BIPM Capacity Building & Knowledge Transfer Programme

2019 BIPM - TÜBİTAK UME Project Placement

REPORT

Project Name	Scattering Parameters Measurements
Description	Developing and improving skills and knowledge transfer in area of scattering parameters measurements.
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Motivation & Introduction

The aim of this project is to develop and improve technical skills in the area of scattering parameters (S-parameters) measurements and transferring the theoretical and practical know-how to the National Measurement and Calibration Centre (SASO-NMCC), which is the NMI of Saudi Arabia.

At microwave frequencies, it is not easy to measure voltage and current at the ports. Voltage and current values change depending on the measurement points and there are no voltmeters and ampermeters capable of measurements at high frequencies. So, to solve these problems scattering (S) parameters are described for characterizing the linear two port circuits at high frequencies. We focused on S-parameters measurements, which is an important area in microwave metrology to ensure and increase product quality and to create end user confidence. In the course of my studies, we worked up to 50 GHz in the coaxial line system, which covered one-port and two-port vector network analyzer (VNA) measurements.

Besides these, we also worked on VNA calibration. VNA calibration is used to determine the VNA error coefficients by measuring a set of known reference standards. A calibrated VNA can be used to characterize other calibration standards to disseminate S-parameter traceability to lower levels in the traceability chain.

Research

The project completed at TUBITAK UME covered S-parameter measurements (reflection and transmission), measurement errors, measurement model, and measurement uncertainty. The program consisted of theoretical calculations, practical applications and uncertainty calculations. The main activities are described below.

Calibration is critical to making good VNA S-parameter measurements. Calibration is a tool for correcting errors originating from match, directivity, frequency response, cables, connectors, and etc. There are a number of possible calibration methods: Short-Open-Load-Through (SOLT), Short-Open-Load (SOL) etc. During our project, we calibrated an N type calibration kit using the SOLT method. Figure 1 shows the measurement result of the short (female) standard of the calibration kit model 85054D. We also calibrated N type female adapter by using the unknown through method.

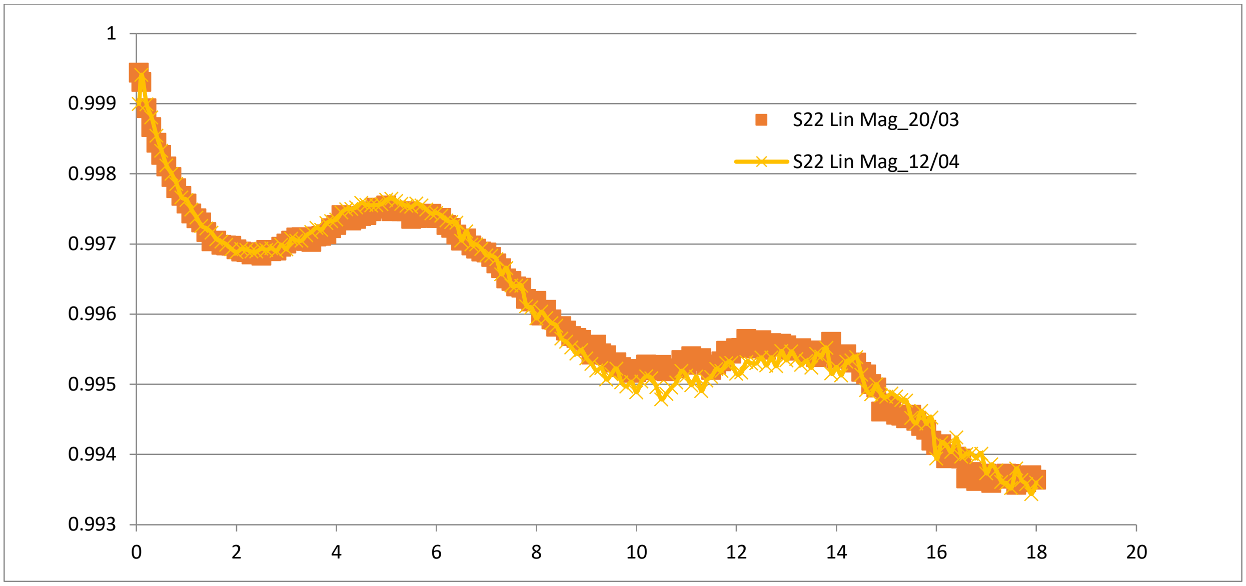

Figure 1. S-parameter measurement of "short (f)" standard.

There are two methods for the uncertainty calculations of s-parameter measurements which are the rigorous method and the ripple method. In our project, we studied the rigorous method. This method follows the methodology recommended by the ISO GUM documents. An advantage of the rigorous method is documented in the EURAMET Guidelines on the Evaluation of VNA. In the second part of the training, we focused on VNA calibration. We characterized an Anritsu Vectorstar VNA according to the rigorous method. In this method, the uncertainty parameters given below of the VNA were determined.

- VNA noise floor and trace noise
- VNA non-linearity
- VNA drift
- Isolation (cross-talk)
- Output power,
- Output frequency,
- Harmonics.

Additional to VNA characterization, calibration standards, connector repeatability and test port stability were characterized.

Characterization of calibration standards

Usually the dominant source of uncertainty in S-parameter measurements is associated with characterizations of calibration standards. Calibration standards are characterized using primary or calibrated traceable calibration standards. Calibration standards can drift or change unexpectedly over time.

VNA noise floor and trace noise

Noise denotes random signal fluctuations, which are characteristic of all electronic circuits. Noise floor denotes random fluctuations in the absence of a deterministic signal (Figure 2). Trace noise denotes random fluctuations of the measurement result. When trace noise is far above the noise floor, it is proportional to the measured value, i.e., it is a constant fraction of the result.

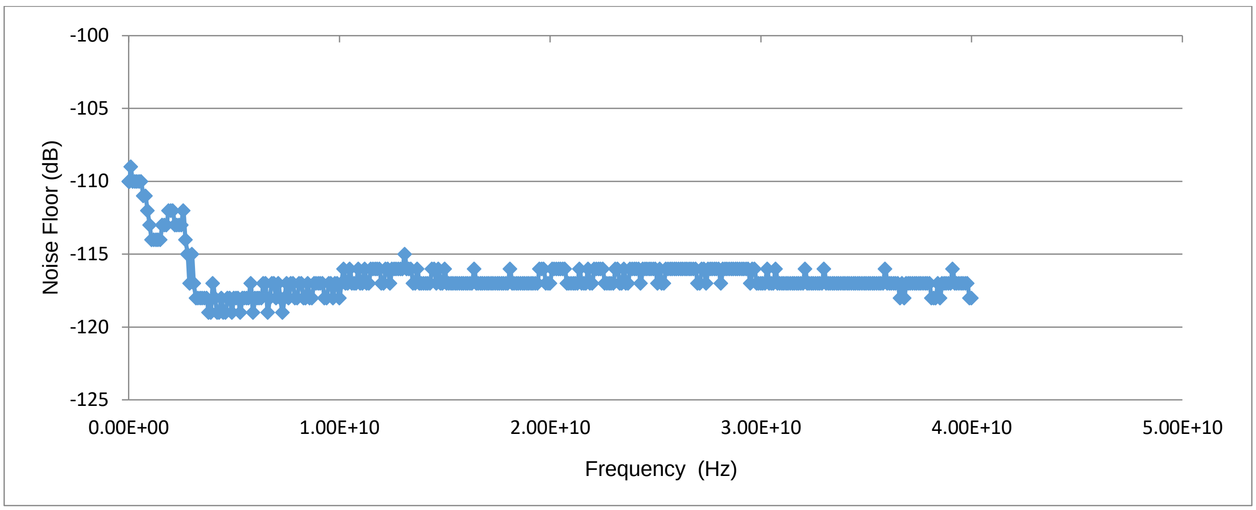

Figure 2. Noise floor measurement result of the VNA.

VNA non-linearity

The VNA is modeled as a linear network; there is a linear relation between the forward and backward propagating waves and their detection by the receivers. The term VNA non-linearity, sometimes also called dynamic accuracy, denotes deviations from this behavior. VNA non-linearity combines effects from different components: amplifiers, filters, etc.

VNA drift

Drift in VNA measurements occurs due to temperature changes and resulting relaxation effects. These effects lead to changes in the electrical length of signal paths and to changes in the performance of couplers, receivers, and other components. Some of the dielectric materials used in test port cables are phase sensitive to temperature changes. Drift measurements are done over a period of 24 hours. Figure 3 displays drift measurement results of the VNA.

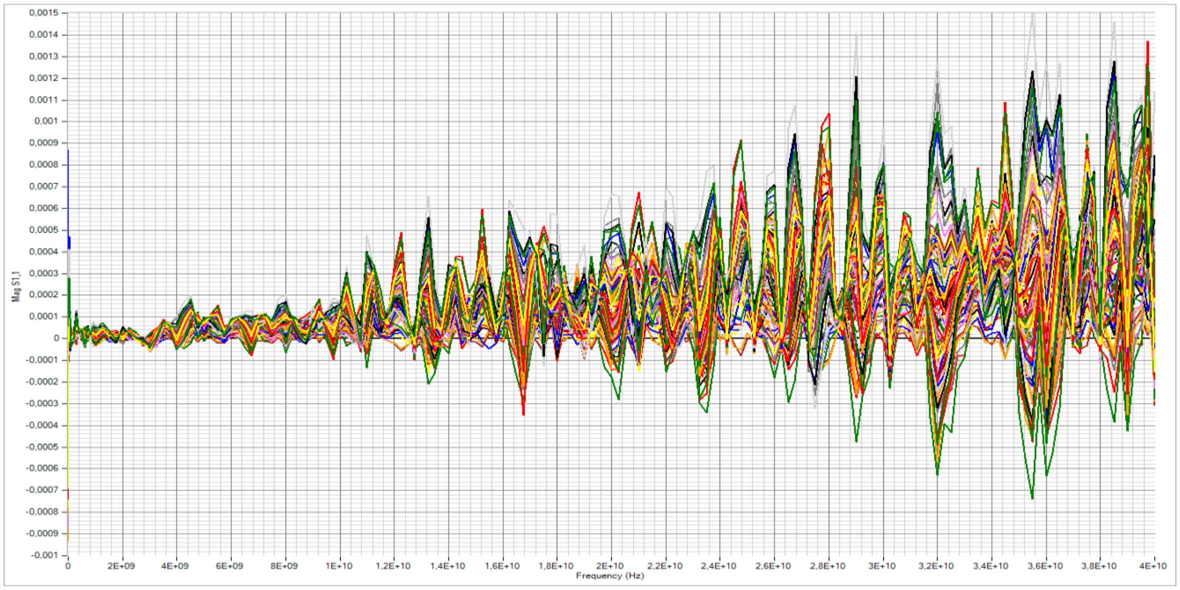

Figure 3. Drift measurement result of the VNA.

Isolation (cross-talk)

Isolation is represented by error coefficients in VNA error models. It is generally of minor importance in coaxial measurements with modern VNAs. For older VNAs, it is known that it affects measurements of large attenuation to the extent that a correction needs to be applied.

Test port cable stability

Test port cables are sensitive to temperature changes, movement and other mechanical influences. This sometimes addresses an unavoidable movement of test port cables. Moving the test port cable(s) during calibration or DUT measurement will change the error coefficients of the VNA. The effects of cable movement are strongly dependent on the quality of the test port cable.

Connection repeatability

Deviations from ideal connector geometry lead to mechanical stress and unwanted deformations when mating connectors. This causes changes in electrical behavior for re-connections under different connector orientations. This effect is dependent on each individual combination of connector pairs.

Conclusions and Future Work

This work has provided comprehensive and intensive training on s-parameters measurement. With the knowledge gained through my studies, I have plans to develop the capabilities at my institute for measurements of s-parameter, participate in an inter-laboratory comparison, submit CMCs, and characterize s-parameters and VNA for improving the uncertainties of measurements. My aim for the near future is to extend our measurement capability with different type connectors, i.e. 1.85 mm, 2.92 mm and BNC type, and in frequencies up to 67 GHz.

Acknowledgements

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