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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

by
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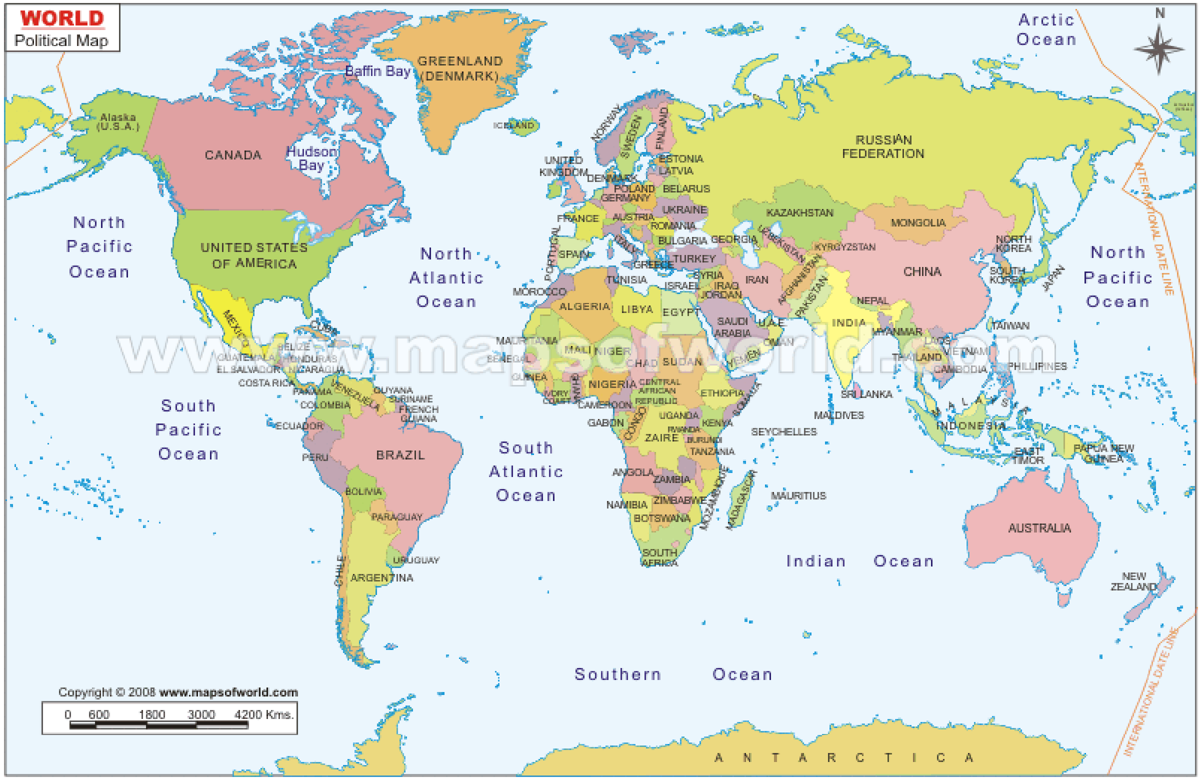
Your measure of excellence

Participants

- 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)



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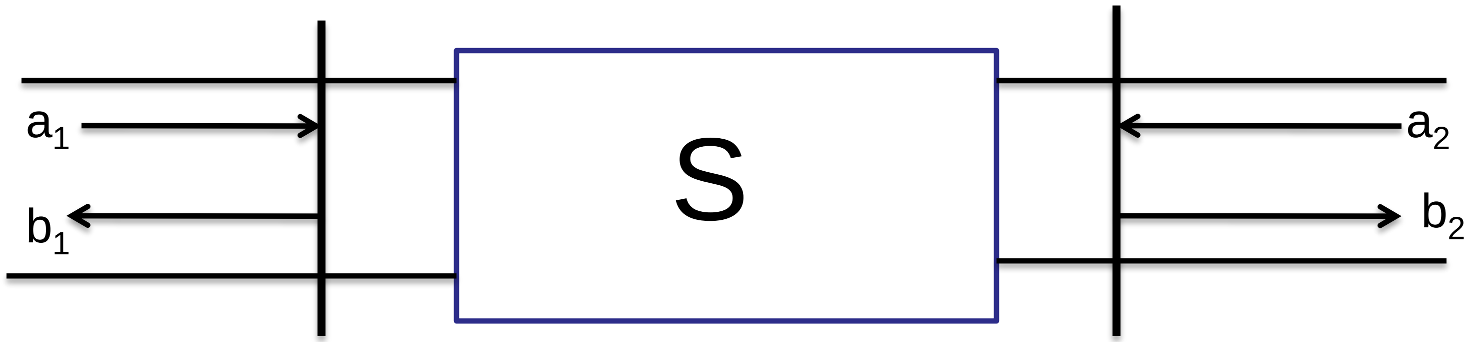
Scope of the intercomparison

- 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

S-parameters

- S-parameters or scattering parameters are used to determine the reflective and transmissive properties of a device when an electromagnetic signal is sent into it (one –port device) or through it (two-port device).
- This can be illustrated with the following figure:



The figure shows a 2-port device (attenuator) with input signals applied to both ports. If the device is linear, the output signals can be defined in terms of the input signals:

$b_1 = S_{11} a_1 + S_{12} a_2$

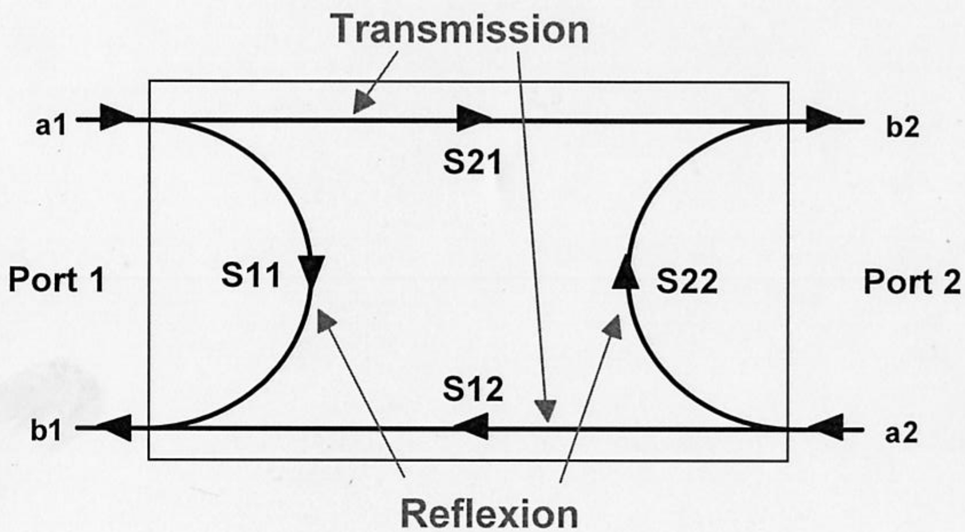
$b_2 = S_{21} a_1 + S_{22} a_2$

with signal amplitudes a,b and the scattering parameters S_{ij}

S-Parameter model for a linear Two-Port network

EM-wave:
1. forward direction

$a2 = 0$



EM-wave:
2. reverse direction

$a1 = 0$

$$S11 = \frac{b1}{a1} \qquad S22 = \frac{b2}{a2}$$

$$S21 = \frac{b2}{a1} \qquad S12 = \frac{b1}{a2}$$

Conversion between attenuation and transmission coefficients

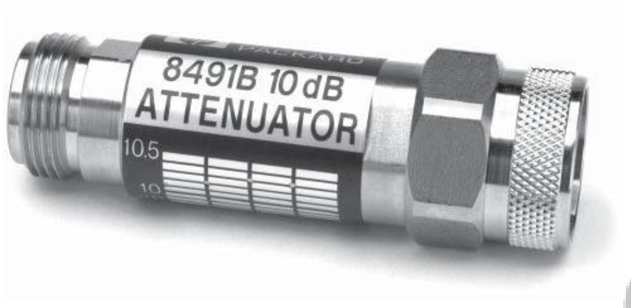
dB	T
3	0.708
6	0.501
10	0.316
20	0.100
30	0.032
40	0.010
50	0.003
60	0.001

T=transmission coefficient (e.g. S-parameters S_{21} or S_{12})

$$20 \cdot \log T = -N \text{ dB}$$

$$T = 10^{-N \text{ dB}/20}$$

Travelling standards

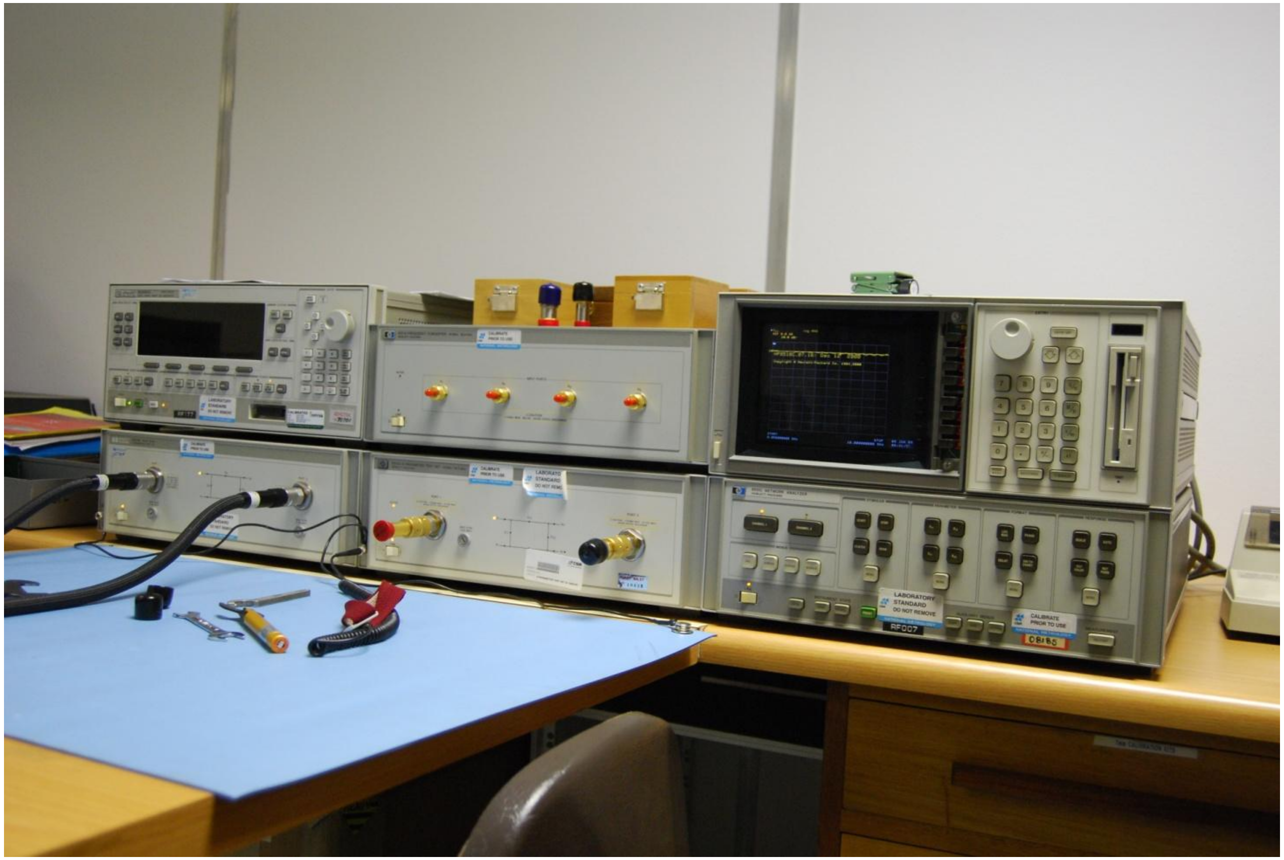


- The seven travelling standards were a selection of one-port and two-port devices:
- Two terminations, two mismatches and three fixed attenuators were chosen.

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

Measurement set-up used by the NMISA

- VNA system: HP 8510C with 8515A test set
- Calibration kit: HP 85054B



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.

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Measurement set-up used by the NMISA-continued

- 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.

Discussion of the results

- S-parameters are two-dimensional vector quantities written in polar coordinates as magnitude and phase or as a complex number with real and imaginary parts.
- The participants were asked to submit their results in the complex notation.
- The graphical evaluation of the results by the pilot laboratory using complex numbers is not as clear as if done for the magnitudes only. Therefore in this presentation a scalar representation is used.
- An example of the diagrams used in the draft B report by the pilot laboratory is shown on the next slide.

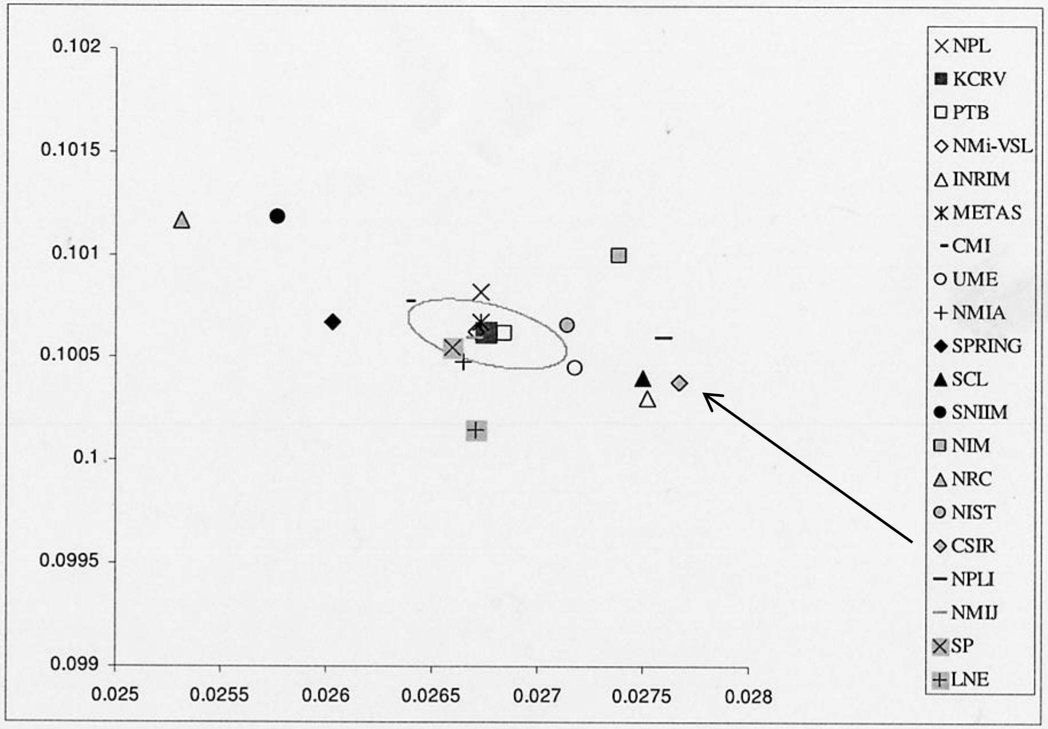

Fig 6 – Plot of measurements of S_{21} of device K5b.CL/2 (20 dB attenuator) at 18 GHz along with the KCRV and its expanded uncertainty (k = 2.5)

Discussion of the results - continued

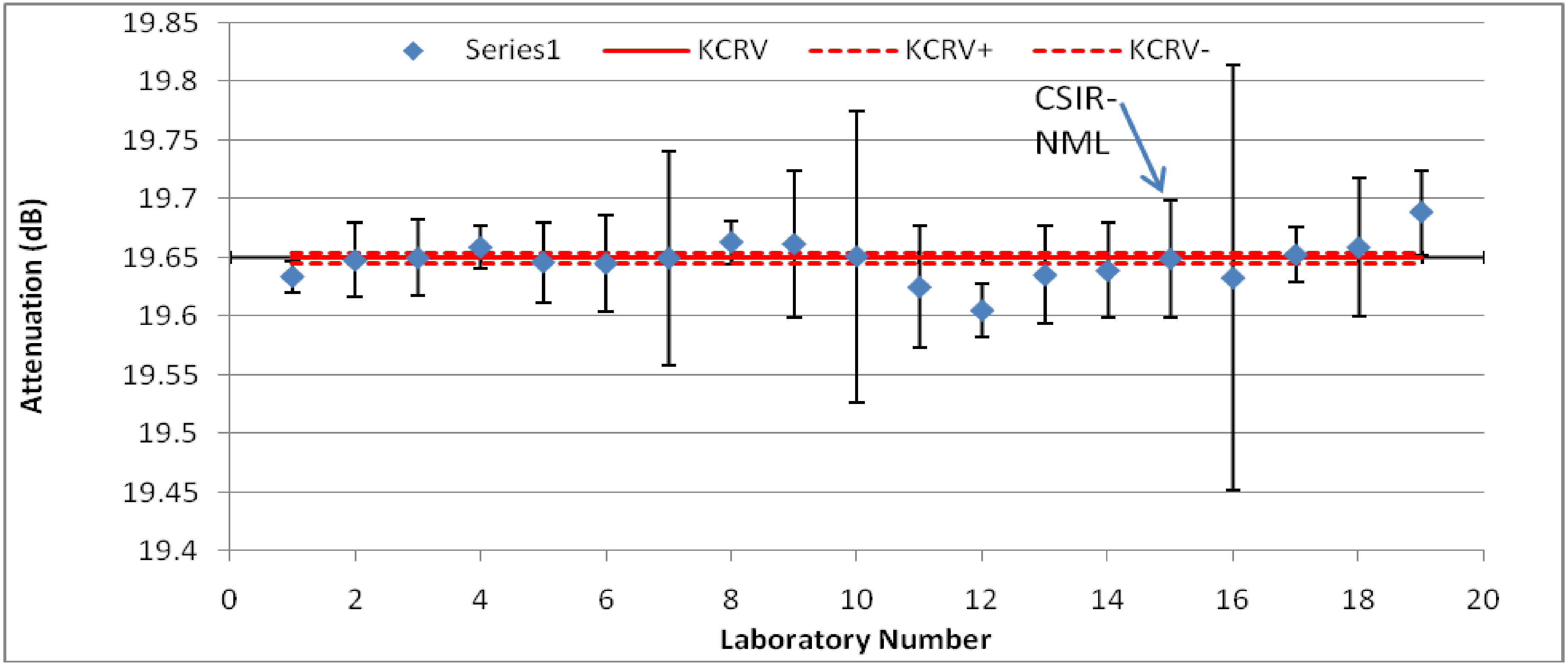

Fig. 1: Measurement and combined standard uncertainty of 20 dB attenuator at 18 GHz (k=1)

Discussion of the results - continued

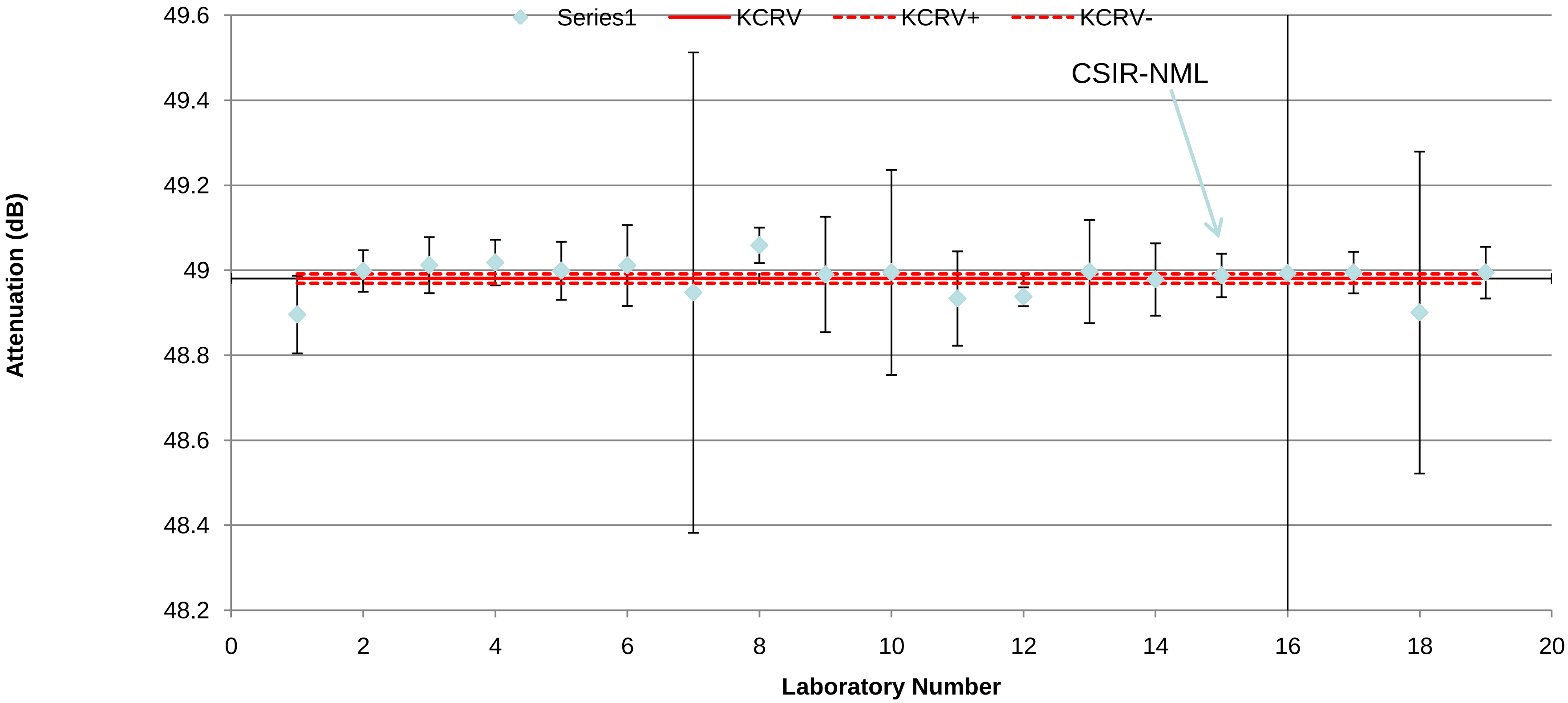

Fig. 2: Measurement and combined standard uncertainty of 50 dB attenuator at 18 GHz (k=1)

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Discussion of the results - continued

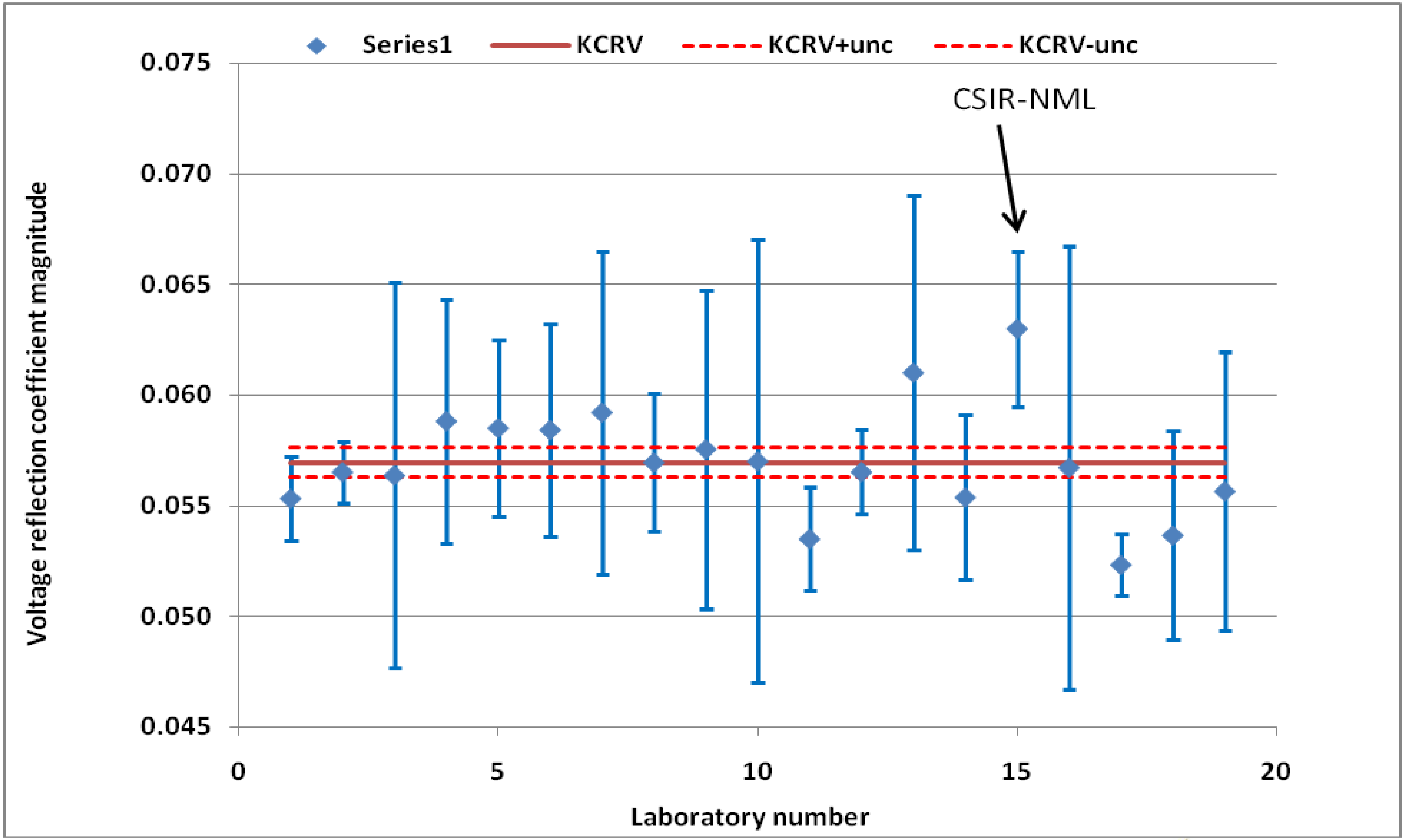

Fig. 3: Measurement and combined standard uncertainty of matched NM load at 18 GHz (k=1)

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Discussion of the results - continued

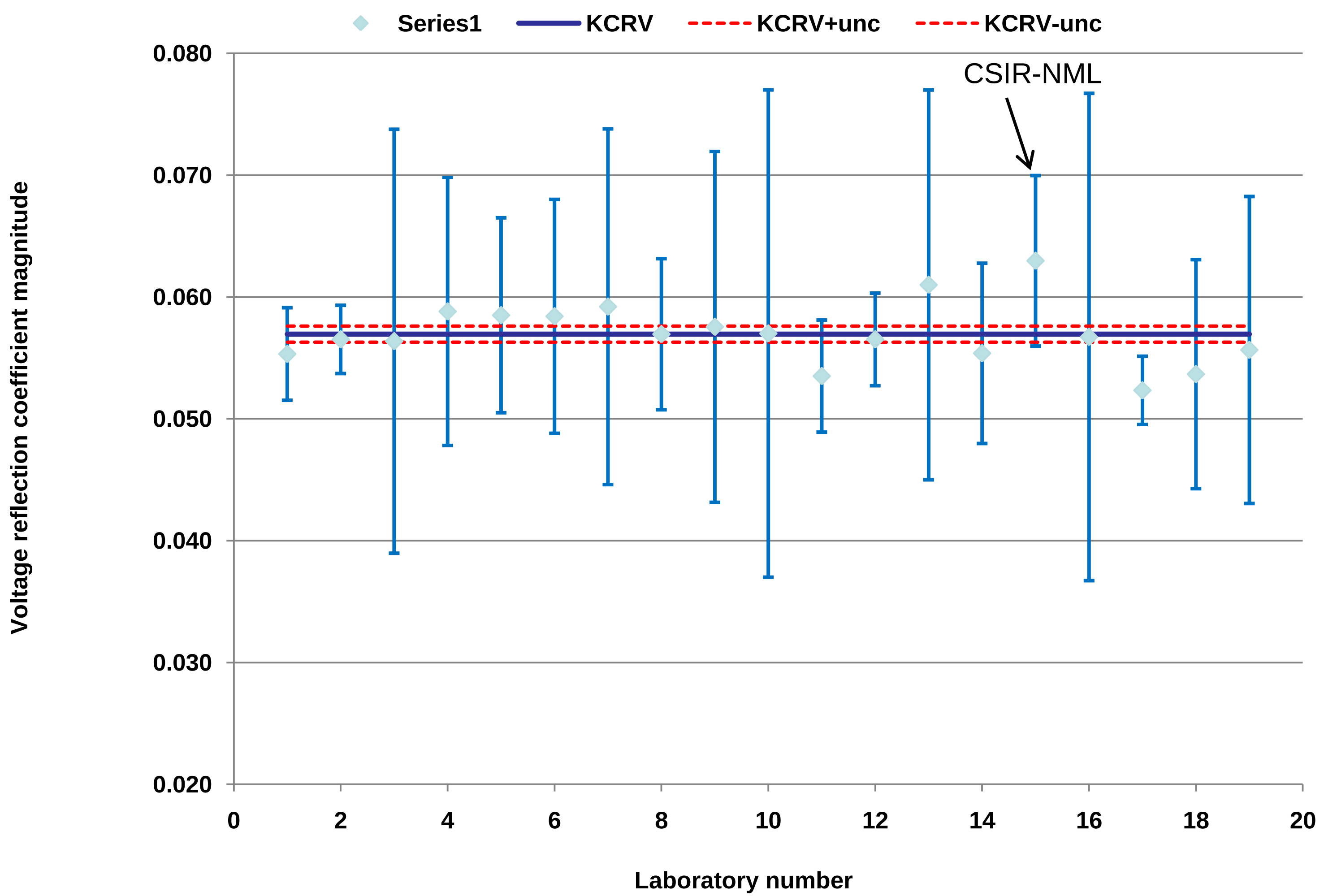

Fig. 4: Measurement and combined standard uncertainty of matched NM load at 18 GHz (k=2)

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Discussion of the results - continued

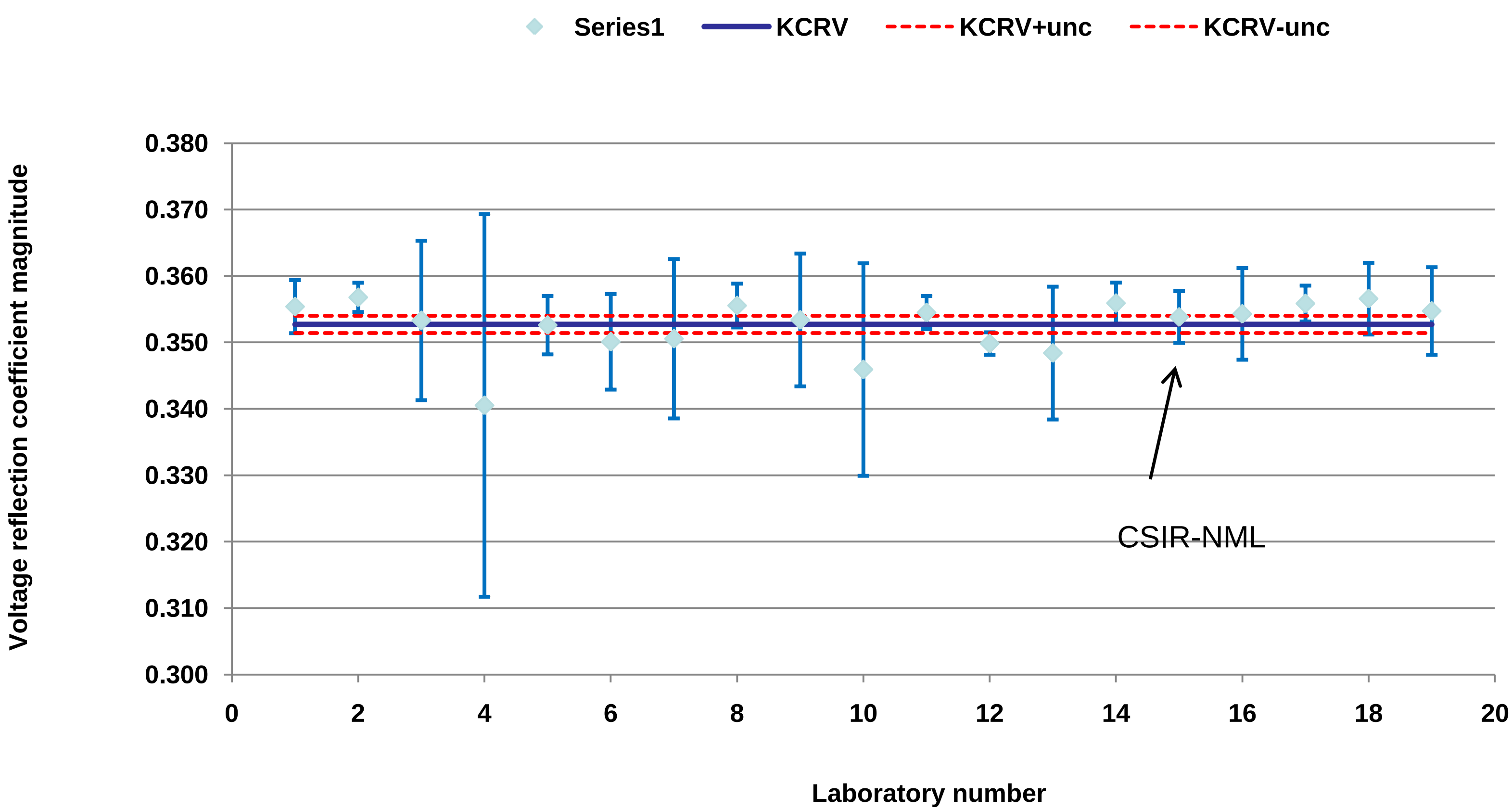

Fig. 5: Measurement and combined standard uncertainty of mismatched NF load at 18 GHz (k=1)

Conclusion

- We participated in an international key comparison concerning S-parameter measurements in the 7 mm coaxial line system (Type N connectors) at frequencies up to 18 GHz.

- Almost all the results compared well with the KCRV (Key Comparison Reference value) taking the combined uncertainties into account.

- The agreement for the NM load at 18 GHz was not as good as expected but even in this case using the expanded standard uncertainty (k=2) there was overlap with the KCRV and its uncertainty. The normalised error or En-value was 0,87 for this measurement.

- A re-evalulation of our vector network analyser uncertainties for one-port devices with type N-male conectors at frequencies of 18 GHz indicated that a more conservative approach has to be followed. This has already been implemented.

Thank you