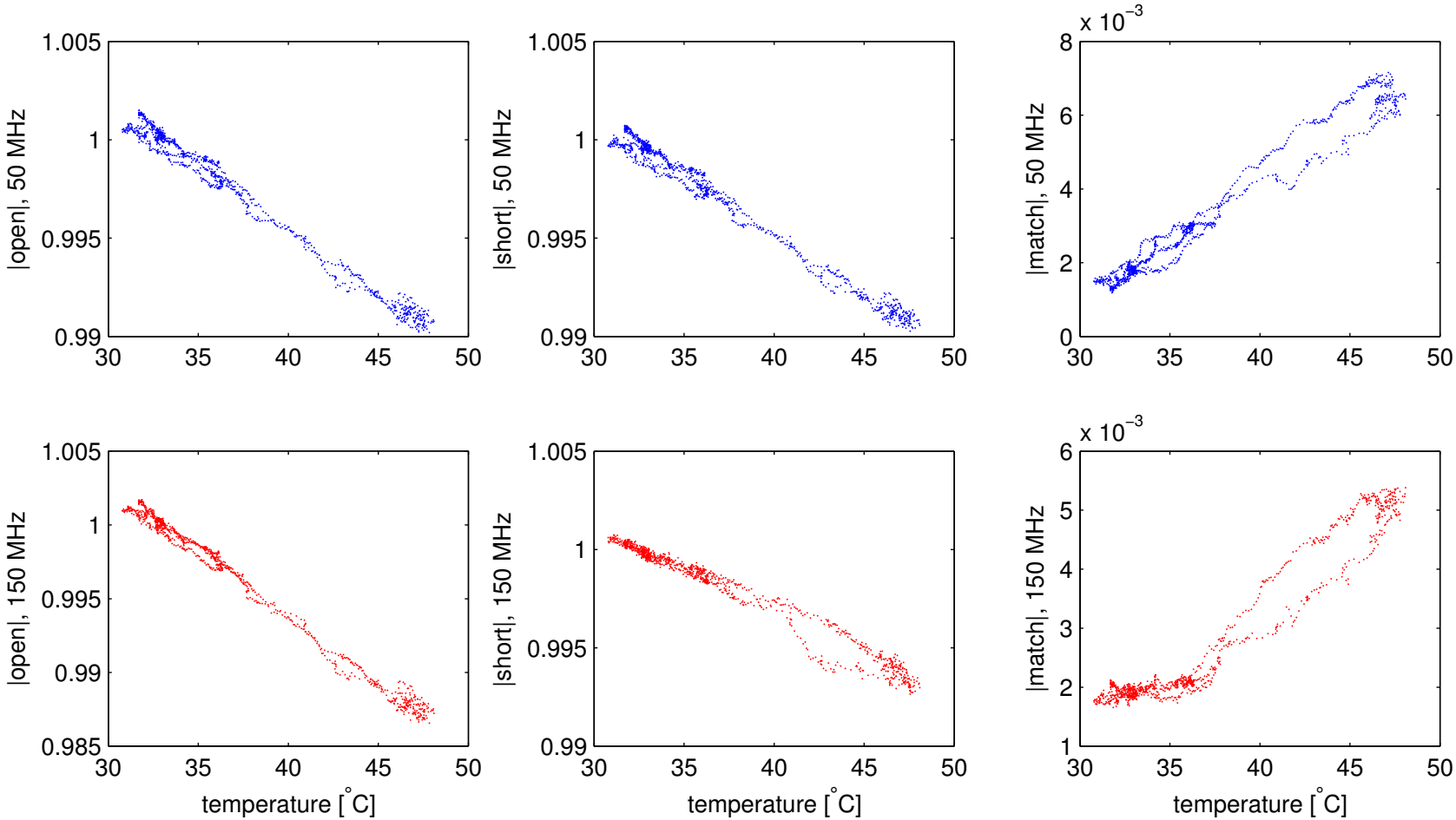

Figure: These correlation plots show hysteresis and non-linearity, especially that for the *match*. It is not possible to know how much of this behavior is due to the *match* and how much to the setup without a better estimation of their temperature.

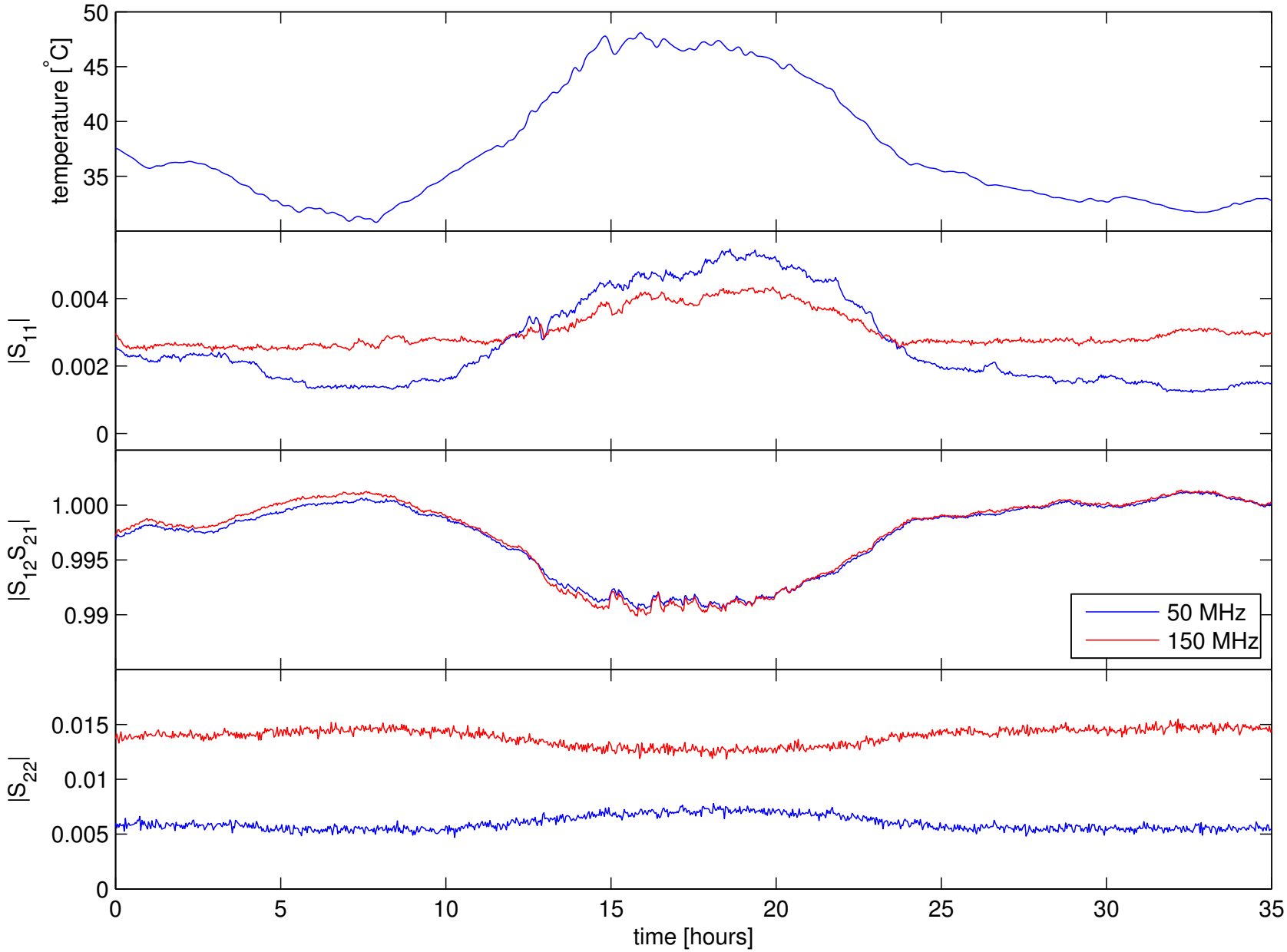

Figure: S-parameters of the setup. They do not seem to exaggerate the effect of temperature variations, as those in the attenuator measurement did.

Conclusions

- Accurate measurements of the temperature of the *match* are needed, for the S-parameters of the setup to be recovered properly.
- Up to this point, only air temperature measurements have been conducted since type-K thermocouples are available. They cannot be connected physically to the setup or loads since electricity flowing through the wires affect the VNA.
- Three paths can be followed: i) Glue the thermocouple to the match, in a way that doesn't affect the reflection coefficient, ii) compute the expected value of the *match* from a temperature that has been smoothed in time, or iii) measure the physical temperature of the *match* with IR thermometers or similar. Fluke has some models, but their accuracy is not great. Their biggest limitation is that they cannot save more than 100 data points, which is insufficient for a long term measurement, requiring a lot of interpolation.
- It is still necessary to measure air temperature for the antenna characterization.