

CCEM.RF-K5b.CL: A Key Comparison of S-Parameter Measurements in the coaxial 7 mm Line System using N-connectors up to 18 GHz

Speaker / Author: E. Dressler

Co-author: C. Matthee

National Metrology Institute of South Africa
Private Bag X34, Lynnwood Ridge 0040, South Africa
redressler@nmisa.org

Abstract

An international laboratory key comparison has been carried out between nineteen national metrology laboratories including CSIR-NML (NMISA). As travelling standards seven commercial devices (Three fixed attenuators, two mismatched loads and two matched loads) with type N connectors were used. The participants measured the complex quantities transmission and voltage reflection coefficient for the attenuators and voltage reflection coefficient for the loads at seventeen frequencies between 2 and 18 GHz. Provisional results in form of a draft A report have been released to the participants in January 2008. They show generally good agreement between the laboratories. The paper describes in detail the measurement set-up that was used by the CSIR-NML (NMISA). Diagrams show the deviation of the CSIR-NML (NMISA) results from the Key Comparison Reference Value (KCRV) at selected frequencies.

1. Introduction

This intercomparison, designated CCEM.RF-K5b.CL, was carried out to measure scattering coefficients by broad-band methods at frequencies between 2 GHz and 18 GHz. The comparison used devices with 50 Ω Type N precision connectors.

Nineteen laboratories have participated in this intercomparison, which took place between June 2003 and November 2006. These are (in alphabetical order by country):

- NMIA (Australia) – formerly CSIRO
- NRC (Canada)
- NIM (China)
- CMI (Czech Republic)
- LNE (France)
- PTB (Germany)
- SCL (Hong Kong)
- NPLI (India)
- INRIM (Italy)
- NMIJ (Japan)
- NMi-VSL (The Netherlands)
- SNIIM (Russia)
- SPRING (Singapore)

- CSIR-NML (South Africa)
- SP (Sweden)
- METAS (Switzerland)
- UME (Turkey)
- NPL (United Kingdom – PILOT LABORATORY)
- NIST (United States of America)

The participants measured the complex scattering parameters of the seven travelling standards at 17 frequencies between 2 GHz and 18 GHz in 1 GHz steps. The items were chosen since they are regarded as being typical DUTs encountered for VNA measurements. However, due to the large amount of data involved, key comparison reference values have only been calculated for the following measurands:

- S_{21} of each attenuator at frequencies 2 GHz, 9 GHz and 18 GHz
- S_{11} of the male matched load at frequencies 2 GHz, 9 GHz and 18 GHz
- S_{11} of the female mismatched load at frequencies 2 GHz, 9 GHz and 18 GHz

2. Travelling Standards

Seven devices were used as the travelling standards in this intercomparison. Each standard is a commercially available artefact. The devices are listed in the table below.

Table1. List of travelling standards

Device	Nominal value	Number of ports
HP 8491B Attenuator	3 dB	2
HP 8491B Attenuator	20 dB	2
HP 8491B Attenuator	50 dB	2
HP 909F termination NM	50 Ω	1
HP 909F termination NF	50 Ω	1
Maury 2562G mismatch NM	VSWR=2	1
Maury 2561G mismatch NF	VSWR=2	1

The CSIR-NML measured these devices in December 2005.

3. Methods of Measurement

With one exception, all participants performed their measurements using a vector network analyser. The equipment used by CSIR-NML was given to the pilot laboratory in form of a report.

3.1 CSIR-NML Measurement Set-Up

The measurements were performed using a Hewlett-Packard 8510C vector network analyser (VNA) with a Hewlett-Packard 8515A S-parameter test set. The VNA was calibrated using a Hewlett-Packard 85054B calibration kit.

One-port measurements were performed using rigid test port adapters connected to the 3,5 mm test ports of the VNA. Two-port measurements were performed using phase stable cables connected to the test ports of the VNA.

The linearity traceability for the VNA comes from a Techtest WBCO 310 piston attenuator. Other uncertainty components were identified using reference airlines and terminations in accordance with the EA document on the estimation of uncertainties of vector network analysers.

4. Discussion of the Results

The results were reported to the pilot laboratory as real and imaginary components of the travelling standards' scattering parameters with the associated standard uncertainties ($k=1$) [1].

The key comparison reference value (KCRV) was determined using an unweighted (arithmetic) mean of the participants' reported measurements, chosen due to the variation of uncertainties reported, as it was felt that, although not necessarily suitable for all of the KCRVs, it would give a fair judgement of the KCRV for the highest number of the measurands over other methods.

Any data identified as inconsistent was excluded from the determination of the KCRV.

Participants who are not a member of CCEM were not included in the determination of the KCRV; these include CMI and UME, both of whom are observers, and SCL.

Participants were also asked to provide combined standard uncertainties (detailed in an uncertainty budget) for the aforementioned measurands and, where possible, the correlation coefficient associated with the real and the imaginary component of each measurand.

A selection of measurement results in scalar form including the key comparison reference values and associated uncertainties are shown graphically in Figs 1 – 4.

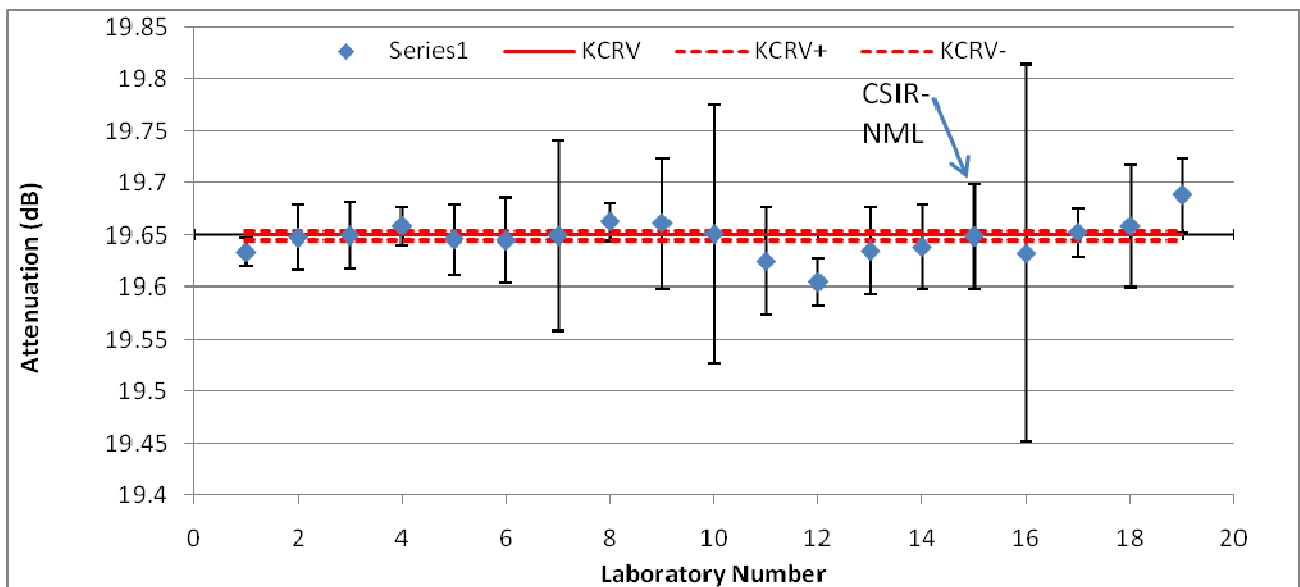


Fig. 1: Measurement and combined standard uncertainty of 20 dB attenuator at 18 GHz ($k=1$)

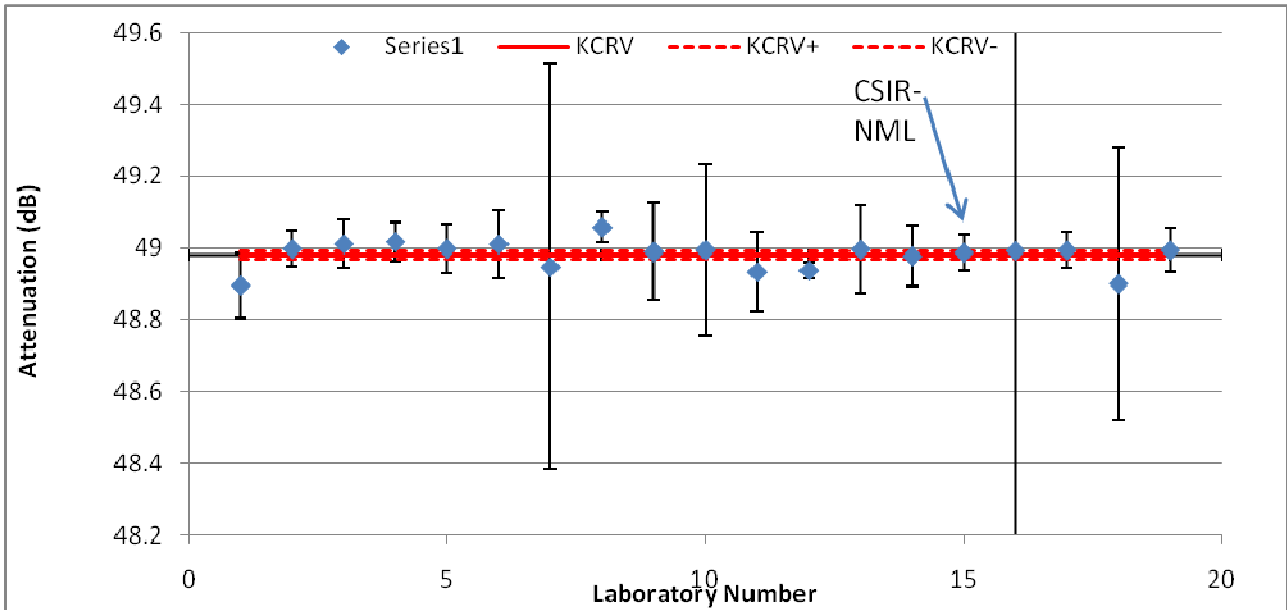


Fig. 2: Measurement and combined standard uncertainty of 50 dB attenuator at 18 GHz ($k=1$)

These two attenuation results from CSIR-NML show an excellent agreement with the KCRV.

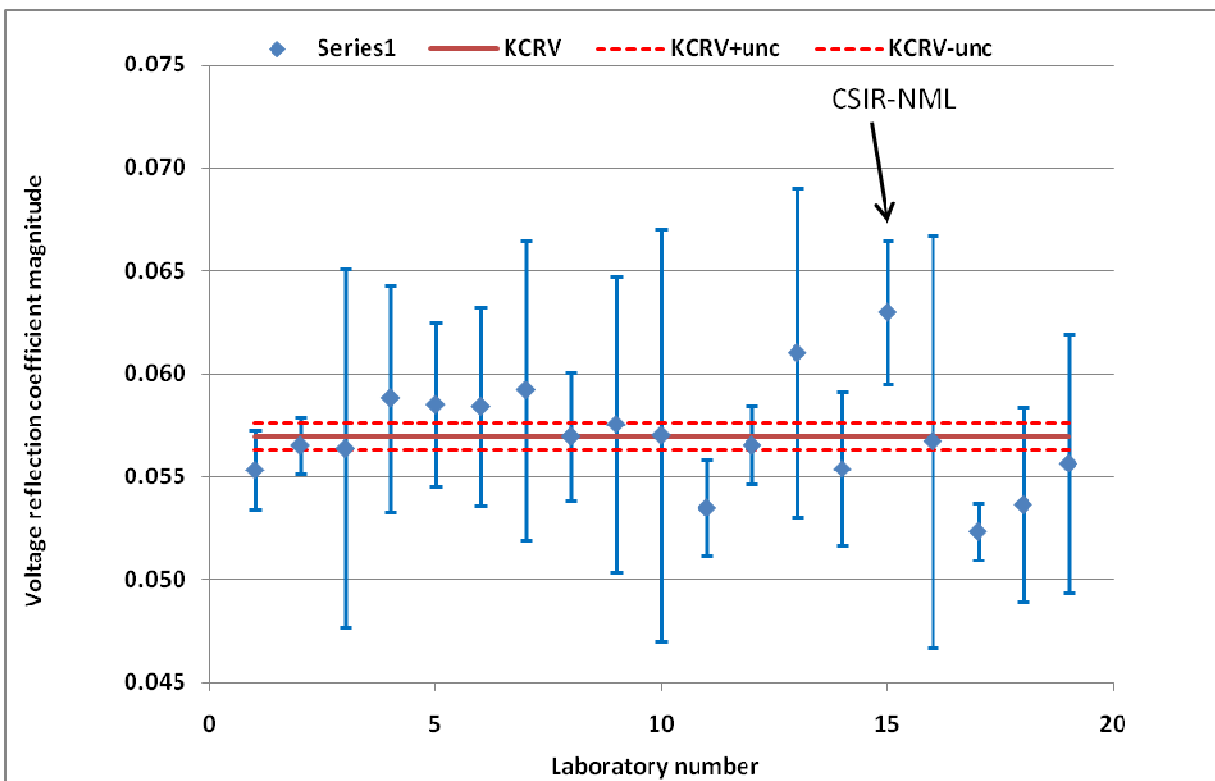


Fig. 3: Measurement and combined standard uncertainty of matched NM load at 18 GHz ($k=1$)

The CSIR-NML result is not in agreement with the KCRV. However when the expanded uncertainty is applied ($k=2$) then the agreement is acceptable.

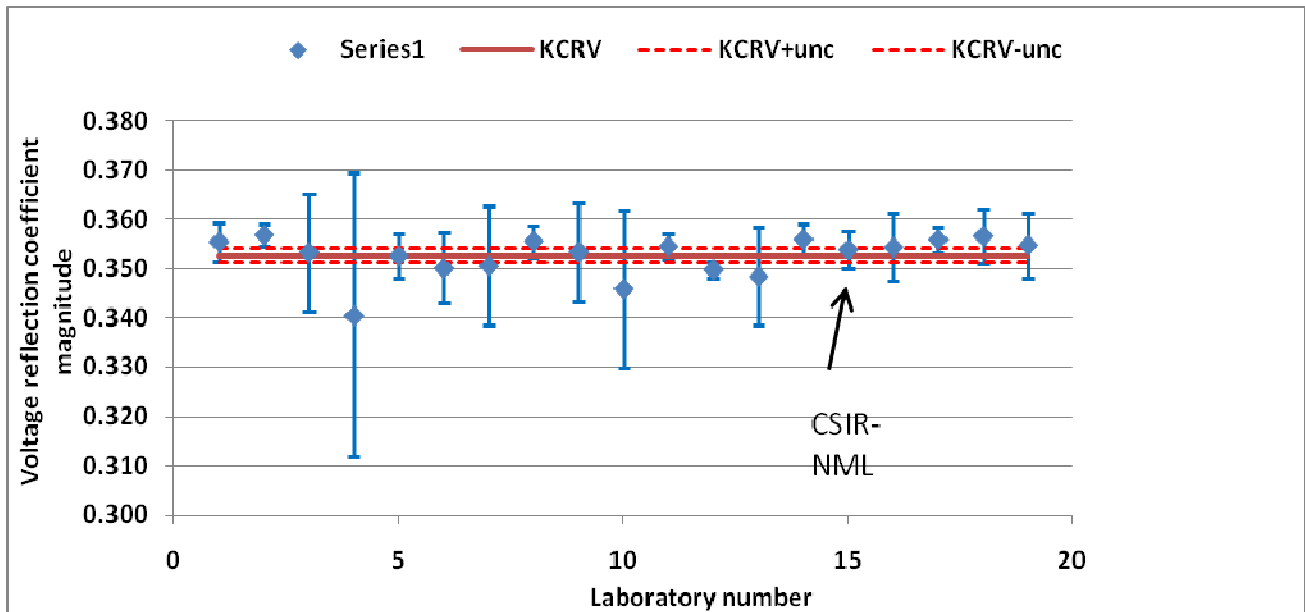


Fig. 4: Measurement and combined standard uncertainty of mismatched NF load at 18 GHz ($k=1$)

The CSIR-NML result is in excellent agreement with the KCRV.

5. Conclusions

An international comparison of scattering coefficients at microwave frequencies has been carried out among nineteen national metrology laboratories around the world. The parameters compared were S -parameters relative to 50Ω for items fitted with Type N precision connectors. The frequency range was 2 – 18 GHz but a detailed analysis is provided only for a choice of parameters at 2, 9 and 18 GHz.

Seven items, consisting of three attenuators, two matched terminations and two mismatched terminations were measured for the purposes of this comparison. The characteristics of the 3 dB attenuator underwent a step change; despite this, the device was stable in both states and is represented by two KCRVs in this comparison.

The size of the uncertainties in the measurements of the transmission coefficients of the attenuators varies somewhat amongst the participants but, with two or three exceptions, the reported values are consistent within those uncertainties.

References

1. Chris Eiø, "CCEM KEY COMPARISON CCEM.RF-K5b.CL (GT-RF/92-3)", draft B, June 2009