Measurement Comparison up to 65 GHz in Coaxial 1.85 mm Line

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***Abstract*—A measurement comparison of scattering parameters has been carried out between four national metrology laboratories in coaxial line using 1.85 mm precision connectors at frequencies between 100 MHz and 67 GHz. Twelve devices have been measured: two pairs of short-circuits, a pair of open-circuits, a pair of matched loads, a pair of mismatched loads, a male-to-female adaptor and a T-checker. The National Physical Laboratory (United Kingdom) acted as the pilot laboratory for the comparison.**

***Index Terms* — Measurement, measurement standards, measurement techniques, measurement uncertainty, precision measurements, uncertainty.**

I. Introduction

This paper describes a measurement comparison in 1.85 mm coaxial line carried out amongst four European National Measurement Institutes (NMIs). In order of participation, these were: National Physical Laboratory (NPL, UK, pilot), Physikalisch-Technische Bundesanstalt (PTB, Germany), Laboratoire National de Metrologie et d'Essais (LNE, France) and the Federal Institute of Metrology (METAS, Switzerland). Twelve traveling standards were identified for use in the comparison.

The participants were asked to provide *S*-parameter measurements of each device at 100 MHz steps from 100 MHz to 67 GHz. The participants were also asked to provide measurements of the connector pin depths in their preferred units.

The comparison took place over a period of six months between February and July 2015.

The purpose of the comparison was to investigate the consistency among different VNA calibration algorithms, traceability schemes and uncertainty evaluation techniques applied at each of the participating laboratories.

II. Traveling standards

The traveling standards had 1.85 mm connectors and consisted of ten one-port and two two-port devices with male and female connectors. The two-port devices were chosen to provide high and medium transmission examples. The single-port devices were chosen to give a range of reflection values.

III. VNA Calibration Techniques

The VNA calibration techniques used by each of the participants are outlined in this section.

A. NPL

NPL used an external TRL calibration scheme [1] using multiple air line standards. Each air line was used to calibrate across the entire frequency band and a weighted mean of the results taken using weightings based on the suitability of each line at each frequency.

The uncertainty was derived using NPL's internally-written software, assessed to be compliant with ISO 17025. Traceability to SI units is derived from the internal dimensions of the air line standards.

B. LNE

LNE used a combination of the standard Short-Open-Load-Reciprocal calibration scheme and a Load-Short-Offset Short-Reciprocal calibration scheme using the manufacturer standards definition. Uncertainty evaluation was derived from the method used internally for the lower frequency ranges and corresponding connectors. Uncertainty due to the calibration standards is derived from a comparison of the measured *S*-parameters of an air line standard against the calculated *S*-parameters from dimensional measurement, which also gives traceability to SI units.

C. METAS

METAS used an over-determined calibration technique [2] with eight calibration standards on each port, including Opens, Offset Shorts, Flush Shorts and Matched Loads. Uncertainty evaluation was performed with rigorous uncertainty propagation through a full measurement model with the help of the software VNA Tools [2]. The traceability to SI units is based on the characterization of a set of primary calibration standards (air lines, offset shorts and flush shorts), taking into account the effects of the connector interface [3].

D. PTB

PTB used an over-determined short-open-load-thru calibration technique with six calibration standards on each port. Uncertainty evaluation was performed with rigorous

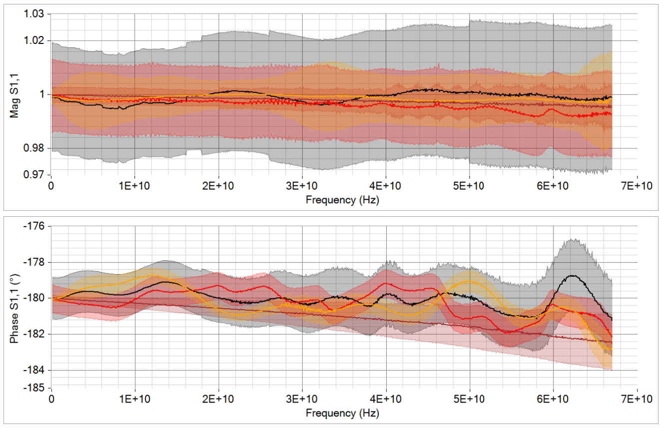

Fig. 1. Measurements of the female flush short-circuit device reflection coefficient. The black line shows LNE's results, the brown line METAS's results, the red line NPL's results and the orange line PTB's results. The top graph is magnitude and the bottom graph is phase.

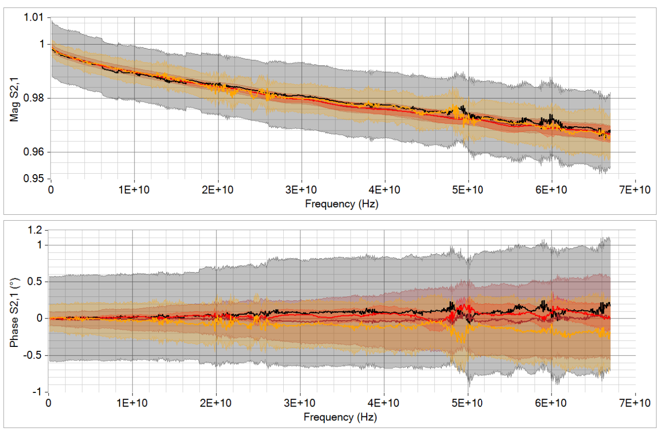

Fig. 2. Measurements of the male-female adaptor transmission coefficient. Refer to Fig 1 for the graph series legend. The top graph is magnitude and the bottom graph is phase with respect to the phase of the mean at each frequency.

uncertainty propagation through the calibration algorithm. The traceability to SI units is based on the standard definitions and uncertainties supplied by the manufacturer of the calibration kit.

IV. Results and Discussion

The *S*-parameter results are presented as they were received. No reference value is calculated for this comparison.

Results for two of the devices are presented graphically in this summary paper: reflection coefficient of the female flush short-circuit and transmission coefficient of the male-female adaptor. The plot of the results can be seen in Figs 1 and 2. In all graphs, the black line represents LNE, the brown line METAS, the red line NPL and the orange line PTB. The shaded regions represent uncertainty in each measurement at 95 % coverage probability. The reported phase is presented relative to the mean of all values at each frequency to make it easier to identify inconsistency between the different measurements.

It is arguable that there is good consistency between participants in the magnitude values for both measurements presented here. In general, there is good consistency in the magnitude values of the reflection coefficient and transmission coefficient (where applicable) of all devices, with the exception of the mismatched terminations.

However, this is not the case for the phase of the reflection coefficient of the flush short-circuit, nor is it the case for the phase of all of the other high reflect devices used in this comparison (phases of the reflection coefficient of the matched terminations and the male-female adaptor are considered indeterminate for the purpose of this comparison due to their low magnitude values). Reasons for this are most likely due to differences and assumptions made in the VNA calibration schemes employed by each participant, the effects of which may be magnified by the small and delicate nature of the standards in the 1.85 mm coaxial line. Further investigations are required to understand these differences fully.

There is arguably good consistency in the phase of the transmission coefficients reported by each participant.

V. Conclusion

The results of this comparison are not as consistent as had been hoped for. Whilst it is clear that current VNA calibration schemes can be applied when using devices with 1.85 mm connectors, previously neglected real-world imperfections become more apparent. See as well [3] in that respect. Further work is required to bring the individual measurements closer together for more consistent results.

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