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National Interlaboratory comparison RF power in N-type coaxial connector systems up to 18 GHz October 2013 - April 2014

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Deutscher Kalibrierdienst (DKD)

Since its foundation in 1977, the DKD brought together calibration laboratories of industrial enterprises, research institutes, technical authorities, inspection and testing institutes. On 3 May 2011, the DKD was reestablished as a *technical body* of the PTB and the accredited laboratories.

This body is called *Deutscher Kalibrierdienst* (DKD – *German Calibration Service*) and is under the direction of the PTB. The guidelines and guides elaborated by the DKD represent the state of the art in the respective technical areas of expertise and can be used by the *Deutsche Akkreditierungsstelle GmbH* (the German accreditation body – DAkkS) for the accreditation of calibration laboratories.

The accredited calibration laboratories are now accredited and monitored by the DAkkS as legal successor of the DKD. They carry out calibrations of measuring devices and measuring standards for the measured values and measuring ranges defined during accreditation. The calibration certificates issued by these laboratories prove the traceability to national standards as required by the family of standards DIN EN ISO 9000 and DIN EN ISO/IEC 17025.

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This document is a translation. The authoritative version is the original German Comparison Report DKD-V 02.02 (edition 02/2015).

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Foreword

DKD comparison reports aim to disclose the results of comparison measurements organized, carried out or evaluated by the German Calibration Service. They contain a lot of information regarding the measurement capabilities of the participating calibration laboratories and the comparability of the measurements. The DKD comparison reports reflect the views of the respective authors which do not necessarily represent in detail the perspective of the Board of the DKD or that of the Technical Committees.

The DKD comparison reports are aimed at presenting the examined aspects and results of the calibration and shall be made available, both nationally and internationally, to the big community of calibration laboratories through publication by the DKD.

This DKD comparison report was approved by the Board of the DKD in February 2015.

Summary

A national interlaboratory comparison for the quantity “RF power in N-type coaxial connector systems up to 18 GHz” was carried out between October 2013 and April 2014.

The aim of this national intercomparison was to give the accredited DAkkS calibration laboratories the opportunity to participate in interlaboratory comparisons, i.e. comparisons between different laboratories (according to DIN EN ISO/IEC 17025:2005 Point 5.9.1).

In this comparison, the calibration factor and the reflection coefficient of a power sensor were to be determined at seven different frequencies between 50 MHz and 18 GHz. In addition, the pin depth of the N-connector was to be measured. In general, the participants’ results showed a good agreement with the reference values.

1 Organisation

The decision to carry out the national interlaboratory comparison “RF power in N-type coaxial connector systems up to 18 GHz” was taken at the 38th meeting of the DKD Technical Committee “High Frequency and Optics“, held on 16 May 2013. The interlaboratory comparison was organized by the PTB Working Group 2.22 “High-Frequency Measuring Techniques”. The working group also carried out the reference measurements of the comparison.

First results, however without numerical values, were presented during the 39th meeting of the Technical Committee “High Frequency and Optics“, held on 8 May 2014. The participants of the comparison who attended the meeting also agreed that in draft A of the report the results should be linked to the names of the participants. The approval of the participants who did not take part in the meeting was obtained afterwards.

2 Transfer standards and measuring frequencies

A power sensor *Rohde & Schwarz NRP-Z51* with the serial number 104095 was used as measurement object (see Figure 11.2.1 on page 47). In addition, a USB adapter (NRP-Z4) with corresponding software to readout the measurement object’s performance was sent to the participants.

The sensor for this comparison as well as the USB adapter, the manuals and the software were kindly provided for temporary use by *Rohde & Schwarz Messgerätebau GmbH* (Memmingen) for which we would like to express our thanks, also on behalf of the participating calibration laboratories and the DKD.

3 Participants

The members of the DKD Technical Committee “High Frequency and Optics“ were contacted by letter. At that time (31 May 2013), a total of seven DAkkS calibration laboratories were accredited for the quantity “RF power“:

- Cassidian, Ulm
- esz AG, Eichenau
- Kalibrierzentrum der Bundeswehr*, Mechernich (*Calibration Centre German Armed Forces)
- Rohde & Schwarz GmbH & Co. KG, Cologne
- Rohde & Schwarz Messgerätebau GmbH, Memmingen
- Teseq GmbH, Berlin
- Testo industrial services GmbH, Kirchzarten

In addition, the following calibration laboratories took part in the comparison measurement on a voluntary basis:

- Cassidian, Manching
- Kalibriercentrum Bayern, Egmating
- Siemens AG, Erlangen
- Systems Engineering Kalibrierlaboratorium GmbH & Co. KG, Stolberg

4 Measurands

For the frequencies of 50 MHz, 500 MHz, 1 GHz, 5 GHz, 10 GHz, 15 GHz and 18 GHz, the following parameters were to be determined:

- the absolute calibration factor K
- the magnitude $|\Gamma|$ and the phase φ of the input reflection coefficient. Moreover,
- the pin depth, i.e. the distance between reference plane and shoulder of the inner connector, had to be measured.

4.1 Absolute calibration factor

For the seven measuring frequencies, the absolute calibration factor K had to be determined according to the following definition:

$$K = \frac{P_{\text{indication}}}{P_{\text{incident}}}$$

$P_{\text{indication}}$: indicated power

P_{incident} : incident power

4.2 Magnitude of the reflection coefficient and phase

The magnitude of the input reflection factor $|\Gamma|$ as well as the phase φ had to be determined for the seven different measuring frequencies.

4.3 Pin depth of the connector

To check the mechanical stability of the sensor during the comparison, the pin depth between the reference plane of the outer connector and the shoulder of the inner connector had to be determined.

The pin depth can be specified by means of two different values (see Figure 4.3.1).

- On the one hand, as distance between the reference plane and the shoulder of the inner connector. It will then be, for example, 5268 µm.
- On the other hand, it can also be specified as distance between the standard distance (5257.8 µm) and the shoulder of the inner connector. For the above-mentioned example, this would be –10.2 µm.

The pin depth for precision N-type connectors (LPC) may range between 0 µm and –76.2 µm (5257.8 µm and 5334 µm).

The pin depth is negative if the distance between the shoulder of the inner connector is greater than the reference level (5.2578 mm). The pin depth may not be positive, because otherwise it could damage the mating connector.

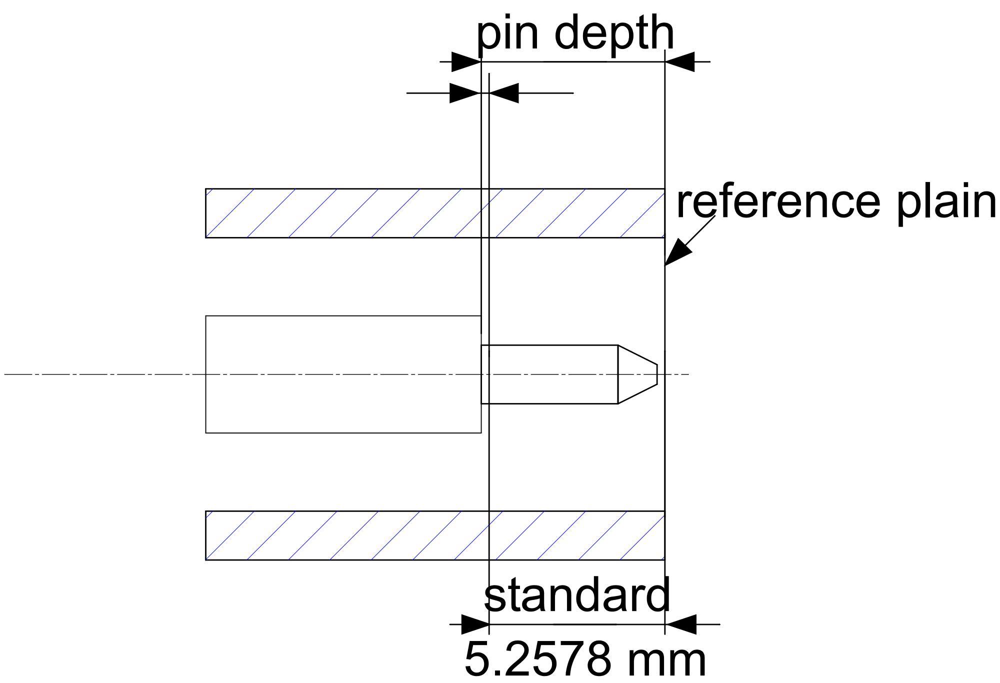

Figure 4.3.1: Representation of the reference plane and the pin depth of a male type N connector.

4.4 Documentation of the measurement results

In order to minimize errors in the transmission of the measurement results, the results were indicated in a result report, which could also be transmitted electronically.

To this end, the following information was required:

a. absolute calibration factor,
b. number of measurements and the
c. incident power,
d. brief description of the measurement procedure,
e. traceability of the standard (traced to PTB, another national institute or another calibration laboratory),
f. magnitude and phase of the reflection coefficient,
g. brief description of the measurement procedure of the reflection measurement and the standards used (Autocal, SOL...),
h. pin depth,
i. brief description of the measurement procedure and the standards used to determine the pin depth,
j. temperature and relative humidity during measurement,
k. calibration date,
l. date and signature.

5 Measurement sequence

Table 5.1.1 shows the calibration schedule of the individual calibration laboratories. A period of one week was estimated for each calibration laboratory to carry out the calibration. Another week was added for shipment to the next participant.

Figure 5.2.1 shows the circulation scheme of the comparison.

5.1 Calibration schedule

		Week number	Start (Mon)	End (Fri)
PTB	Preliminary measurement	40	30.09.2013	11.10.2013
Kalibriercentrum Bayern	Egmating	42	14.10.2013	25.10.2013
Testo industrial services	Kirchzarten	44	28.10.2013	08.11.2013
Kalibrierzentrum der Bundeswehr	Mechernich	46	11.11.2013	22.11.2013
Cassidian	Ulm	48	25.11.2013	06.12.2013
Rohde & Schwarz	Memmingen	50	09.12.2013	20.12.2013
PTB	Intermediate measurement	2	06.01.2014	17.01.2014
Teseq GmbH	Berlin	4	20.01.2014	31.01.2014
esz AG	Eichenau	6	03.02.2014	14.02.2014
Siemens	Erlangen	8	17.02.2014	28.02.2014
Rohde & Schwarz	Cologne	10	03.03.2014	14.03.2014
Cassidian	Manching	12	17.03.2014	28.03.2014
Systems Engineering	Stolberg	14	31.03.2014	11.04.2014
PTB	Return measurement	16	14.04.2014	25.04.2014

Table 5.1.1: Calibration schedule of the participants

5.2 Circulation of the standard

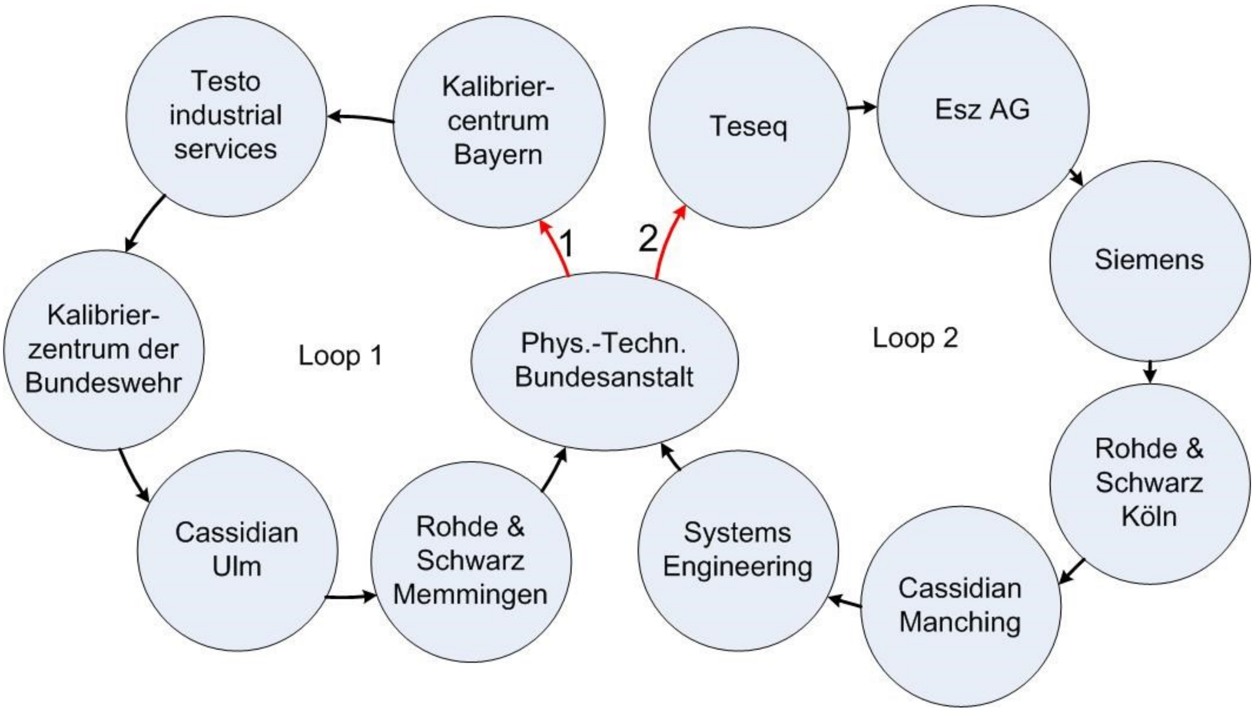

Figure 5.2.1: Circulation scheme of the standard

6 Calibration methods

6.1 Physikalisch-Technische Bundesanstalt, Braunschweig

Initially, the sensor *NRP-Z51* was calibrated by the PTB working group 2.22 at the beginning of the comparison, on 2 October 2013 (PTB preliminary measurement). On 16 January 2014, it was calibrated for the second time (PTB intermediate measurement) and a third calibration (PTB final measurement) took place on 29 April 2014. The measurement power was approximately 1 mW.

The device under test was calibrated by the direct comparison method, using a NRVC power splitter and one or two standards. Previously, the standards had been traced back in the microcalorimeter of PTB.

The reflection coefficient was determined according to magnitude and phase by means of a *R&S ZVA* network analyzer. A SOL calibration was applied as calibration method. For frequencies below 2 GHz, calibration was carried out by using a broadband load; for frequencies above 2 GHz, a sliding load was used. The verification of the calibration was carried out with a known load.

The pin depth was determined by means of a gauge meter from the N-calibration kit.

Respective intervals of the ambient conditions during the calibrations: (23 ± 1) °C and (50 ± 10) % relative humidity.

6.2 Kalibriercentrum Bayern, Egmating

At the time of the comparison, the *Kalibriercentrum Bayern* (Egmating) was not accredited for the measurand “RF power”. The calibration was carried out on 21 October 2013.

The calibration factor was determined by means of a resistive power splitter. A *NRV-Z51* power sensor served as reference head. A NRS (calibrated by PTB) as well as a *HP 8478 B* thermistor sensor head (also calibrated by PTB) were used as standards at the measurement port. The measurement power was approximately 1 mW.

The reflection coefficient was determined according to magnitude and phase by means of a *HP 8510C* network analyzer. A SOL calibration was used as calibration method. The traceability of the reflection standards was achieved via the dimensional quantities of air lines (100 mm and 300 mm) which themselves have been traced back (accredited by DAkkS). ‘Open’ and ‘short’ were calibrated by the manufacturer (Rosenberger).

The calibration of the pin depth was carried out using a calibrated dial gauge by the company *Rosenberger*. The zero position of the dial gauge was determined by the setting standard. The setting standard was calibrated by the *Kalibriercentrum Bayern* itself.

Ambient conditions at the time of calibration: (23 ± 1) °C and (50 ± 10) % relative humidity.

6.3 Testo industrial services, Kirchzarten

At the time of the comparison, *Testo industrial services* (Kirchzarten) was accredited for the measurand “RF power”. The calibration was carried out on 5 November 2013.

The calibration factor was determined by means of a *Tegam F1130B* transfer standard. The reference standard was traced back by *Metas* (Federal Institute of Metrology, Switzerland). The measurement power was approximately 1 mW.

The reflection coefficient was determined by means of an *Agilent N5230C* network analyzer and an *Agilent 85054D* calibration kit. The verification of the calibration was carried out with a *Maury* mismatch. The reflection phase was also measured. The uncertainty of the phase was not specified since the accreditation is only valid for the magnitude of the reflection coefficient ≥ 0.2. Thus, the uncertainty of the phase was subsequently calculated at PTB.

The pin depth was determined using a *Maury* gauge.

Ambient conditions at the time of calibration: (23 ± 1) °C and (40 ± 10) % relative humidity.

6.4 Kalibrierzentrum der Bundeswehr, Mechernich

At the time of the comparison, the *Kalibrierzentrum der Bundeswehr* (Mechernich) was not accredited for the measurand “RF power”. The calibration was carried out on 15 November 2013.

The calibration factor was determined by means of the power measuring system “System II“ by the company *Lucas Weinschel*. Traceability was achieved by means of two thermistor sensor heads (478A und 8478B) which had been calibrated at PTB.

The reflection coefficient was determined by means of a network analyzer from the company *Wiltron*, type 360. For this purpose, it had been calibrated using a *Wiltron/Anritsu* calibration kit (traced back to NIST) and had been verified with a *HP 909F* termination (calibrated by PTB).

The pin depth was determined using a dial gauge from the *Wiltron* calibration kit. The reference gauge was calibrated at PTB.

Ambient conditions at the time of calibration: (23 ± 2) °C and (50 ± 10) % relative humidity.

6.5 Cassidian, Ulm

At the time of the comparison, *Cassidian* (Ulm) was accredited for the measurand “RF power”. The calibration was carried out on 26 November 2013.

The calibration factor was determined by means of an N-type power splitter with a *HP 8478B* thermistor sensor head on the reference arm. A thermistor sensor head calibrated by PTB was used as standard. The measurement power was between 0.7 mW and 1 mW.

The reflection coefficient was determined by means of *HP 8510C* and a *HP 8753B* network analyzer. A SOL calibration was used as calibration method. A low-band termination was used up to 1 GHz, and a sliding load from 5 GHz upwards. The verification of the calibration was carried out with *Wiltron* termination.

The pin depth was determined using a dial gauge from the *HP* calibration kit.

Ambient conditions at the time of calibration: (23 ± 1) °C and (50 ± 10) % relative humidity.

6.6 Rohde & Schwarz, Memmingen

At the time of the comparison, *Rohde & Schwarz Messgerätebau* (Memmingen) was accredited for the measurand “RF power”. The calibration was carried out on 17 December 2013.

The calibration factor was determined using an *R&S MP733* test system. The calibration was traced back to PTB by means of a *NRV-Z51* and a *HP 8478B*. The measurement power was approximately 1 mW.

The reflection coefficient was determined by means of an R&S ZVA-40 network analyzer which had been calibrated using the SOL method.

The calibration of the pin depth was performed using an *Agilent* dial gauge from the calibration kit.

Ambient conditions at the time of calibration: (23 ± 1) °C and (40 ± 20) % relative humidity.

6.7 Teseq, Berlin

At the time of the comparison, *Teseq* (Berlin) was accredited for the measurand “RF power”. The calibration was carried out on 22 January 2014.

The calibration factor was determined using a power splitter, according to the procedure DKD-3-E1 (p. 6), Edition 10/1998. A *NRV-Z51* sensor head, which had been traced back in an accredited laboratory, was used as standard.

The calibration of the reflection coefficient was carried out by means of a *ZVK* network analyzer by *Rohde & Schwarz* and an PC3.5(f) to N(f) adapter. The OSM calibration was performed with the *ZV-Z21* calibration kit.

The pin depth was determined using a dial gauge and an adapter.

Ambient conditions at the time of calibration: (23 ± 2) °C and (50 ± 20) % relative humidity.

6.8 esz AG, Eichenau

At the time of the comparison, the *esz AG* (Eichenau) was accredited for the measurand “RF power”. The calibration was carried out on 5 February 2014.

The calibration factor was determined by using a *NRVC* by *Rohde & Schwarz*. The measurement power was 1 mW. Before the actual calibration, a verification was carried out by means of a control standard.

The reflection coefficient was determined by means of an *Agilent 85054B/E8361A* network analyzer. The calibration was carried out according to the SOL method, using a broadband load in the lower frequency range and a sliding load in the upper frequency range. Verification was performed by means of traceable reference standards.

The calibration of the pin depth was carried out using a *Maury* dial gauge and an *Agilent* calibration kit. A length standard, which is linked to the length laboratory of the *esz AG*, served as standard.

Ambient conditions at the time of calibration: (22.5 ± 1) °C and (36 ± 10) % relative humidity.

6.9 Siemens, Erlangen

At the time of the comparison, the *Siemens AG* (Erlangen) was not accredited for the measurand “RF power”. The calibration was carried out on 19 and 20 October 2014.

The determination of the calibration factor was carried out using a *Weinschel 1870A* power splitter and a *NRV-Z51* sensor head as reference power meter. A *NRV-Z51* sensor head, which had been traced back to PTB, was used as standard. The measurement power was between 0.7 mW and 1 mW.

The reflection coefficient was calibrated using a *HP 8510B*, which was traced back by means of a SOL calibration from a *HP 85054B* calibration kit.

The pin depth was determined by means of a dial gauge from the *HP 85054B* calibration kit.

Ambient conditions at the time of calibration: (23 ± 1) °C and (45 ± 15) % relative humidity.

6.10 Rohde & Schwarz, Köln

At the time of the comparison, *Rohde & Schwarz* (Cologne) was accredited for the measurand “RF power”. The calibration was carried out on 5 March 2014.

The calibration factor was determined with a *NRVC* power reference. A *NRV-Z51* with traceablity to *Rohde & Schwarz* in Memmingen was used as standard. The measurement power was approximately 1 mW.

The reflection coefficient was determined by means of a *ZVA* network analyzer. The calibration was carried out using an OSM calibration kit, type *ZV-Z21*.

The determination of the pin depth was carried out using a Maury dial gauge from the *Agilent 85054B* calibration kit.

Ambient conditions at the time of calibration: (23 ± 1) °C and (50 ± 10) % relative humidity.

6.11 Cassidian, Manching

At the time of the comparison, *Cassidian* (Manching) was not accredited for the measurand “RF power”. The calibration was carried out on 28 March 2014.

The calibration factor was determined at 50 MHz and 500 MHz, using a *Weinschel* power splitter. A tuner system, which was tuned to a source reflection factor of ≤ –40 dB, was used for the frequencies from 1 GHz to 18 GHz. On the one hand, a *HP 8478B* thermistor sensor (traced back to PTB), which was operated on two Tech-Type-II bridges, was used as standard. On the other hand, a *NRV-Z51* sensor (traced back to Rohde & Schwarz) was used. The measurement power was approximately 1 mW.

The reflection coefficient was determined using an *Agilent E8364C* network analyzer. An *Agilent 85054B* calibration kit was used for the SOL calibration.

The pin depth was determined by means of a dial gauge from the company Rosenberger.

Ambient conditions at the time of calibration: (23 ± 1) °C and (50 ± 15) % relative humidity.

6.12 Systems Engineering, Stolberg

At the time of the comparison, *Systems Engineering* (Stollberg) was not accredited for the measurand “RF power”. The calibration was carried out on 11 April 2014.

The calibration factor was performed using a *HP 11667A* power splitter. A *NRV-Z51* power meter, which had been traced back to PTB, served as standard. The measurement power was approximately 1 mW.

The reflection and the pin depth were not determined.

Ambient conditions at the time of calibration: (23 ± 1) °C and (41 ± 10) % relative humidity.

7 Stability of the travelling standard

During the interlaboratory comparison, the measurement object was measured three times by PTB. The first measurement was performed before the start of the intercomparison, on 28 October 2013. The second measurement took place on 16 January 2014, i.e. after the first round and before starting the second round. And finally, it was measured at the end of the comparison, on 29 April 2014.

This section presents the results of these measurements, and thus describes the stability of the measurement object.

During the interlaboratory comparison, there was no substantial change of the calibration factor (section 7.1) or of the reflection factor (section 7.2) of the sensor.

7.1 Stability of the calibration factor

	Preliminary measurement		Intermediate measurement		Final measurement		Mean values	
Frequency	K_1	$U(K_1)$	K_2	$U(K_2)$	K_3	$U(K_3)$	K_M	$U(K_M)$
50 MHz	0.9982	0.0034	0.9982	0.0034	0.9982	0.0034	0.9982	0.0034
500 MHz	0.9908	0.0034	0.9915	0.0034	0.9925	0.0034	0.9916	0.0035
1 GHz	0.9867	0.0034	0.9878	0.0033	0.9880	0.0033	0.9875	0.0034
5 GHz	0.9667	0.0034	0.9669	0.0041	0.9669	0.0040	0.9668	0.0034
10 GHz	0.9506	0.0040	0.9504	0.0050	0.9502	0.0050	0.9504	0.0040
15 GHz	0.9370	0.0050	0.9370	0.0070	0.9364	0.0070	0.9368	0.0050
18 GHz	0.9294	0.0070	0.9272	0.0070	0.9288	0.0070	0.9285	0.0071

Table 7.1.1: Stability of the calibration factor *K*

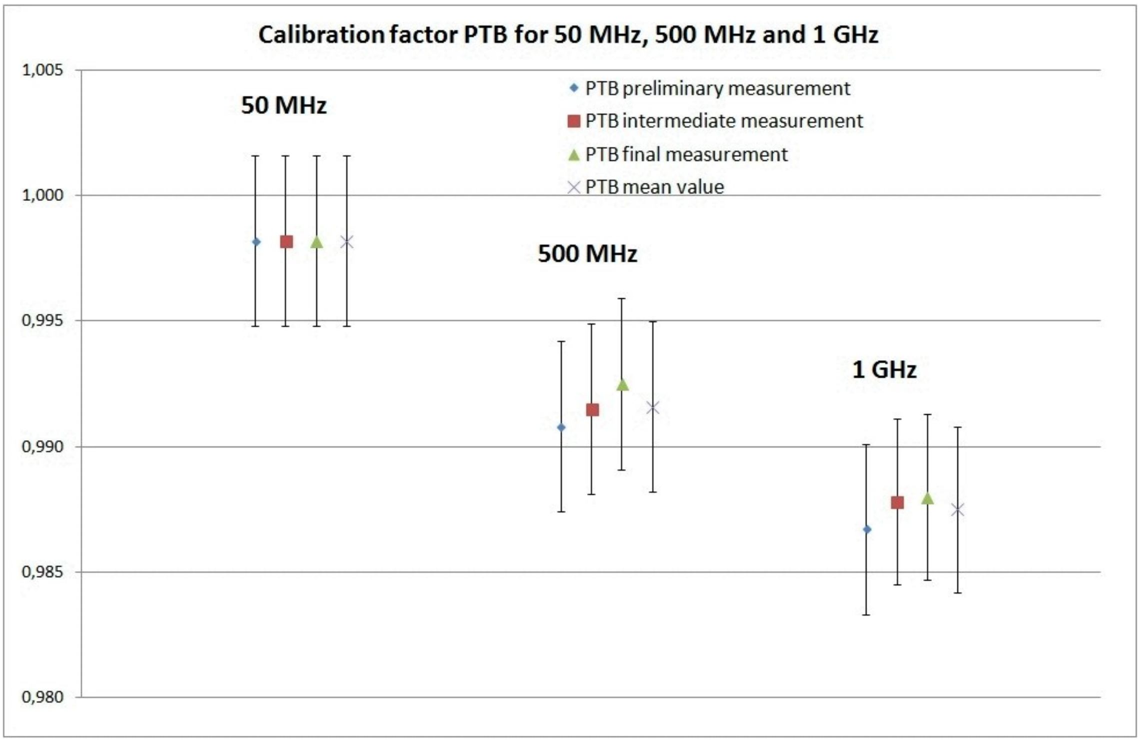

Figure 7.1.1: Stability of the calibration factor of the measurement object between 50 MHz and 1 GHz

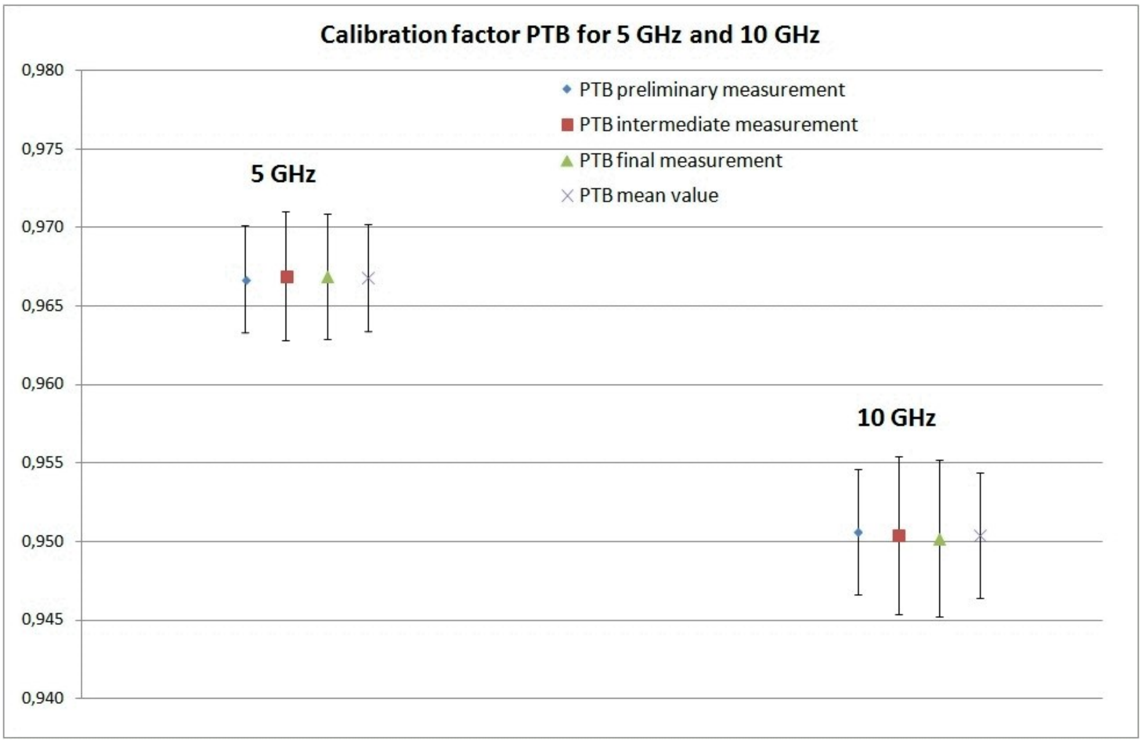

Figure 7.1.2: Stability of the calibration factor of the measurement object at 5 GHz and 10 GHz

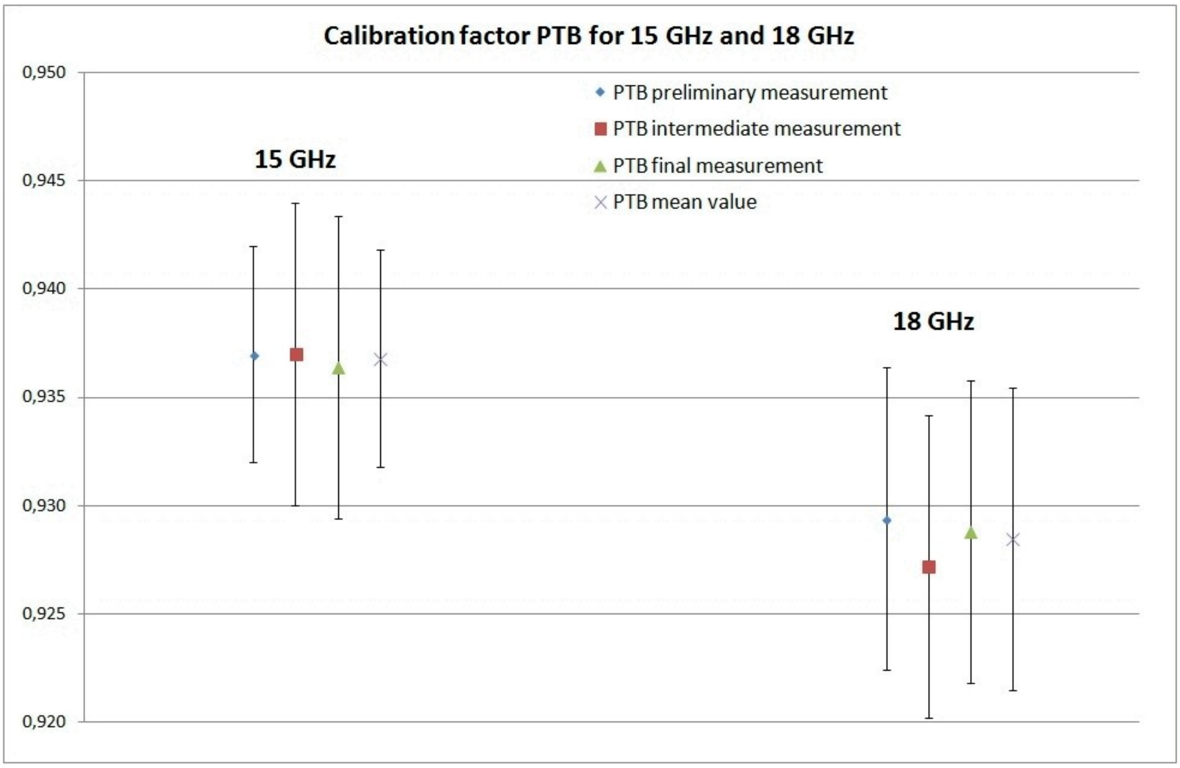

Figure 7.1.3: Stability of the calibration factor of the measurement object at 15 GHz and 18 GHz

7.2 Stability of the reflection factor

	Preliminary measurement		Intermediate measurement		Final measurement		Mean value	
Frequency	$\lvert\Gamma_1\rvert$	$U(\lvert\Gamma_1\rvert)$	$\lvert\Gamma_2\rvert$	$U(\lvert\Gamma_2\rvert)$	$\lvert\Gamma_3\rvert$	$U(\lvert\Gamma_3\rvert)$	$\lvert\Gamma_M\rvert$	$U(\lvert\Gamma_M\rvert)$
50 MHz	0.0016	0.0060	0.0015	0.0060	0.0015	0.0060	0.0015	0.0060
500 MHz	0.0055	0.0061	0.0056	0.0061	0.0056	0.0061	0.0056	0.0061
1 GHz	0.0099	0.0061	0.0099	0.0061	0.0099	0.0061	0.0099	0.0061
5 GHz	0.0287	0.0065	0.0288	0.0065	0.0287	0.0065	0.0287	0.0065
10 GHz	0.0326	0.0070	0.0327	0.0070	0.0328	0.0070	0.0327	0.0070
15 GHz	0.0450	0.0075	0.0444	0.0075	0.0443	0.0075	0.0446	0.0075
18 GHz	0.0380	0.0078	0.0379	0.0078	0.0383	0.0078	0.0381	0.0078

Table 7.2.1: Stability of the magnitude of the reflection coefficient $\lvert\Gamma\rvert$

	Preliminary measurement		Intermediate measurement		Final measurement		Mean value	
Frequency	φ_1	$U(\varphi_1)$	φ_2	$U(\varphi_2)$	φ_3	$U(\varphi_3)$	φ_M	$U(\varphi_M)$
50 MHz	-11.3°	180°	-10.1°	180°	-13.4°	180°	-11.6°	180°
500 MHz	31.3°	180°	31.4°	180°	32.5°	180°	31.7°	180°
1 GHz	-12.8°	37.2°	-12.5°	38.2°	-12.1°	37.8°	-12.5°	37.2°
5 GHz	-82.3°	12.1°	-82.4°	13°	-82.7°	13.1°	-82.5°	12.1°
10 GHz	19.8°	10.6°	19.2°	12.3°	18.9°	12.3°	19.3°	10.6°
15 GHz	95.5°	7.7°	95°	9.7°	95.3°	9.8°	95.3°	7.7°
18 GHz	68.6°	9.1°	69.1°	11.9°	68.9°	11.7°	68.9°	9.1°

Table 7.2.2: Stability of the phase φ of the reflection coefficient

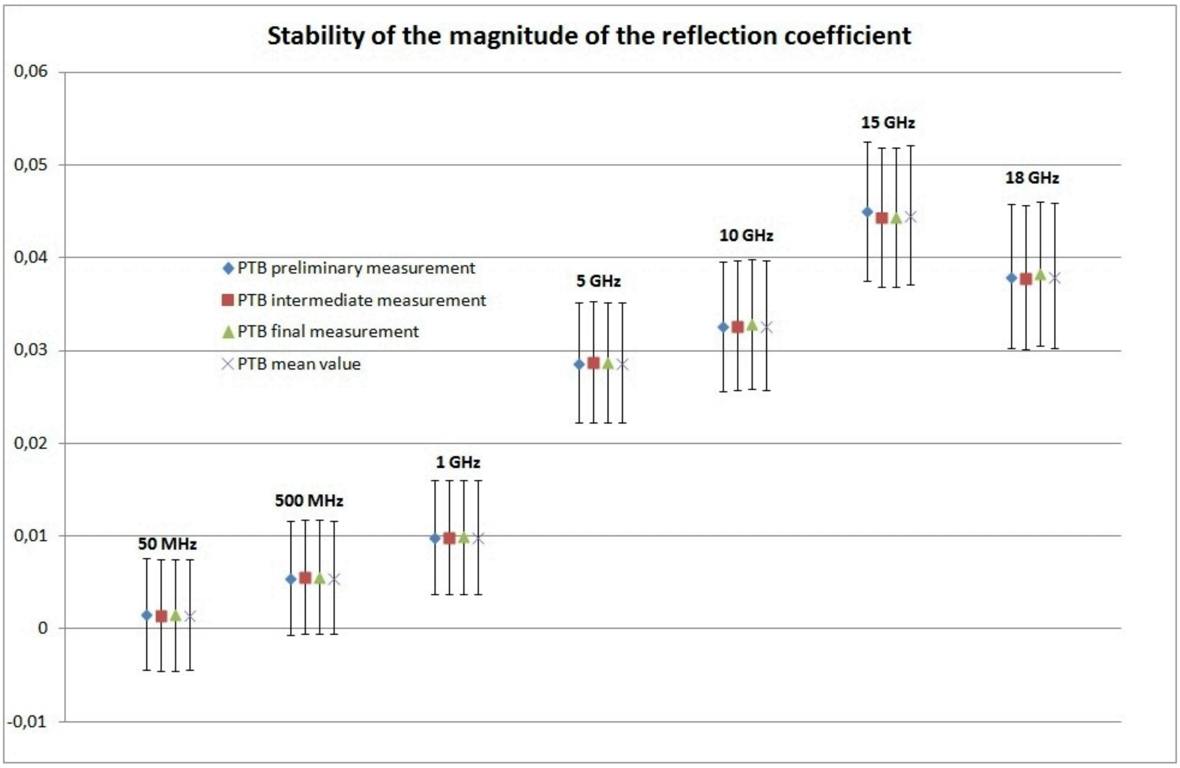

Figure 7.2.1: Stability of the magnitude of the reflection coefficient

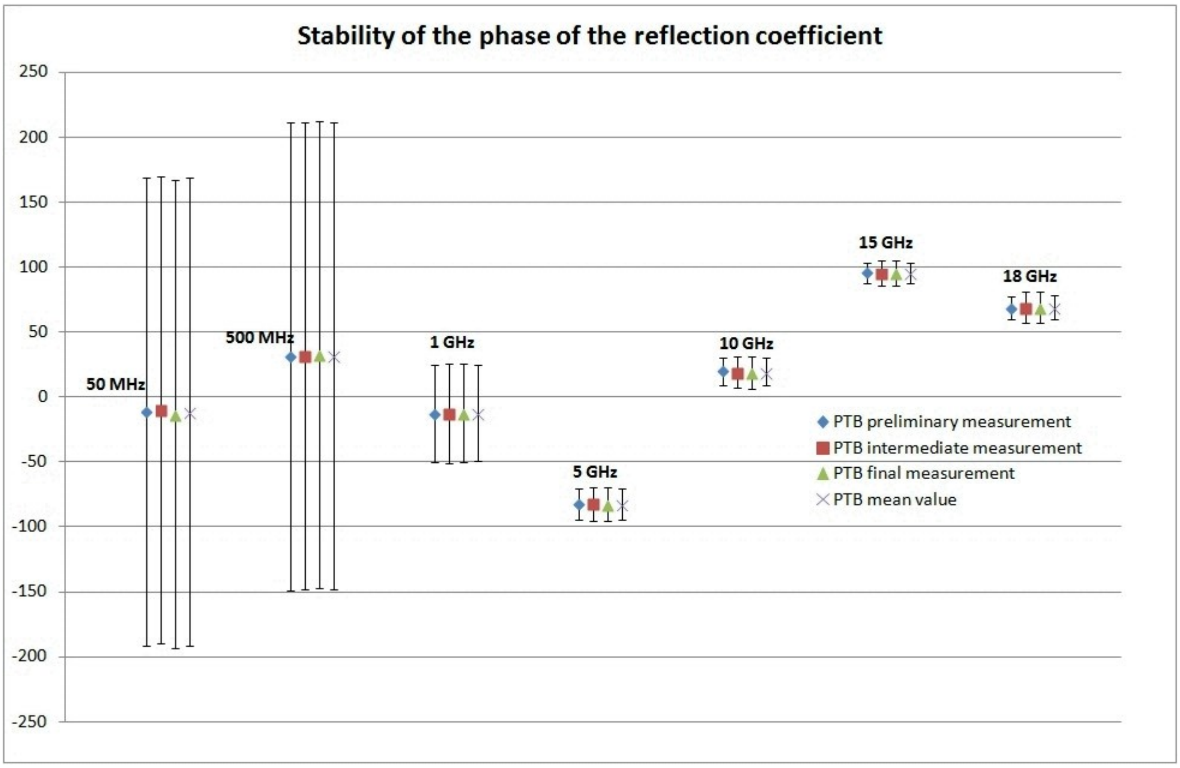

Figure 7.2.2: Stability of the reflection phase

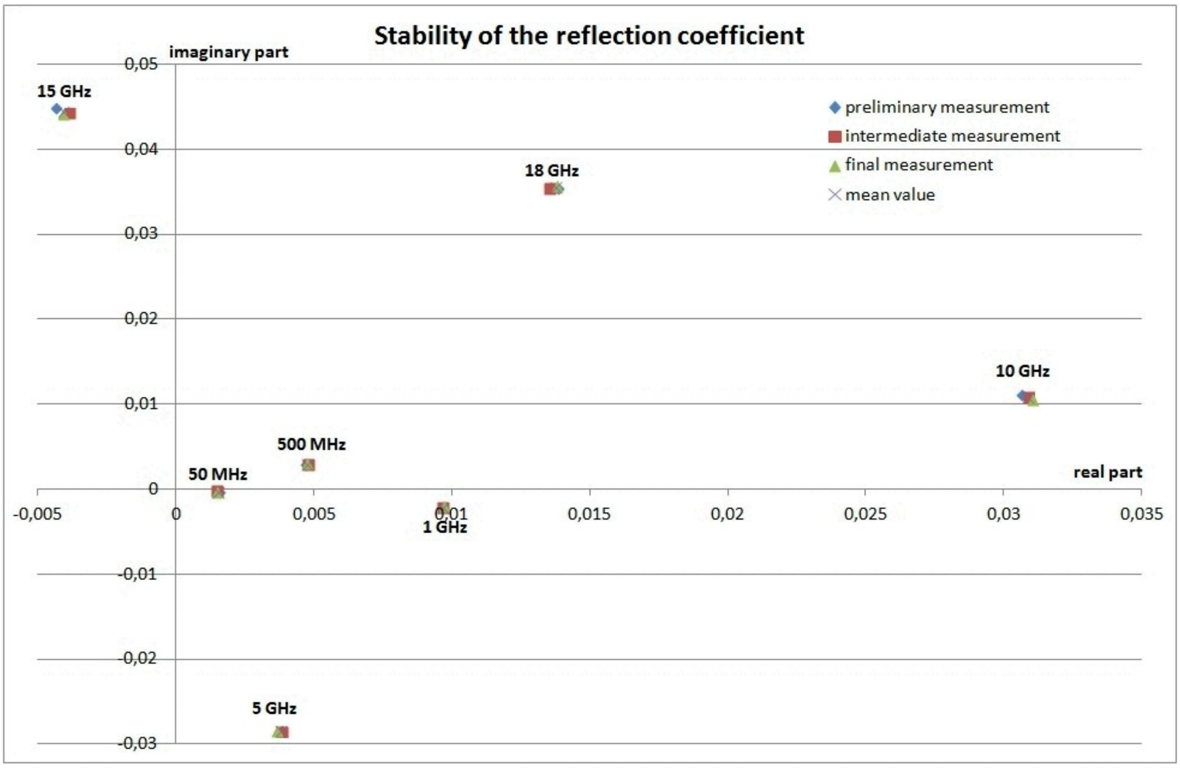

Figure 7.2.3: Stability of the reflection coefficient in the complex plane

8 Results of the calibration laboratories

In section 8, the measurement results for each calibration laboratory are set out in tabular form.

As is customary in comparisons, the E_N value was determined for the evaluation[1].

In the comparison measurements of the EA (European Cooperation for Accreditation), the former EAL (European Co-operation for Accreditation of Laboratories), the E_N value is a specified quality factor.

This value is calculated as follows:

$$E_{\mathrm{N}} = \frac{K_{\mathrm{Lab}} - K_{\mathrm{Ref}}}{\sqrt{U(K_{\mathrm{Lab}})^2 + U(K_{\mathrm{Ref}})^2}} \quad (1)$$

Components of the equation:

K_{Lab} : Measurement value of the participating calibration laboratory

K_{Ref} : Reference value of PTB

$U(K_{\mathrm{Lab}})$: Expanded uncertainty of the calibration factor of the calibration laboratory

$U(K_{\mathrm{Ref}})$: Expanded uncertainty of the reference value of PTB

The expanded uncertainties have the coverage factor $k = 2$.

The arithmetic mean value of the three measurements carried out by PTB was determined as reference value of the PTB. Due to the correlation of the measured values, the minimum measurement uncertainty from the three measurement uncertainties of PTB was used as expanded uncertainty of the reference value.

The values $-1 \leq E_N \leq 1$ are an acceptable result, and the values $-0.5 \leq E_N \leq 0.5$ constitute a good result. If the absolute value is greater, corrective and monitoring measures have to be carried out.

A summary of the E_N values of the measurement results of the comparison is shown on the following pages.

[1] EAL-P7 or EA-2/03, EA Interlaboratory Comparison, (1996)

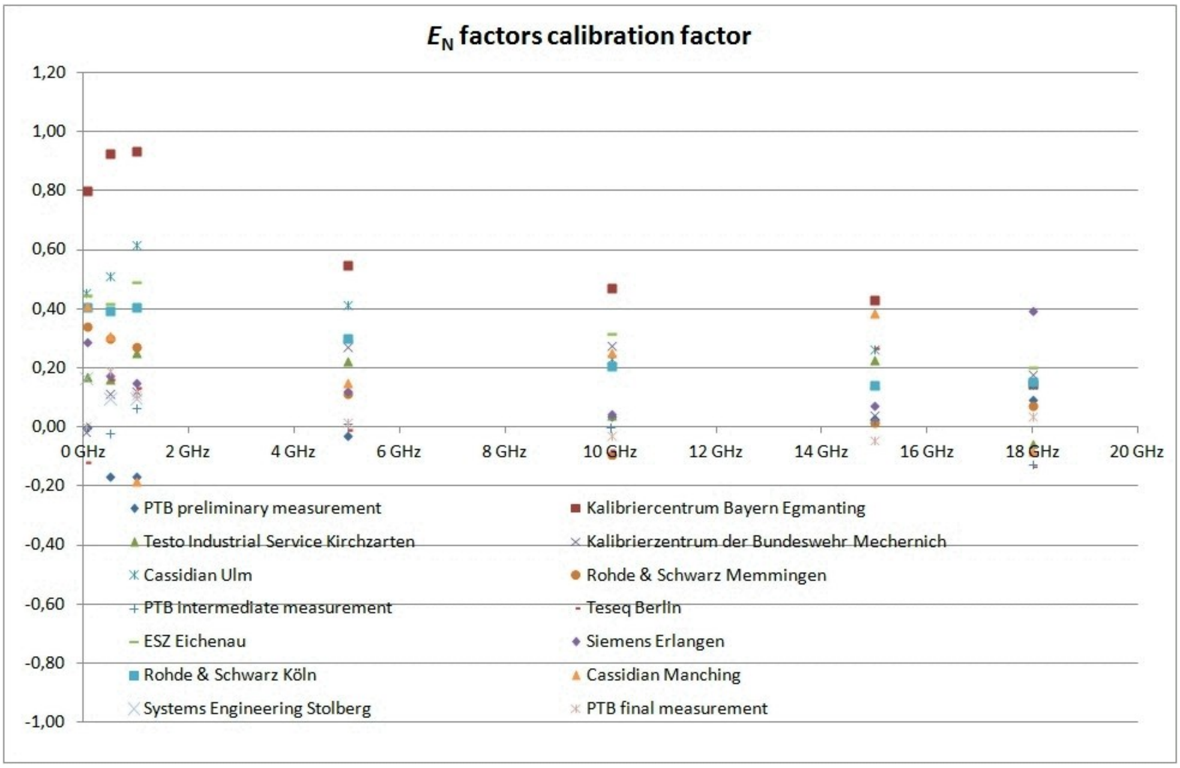

Figure 7.2.1: E_N factors of the calibration factor

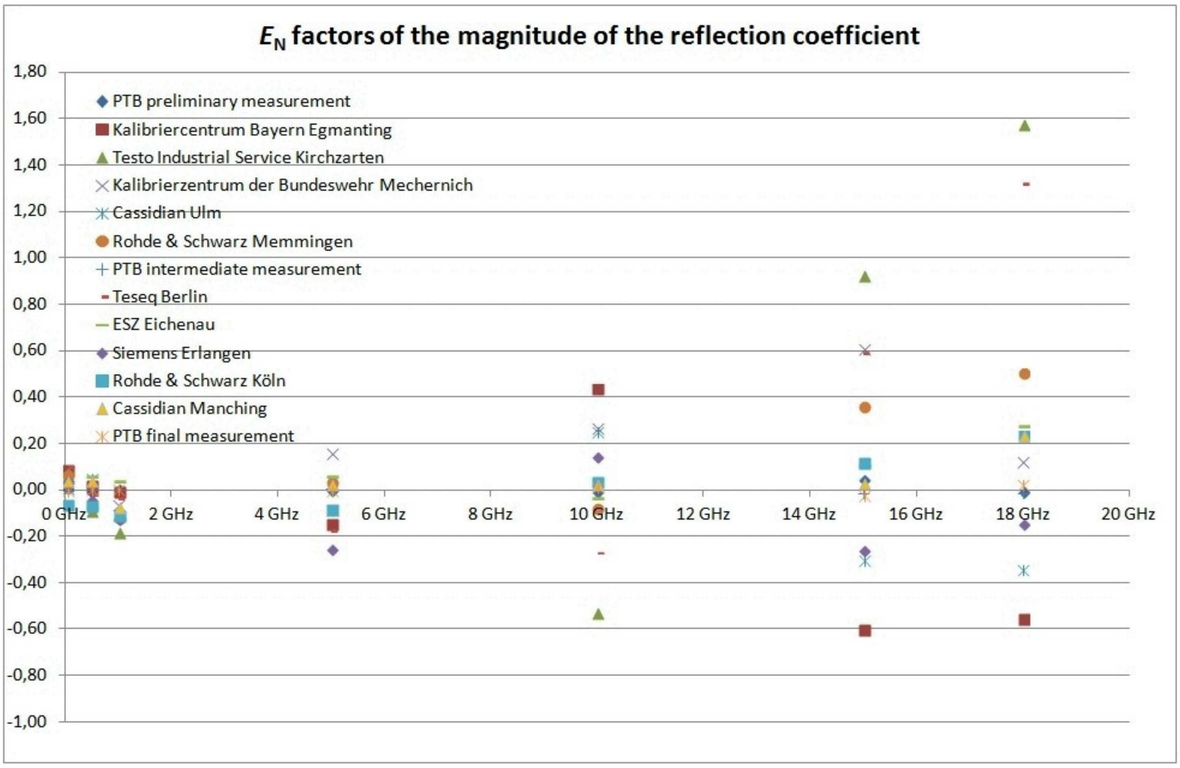

Figure 7.2.2: E_N factors of the magnitude of the reflection coefficient

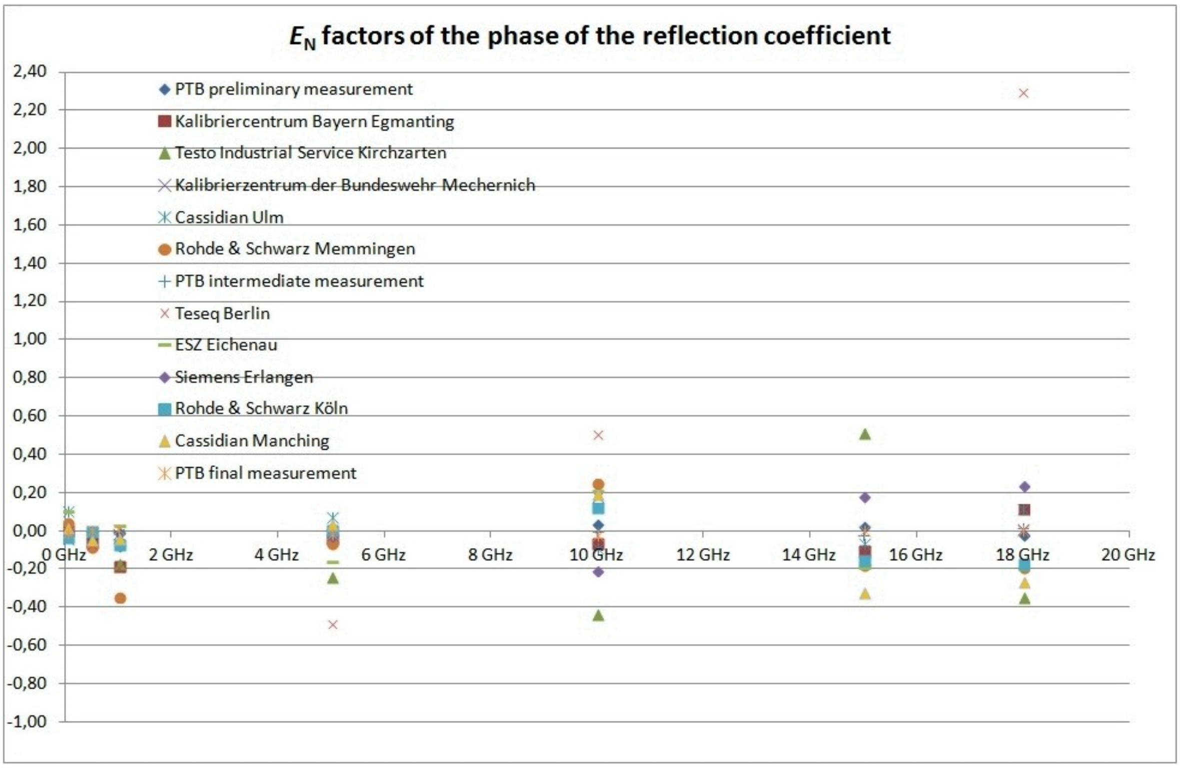

Figure 7.2.3: E_N factors of the phase of the reflection coefficient

9 The measurement results of the individual calibration laboratories

9.1 Kalibriercentrum Bayern, Egmating

The calibration factors and reflection coefficients of the measurement object show good agreement.

$$0.93 \geq E_N(K) \geq 0.14$$

$$0.43 \geq E_N(|\Gamma|) \geq -0.61$$

$$0.11 \geq E_N(\varphi) \geq -0.19$$

The stated value for the pin depth was 5294 µm, which corresponds to –36 µm. The expanded uncertainty was 10 µm.

Frequency	K	$U(K)$	$E_N(K)$
50 MHz	1.0024	0.004	0.80
500 MHz	0.9972	0.005	0.93
1 GHz	0.9931	0.005	0.93
5 GHz	0.9726	0.010	0.55
10 GHz	0.9577	0.015	0.47
15 GHz	0.9456	0.020	0.43
18 GHz	0.9315	0.020	0.14

Table 9.1.1: Results of the calibration factor, *Kalibriercentrum Bayern* (Egmating)

Frequency	$\|\Gamma\|$	$U(\|\Gamma\|)$	$E_N(\|\Gamma\|)$	φ	$U(\varphi)$	$E_N(\varphi)$
50 MHz	0.0025	0.01	0.08	-10.8°	10°	0.00
500 MHz	0.0058	0.01	0.02	20.6°	10°	-0.06
1 GHz	0.0098	0.01	-0.01	-19.7°	10°	-0.19
5 GHz	0.027	0.01	-0.15	-83.1°	10°	-0.04
10 GHz	0.038	0.01	0.43	18.3°	10°	-0.07
15 GHz	0.037	0.01	-0.61	94°	10°	-0.10
18 GHz	0.031	0.01	-0.56	70.4°	10°	0.11

Table 9.1.2: Results of the reflection coefficient, *Kalibriercentrum Bayern* (Egmating)

9.2 Testo industrial services, Kirchzarten

The calibration factor and the phase of the travelling standard show good agreement. The magnitude of the reflection coefficient differs slightly at 15 GHz, and the E_N value at 18 GHz is 1.57.

$$0.25 \geq E_N(K) \geq -0.06$$

$$1.57 \geq E_N(|\Gamma|) \geq -0.53$$

$$0.51 \geq E_N(\varphi) \geq -0.44$$

The stated value for the pin depth was –36.1 µm. The expanded uncertainty was 5 µm.

Frequency	K	$U(K)$	$E_N(K)$
50 MHz	1	0.01	0.17
500 MHz	0.9941	0.015	0.16
1 GHz	0.9914	0.015	0.25
5 GHz	0.9703	0.015	0.23
10 GHz	0.9512	0.02	0.04
15 GHz	0.9415	0.02	0.23
18 GHz	0.9273	0.02	-0.06

Table 9.2.1: Results of the calibration factor, *Testo industrial services* (Kirchzarten)

Frequency	$\|\Gamma\|$	$U(\|\Gamma\|)$	$E_N(\|\Gamma\|)$	φ	$U(\varphi)$	$E_N(\varphi)$
50 MHz	0.0022	0.007	0.07	-16.5°	180.0°*	-0.02
500 MHz	0.0047	0.007	-0.09	19.3°	180.0°*	-0.05
1 GHz	0.0082	0.007	-0.18	-24.6°	58.6°*	-0.17
5 GHz	0.029	0.01	0.02	-88.2°	20.2°*	-0.24
10 GHz	0.0262	0.01	-0.53	8.4°	22.4°*	-0.44
15 GHz	0.0561	0.01	0.92	101.8°	10.3°*	0.51
18 GHz	0.058	0.01	**1.57**	64.2°	9.9°*	-0.35

Table 9.2.2: Results of the reflection coefficient, *Testo industrial services* (Kirchzarten)

* The expanded uncertainty of the phase was calculated at PTB since it was not stated in the result report. With regard to the phase, the accreditation only comprises values in which the amount of the reflection coefficient is ≤ 0.2.

9.3 *Kalibrierzentrum der Bundeswehr, Mechernich*

The calibration factors and reflection coefficients show good agreement.

$$0.27 \geq E_N(K) \geq -0.02$$

$$0.61 \geq E_N(|\Gamma|) \geq -0.06$$

$$0.18 \geq E_N(\varphi) \geq -0.11$$

The stated value for the pin depth was 5300.98 µm. This corresponds to –42.98 µm. The expanded uncertainty was 2.54 µm.

Frequency	K	$U(K)$	$E_N(K)$
50 MHz	0.998	0.012	-0.02
500 MHz	0.993	0.012	0.11
1 GHz	0.989	0.012	0.12
5 GHz	0.971	0.015	0.27
10 GHz	0.956	0.02	0.27
15 GHz	0.938	0.03	0.04
18 GHz	0.934	0.03	0.18

Table 9.3.1: Results of the calibration factor, *Kalibrierzentrum der Bundeswehr* (Mechernich)

Frequency	$\|\Gamma\|$	$U(\|\Gamma\|)$	$E_N(\|\Gamma\|)$	φ	$U(\varphi)$	$E_N(\varphi)$
50 MHz	0.0016	0.01	0.01	-18.5°	37.4°	-0.04
500 MHz	0.0052	0.009	-0.03	29.1°	180°	-0.01
1 GHz	0.0092	0.009	-0.06	-13.7°	79.3°	-0.01
5 GHz	0.0306	0.01	0.16	-83.1°	19.1°	-0.03
10 GHz	0.0369	0.014	0.27	23.7°	22.3°	0.18
15 GHz	0.0542	0.014	0.61	93.4°	15°	-0.11
18 GHz	0.0405	0.018	0.12	69.2°	26.4°	0.01

Table 9.3.2: Results of the reflection coefficient, *Kalibrierzentrum der Bundeswehr* (Mechernich)

9.4 Cassidian, Ulm

The calibration factors and reflection coefficients show good agreement.

$$0.62 \geq E_N(K) \geq 0.15$$

$$0.25 \geq E_N(|\Gamma|) \geq -0.34$$

$$0.12 \geq E_N(\varphi) \geq -0.08$$

The stated value for the pin depth was –38.1 µm. The expanded uncertainty was 10 µm.

Frequency	K	$U(K)$	$E_N(K)$
50 MHz	1.003	0.010	0.45
500 MHz	0.997	0.010	0.51
1 GHz	0.994	0.010	0.62
5 GHz	0.972	0.012	0.41
10 GHz	0.954	0.015	0.23
15 GHz	0.941	0.015	0.27
18 GHz	0.931	0.016	0.15

Table 9.4.1: Results of the calibration factor, *Cassidian* (Ulm)

Frequency	$|\Gamma|$	$U(|\Gamma|)$	$E_N(|\Gamma|)$	φ	$U(\varphi)$	$E_N(\varphi)$
50 MHz	0.002	0.006	0.05	15°	180°	0.10
500 MHz	0.006	0.006	0.05	25°	180°	-0.03
1 GHz	0.009	0.006	-0.11	-15°	80°	-0.03
5 GHz	0.028	0.006	-0.08	-80°	30°	0.08
10 GHz	0.035	0.006	0.25	17°	25°	-0.08
15 GHz	0.041	0.009	-0.30	94°	20°	-0.06
18 GHz	0.034	0.009	-0.34	72°	25°	0.12

Table 9.4.2: Results of the reflection coefficient, *Cassidian* (Ulm)

9.5 Rohde & Schwarz, Memmingen

The calibration factors and reflection coefficients show good agreement.

$$0.34 \geq E_N(K) \geq -0.09$$

$$0.50 \geq E_N(|\Gamma|) \geq -0.12$$

$$0.25 \geq E_N(\varphi) \geq -0.19$$

The stated value for the pin depth was –37 µm. The expanded uncertainty was 4 µm.

Frequency	K	$U(K)$	$E_N(K)$
50 MHz	1	0.004	0.34
500 MHz	0.9932	0.0041	0.30
1 GHz	0.9895	0.0066	0.27
5 GHz	0.9678	0.0077	0.11
10 GHz	0.9495	0.0088	-0.09
15 GHz	0.937	0.012	0.02
18 GHz	0.9295	0.012	0.07

Table 9.5.1: Results of the calibration factor, *Rohde & Schwarz* (Memmingen)

Frequency	$\|\Gamma\|$	$U(\|\Gamma\|)$	$E_N(\|\Gamma\|)$	φ	$U(\varphi)$	$E_N(\varphi)$
50 MHz	0.002	0.004	0.06	0°	180°	0.05
500 MHz	0.005	0.004	-0.08	16.3°	59°	-0.08
1 GHz	0.009	0.004	-0.12	-28.5°	28°	-0.34
5 GHz	0.029	0.004	0.03	-83.4°	7.9°	-0.06
10 GHz	0.032	0.005	-0.08	22.5°	7.3°	0.25
15 GHz	0.048	0.006	0.36	93.7°	4.7°	-0.17
18 GHz	0.043	0.006	0.50	66.9°	5.3°	-0.19

Table 9.5.2: Results of the reflection coefficient, *Rohde & Schwarz* (Memmingen)

9.6 *Teseq, Berlin*

The calibration factors show good agreement. At 18 GHz, the E_N values for the magnitude of the reflection as well as for the phase are above 1.

$$0.27 \geq E_N(K) \geq -0.13$$

$$1.32 \geq E_N(|\Gamma|) \geq -0.27$$

$$2.30 \geq E_N(\varphi) \geq -0.48$$

The stated value for the pin depth was 5730 µm. This corresponds to –472 µm. The expanded uncertainty was 30 µm.

Frequency	K	$U(K)$	$E_N(K)$
50 MHz	0.9969	0.0101	-0.12
500 MHz	0.9933	0.0101	0.16
1 GHz	0.9889	0.0101	0.13
5 GHz	0.9667	0.0123	-0.01
10 GHz	0.9492	0.0145	-0.08
15 GHz	0.9415	0.0169	0.27
18 GHz	0.9254	0.0217	-0.13

Table 9.6.1: Results of the calibration factor, *Teseq* (Berlin)

Frequency	$\|\Gamma\|$	$U(\|\Gamma\|)$	$E_N(\|\Gamma\|)$	φ	$U(\varphi)$	$E_N(\varphi)$
50 MHz	0.002576	0.0079683	0.10	-11.09°	172.64°	0.00
500 MHz	0.005389	0.0079683	-0.02	17.22°	85.42°	-0.07
1 GHz	0.009597	0.0079683	-0.03	-24.11°	47.88°	-0.19
5 GHz	0.026956	0.0079684	-0.17	-92.57°	17°	-0.48
10 GHz	0.029858	0.0079685	-0.27	28.69°	15.28°	0.50
15 GHz	0.051052	0.0079687	0.59	93.97°	8.94°	-0.11
18 GHz	0.052827	0.0079687	**1.32**	98.12°	8.92°	**2.30**

Table 9.6.2: Results of the reflection coefficient, *Teseq* (Berlin)

9.7 esz AG, Eichenau

The calibration factors and reflection coefficients show good agreement.

$$0.49 \geq E_N(K) \geq 0.13$$

$$0.27 \geq E_N(|\Gamma|) \geq -0.04$$

$$0.21 \geq E_N(\varphi) \geq -0.20$$

The stated value for the pin depth was –33 µm. The expanded uncertainty was 19 µm.

Frequency	K	$U(K)$	$E_N(K)$
50 MHz	1.002	0.0078*	0.45
500 MHz	0.9957	0.0092*	0.42
1 GHz	0.9923	0.0092*	0.49
5 GHz	0.971	0.014*	0.29
10 GHz	0.955	0.014*	0.32
15 GHz	0.939	0.016*	0.13
18 GHz	0.932	0.016*	0.20

Table 9.7.1: Results of the calibration factor, *esz AG* (Eichenau)

*Newly requested measurement uncertainties

Frequency	$\|\Gamma\|$	$U(\|\Gamma\|)$	$E_N(\|\Gamma\|)$	φ	$U(\varphi)$	$E_N(\varphi)$
50 MHz	0.0018	0.005	0.03	14°	180°	0.10
500 MHz	0.006	0.005	0.05	29°	56°	-0.01
1 GHz	0.0102	0.005	0.04	-11°	30°	0.03
5 GHz	0.0292	0.005	0.06	-85°	10°	-0.16
10 GHz	0.0323	0.008	-0.04	23°	14°	0.21
15 GHz	0.046	0.012	0.10	92°	15°	-0.19
18 GHz	0.042	0.012	0.27	65°	17°	-0.20

Table 9.7.2: Results of the reflection coefficient, *esz AG* (Eichenau)

9.8 Siemens AG, Erlangen

The calibration factors and reflection coefficients show good agreement.

$$0.40 \geq E_N(K) \geq 0.04$$

$$0.14 \geq E_N(|\Gamma|) \geq -0.26$$

$$0.24 \geq E_N(\varphi) \geq -0.20$$

The stated value for the pin depth was –35 µm. The expanded uncertainty was 10 µm.

Frequency	K	$U(K)$	$E_N(K)$
50 MHz	1.0007	0.008	0.29
500 MHz	0.9931	0.008	0.17
1 GHz	0.9888	0.008	0.15
5 GHz	0.9679	0.008	0.12
10 GHz	0.9508	0.008	0.04
15 GHz	0.9376	0.01	0.07
18 GHz	0.9333	0.01	0.40

Table 9.8.1: Results of the calibration factor, *Siemens AG* (Erlangen)

Frequency	$\|\Gamma\|$	$U(\|\Gamma\|)$	$E_N(\|\Gamma\|)$	φ	$U(\varphi)$	$E_N(\varphi)$
50 MHz	0.0019	0.008	0.04	-13°	180°	-0.01
500 MHz	0.0051	0.008	-0.05	26.2°	180°	-0.02
1 GHz	0.0086	0.008	-0.13	-18.6°	69°	-0.08
5 GHz	0.0261	0.008	-0.26	-83°	18°	-0.02
10 GHz	0.0344	0.01	0.14	15.2°	17°	-0.20
15 GHz	0.0413	0.01	-0.26	98.2°	14°	0.18
18 GHz	0.0362	0.01	-0.15	73.2°	16°	0.24

Table 9.8.2: Results of the reflection coefficient, *Siemens AG* (Erlangen)

9.9 Rohde & Schwarz, Cologne

The calibration factors and reflection coefficients show good agreement.

$$0.41 \geq E_N(K) \geq 0.14$$

$$0.23 \geq E_N(|\Gamma|) \geq -0.11$$

$$0.12 \geq E_N(\varphi) \geq -0.17$$

The stated value for the pin depth was –45 µm. The expanded uncertainty was 5 µm.

Frequency	K	$U(K)$	$E_N(K)$
50 MHz	1.001	0.006	0.41
500 MHz	0.995	0.008	0.39
1 GHz	0.991	0.008	0.40
5 GHz	0.97	0.01	0.30
10 GHz	0.953	0.012	0.21
15 GHz	0.939	0.015	0.14
18 GHz	0.931	0.015	0.15

Table 9.9.1: Results of the calibration factor, *Rohde & Schwarz* (Cologne)

Frequency	$\|\Gamma\|$	$U(\|\Gamma\|)$	$E_N(\|\Gamma\|)$	φ	$U(\varphi)$	$E_N(\varphi)$
50 MHz	0.001	0.005	-0.07	-20.3°	180°	-0.03
500 MHz	0.005	0.005	-0.07	31.3°	83°	0.00
1 GHz	0.009	0.005	-0.11	-16.1°	35°	-0.07
5 GHz	0.028	0.005	-0.09	-82.4°	11°	0.00
10 GHz	0.033	0.007	0.03	21.3°	13°	0.12
15 GHz	0.046	0.01	0.11	92.8°	14°	-0.15
18 GHz	0.041	0.01	0.23	65.8°	15°	-0.17

Table 9.9.2: Results of the reflection coefficient, *Rohde & Schwarz* (Cologne)

9.10 *Cassidian, Manching*

The calibration factors and reflection coefficients show good agreement.

$$0.41 \geq E_N(K) \geq -0.18$$

$$0.23 \geq E_N(|\Gamma|) \geq -0.08$$

$$0.19 \geq E_N(\varphi) \geq -0.32$$

The stated value for the pin depth was 5307 µm. This corresponds to –49 µm. The expanded uncertainty was 10 µm.

Frequency	K	$U(K)$	$E_N(K)$
50 MHz	1.0007	0.005	0.41
500 MHz	0.9943	0.008	0.31
1 GHz	0.9864	0.005	-0.18
5 GHz	0.968	0.007	0.15
10 GHz	0.9529	0.009	0.25
15 GHz	0.9422	0.013	0.39
18 GHz	0.9272	0.014	-0.08

Table 9.10.1: Results of the calibration factor, *Cassidian* (Manching)

Frequency	$\|\Gamma\|$	$U(\|\Gamma\|)$	$E_N(\|\Gamma\|)$	φ	$U(\varphi)$	$E_N(\varphi)$
50 MHz	0.002	0.01	0.04	-6.588°	180°	0.02
500 MHz	0.006	0.01	0.04	20.48°	180°	-0.04
1 GHz	0.009	0.01	-0.08	-19.375°	180°	-0.04
5 GHz	0.029	0.01	0.02	-81.832°	10°	0.04
10 GHz	0.033	0.01	0.02	22.092°	10°	0.19
15 GHz	0.045	0.015	0.03	91.194°	10°	-0.32
18 GHz	0.042	0.015	0.23	65.332°	10°	-0.26

Table 9.10.2: Results of the reflection coefficient, *Cassidian* (Manching)

9.11 Systems Engineering, Stolberg

Systems Engineering in Stolberg only took part in a partial frequency range of the comparison. Only the calibration factors between 50 MHz and 1 GHz were determined.

In the limited range, the calibration factors showed good agreement.

$$0.17 \geq E_N(K) \geq 0.09$$

The reflection coefficient and the pin depth were not measured.

Frequency	K	$U(K)$	$E_N(K)$
50 MHz	0.9992	0.005	0.17
500 MHz	0.9931	0.015	0.10
1 GHz	0.9894	0.02	0.09

Table 9.11.1: Results of the calibration factor, *Systems Engineering* (Stolberg)

10 Diagrams of the measurement results

10.1 Calibration factor

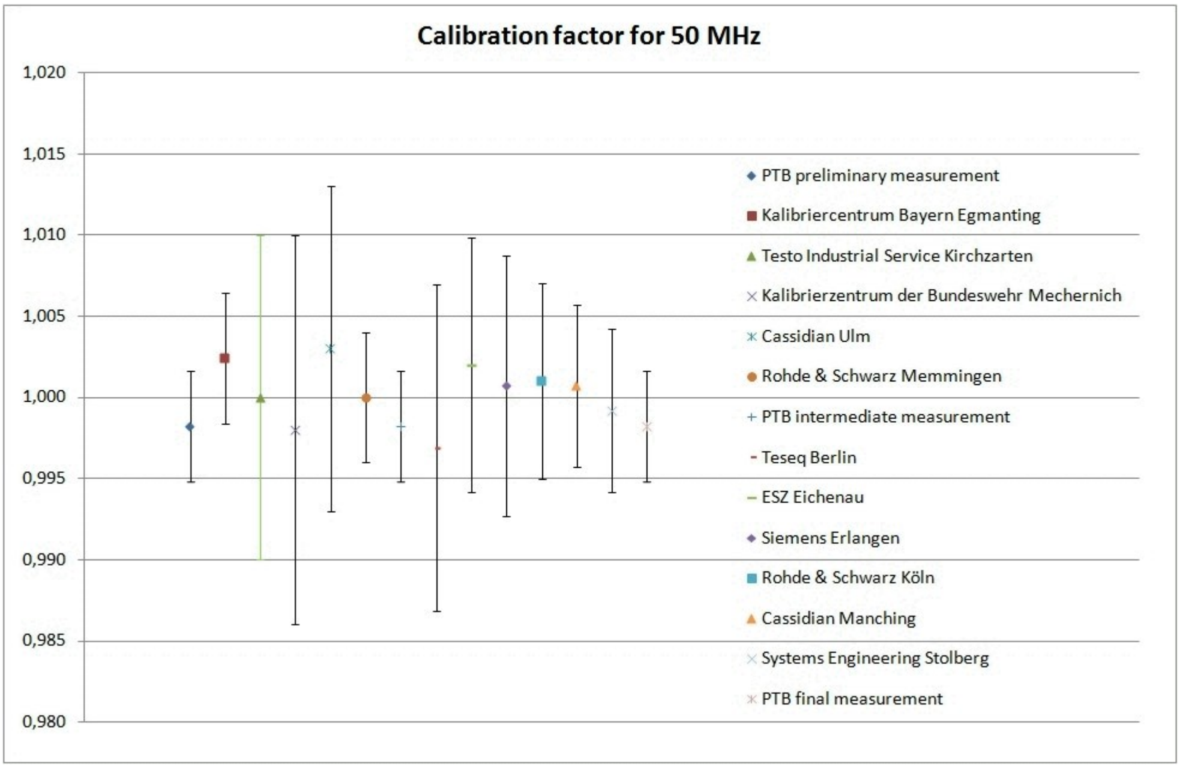

Figure 10.1.1: Calibration factors at 50 MHz

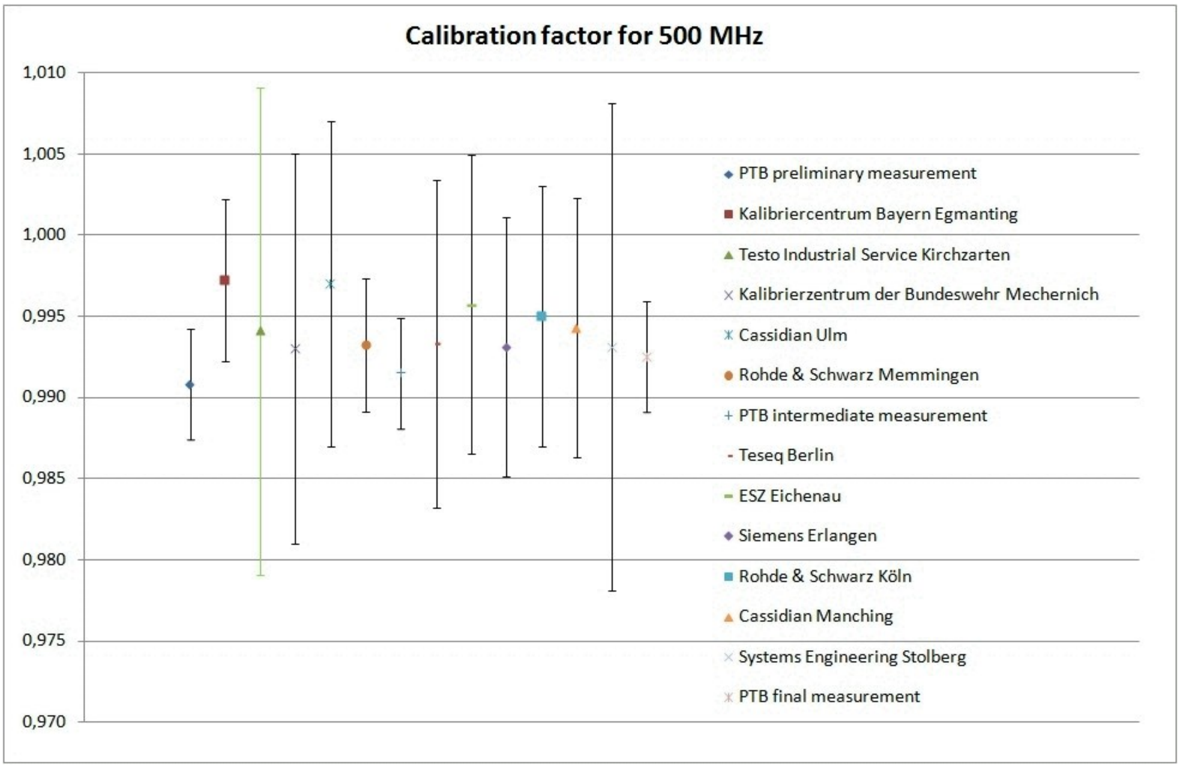

Figure 10.1.2: Calibration factors at 500 MHz

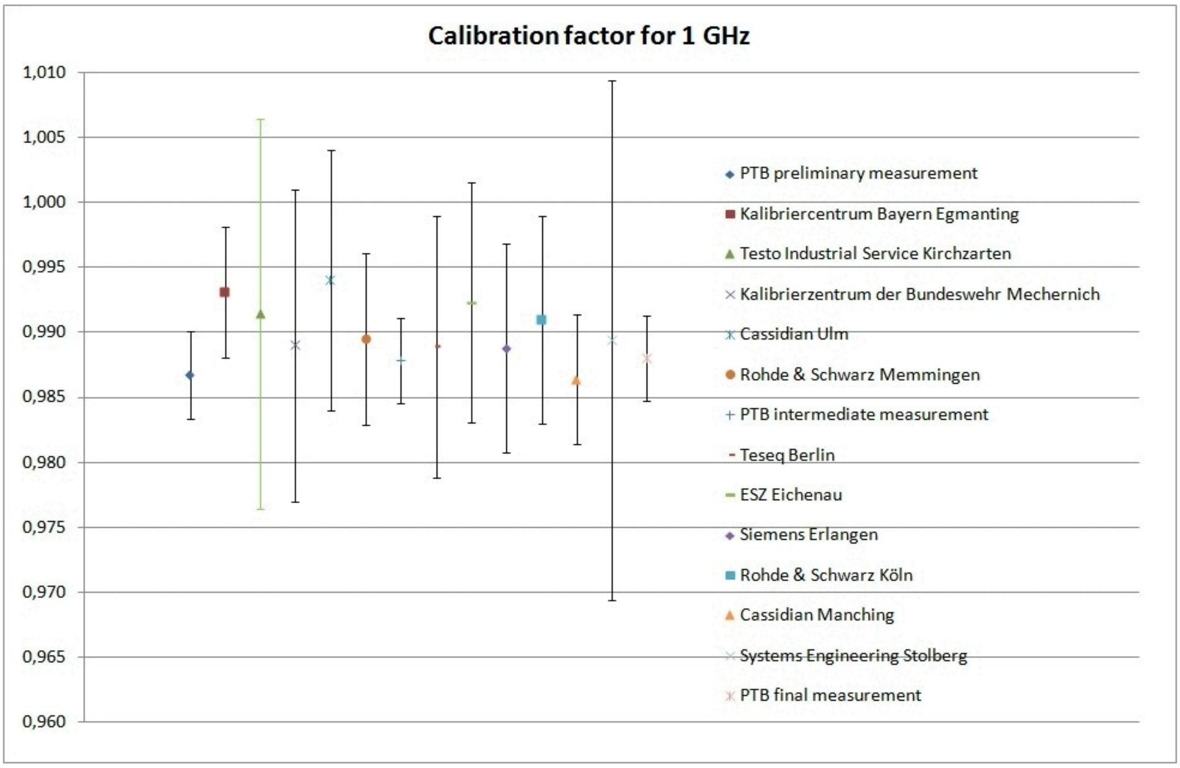

Figure 10.1.3: Calibration factors at 1 GHz

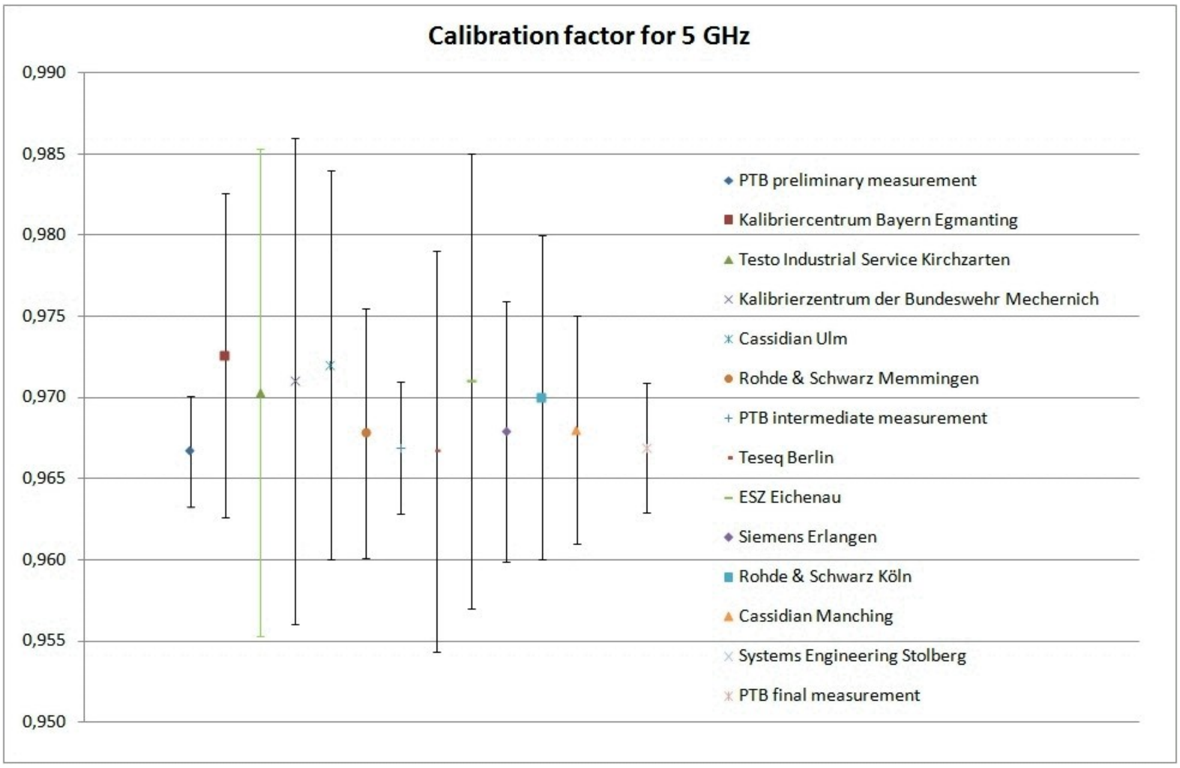

Figure 10.1.4: Calibration factors at 5 GHz

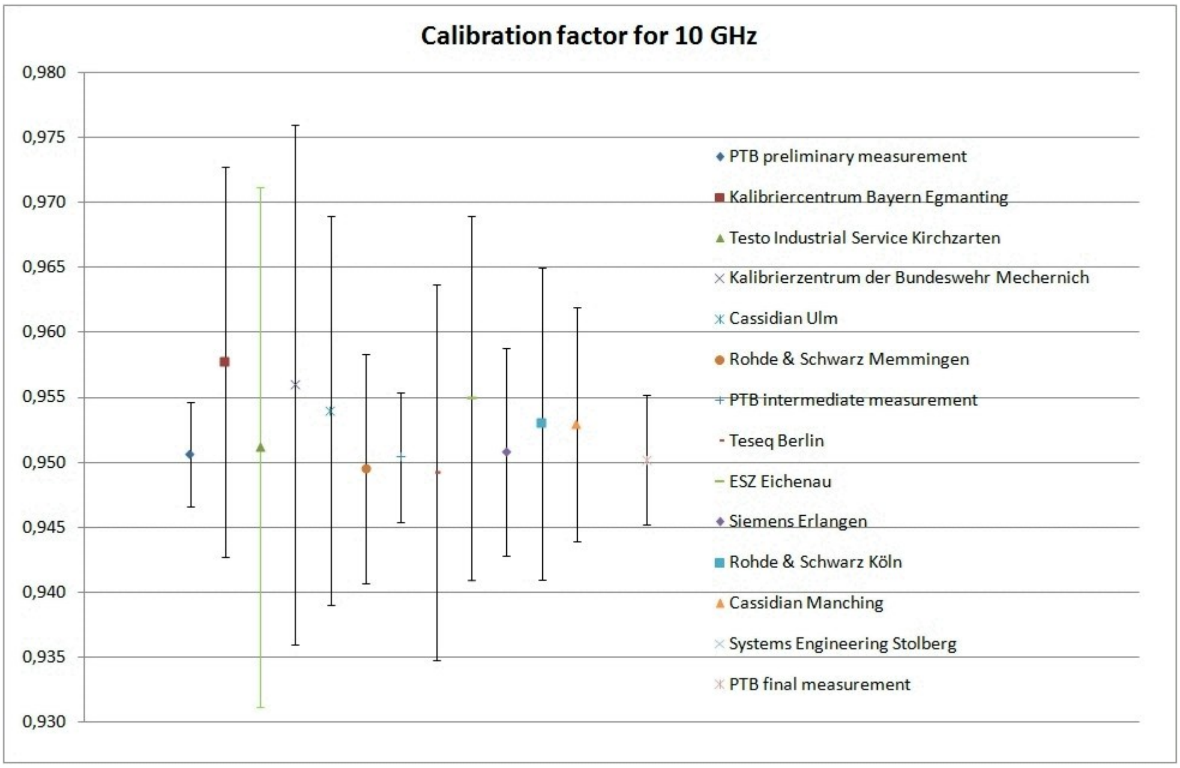

Figure 10.1.5: Calibration factors at 10 GHz

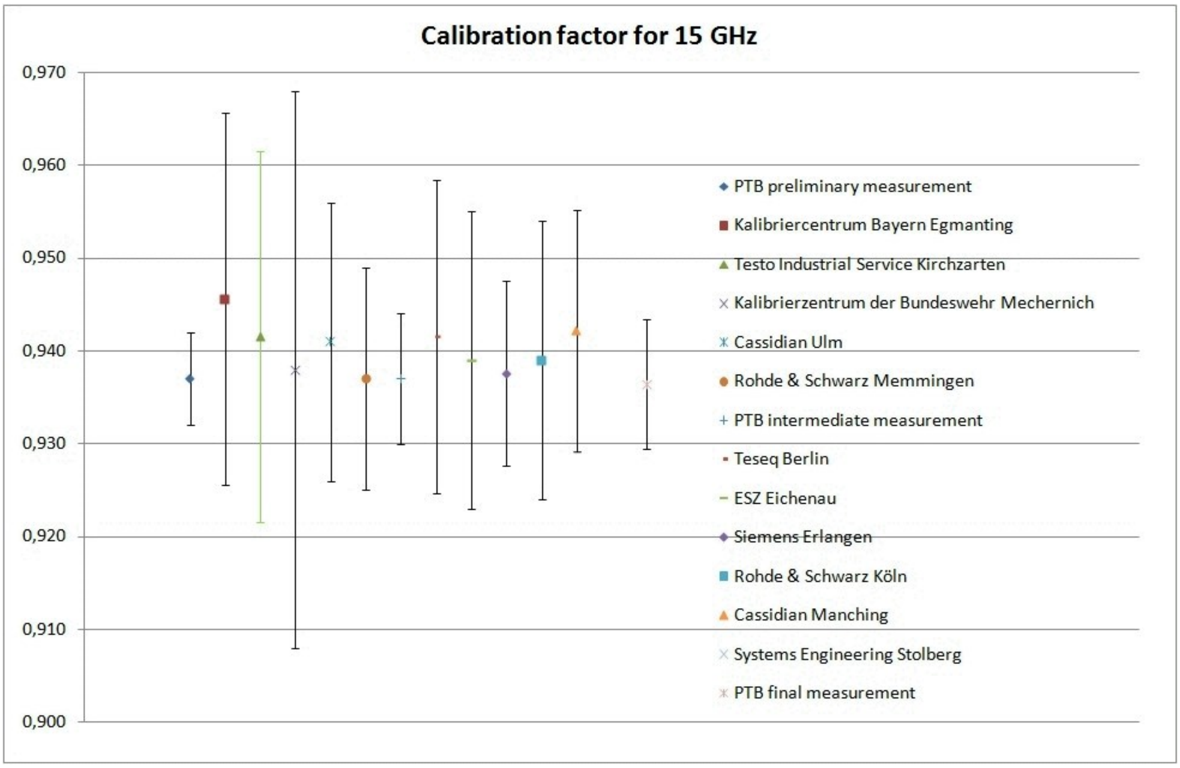

Figure 10.1.6: Calibration factors at 15 GHz

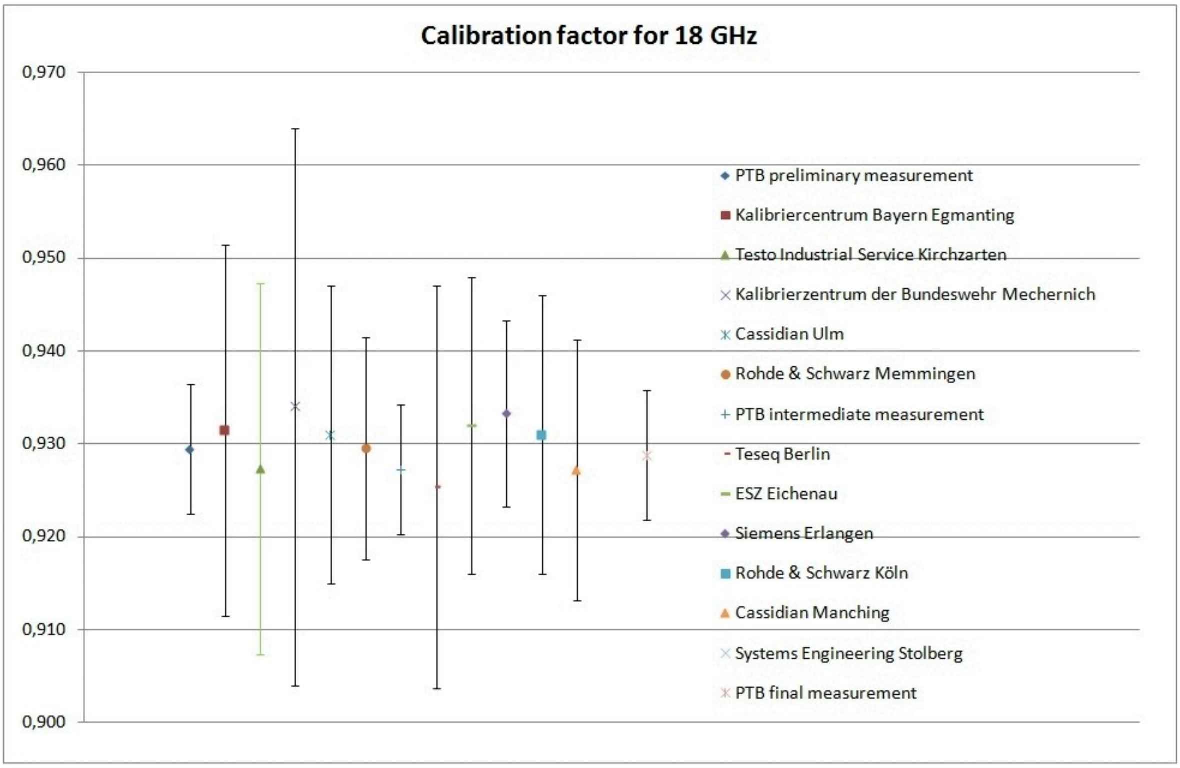

Figure 10.1.7: Calibration factors at 18 GHz

10.2 *Magnitude of the reflection coefficient*

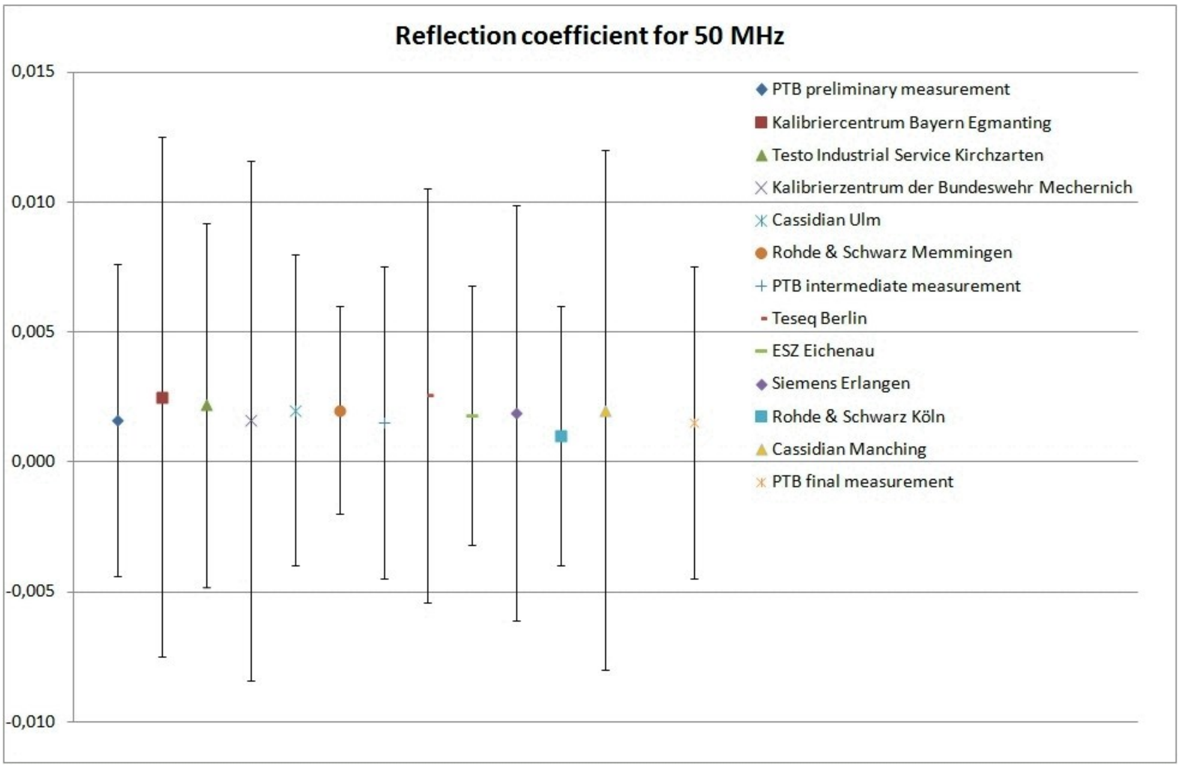

Figure 10.2.1: The magnitudes of the reflection coefficient at 50 MHz

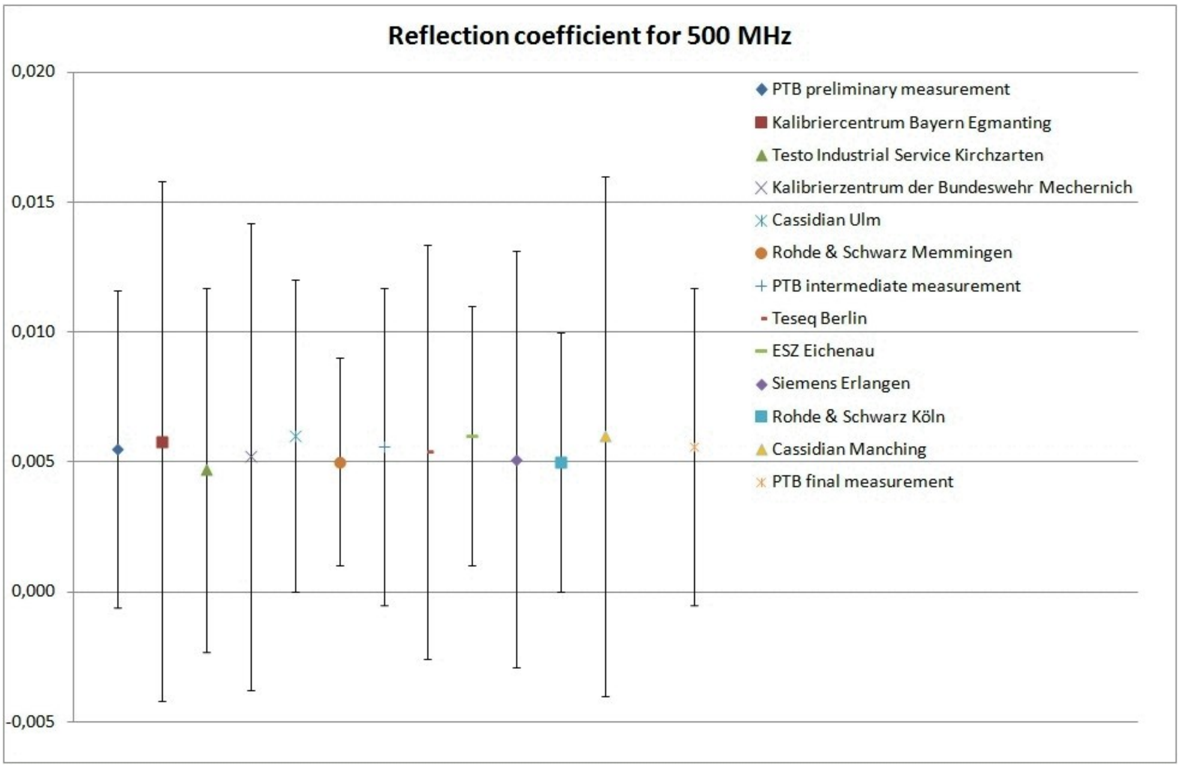

Figure 10.2.2: The magnitudes of the reflection coefficients at 500 MHz

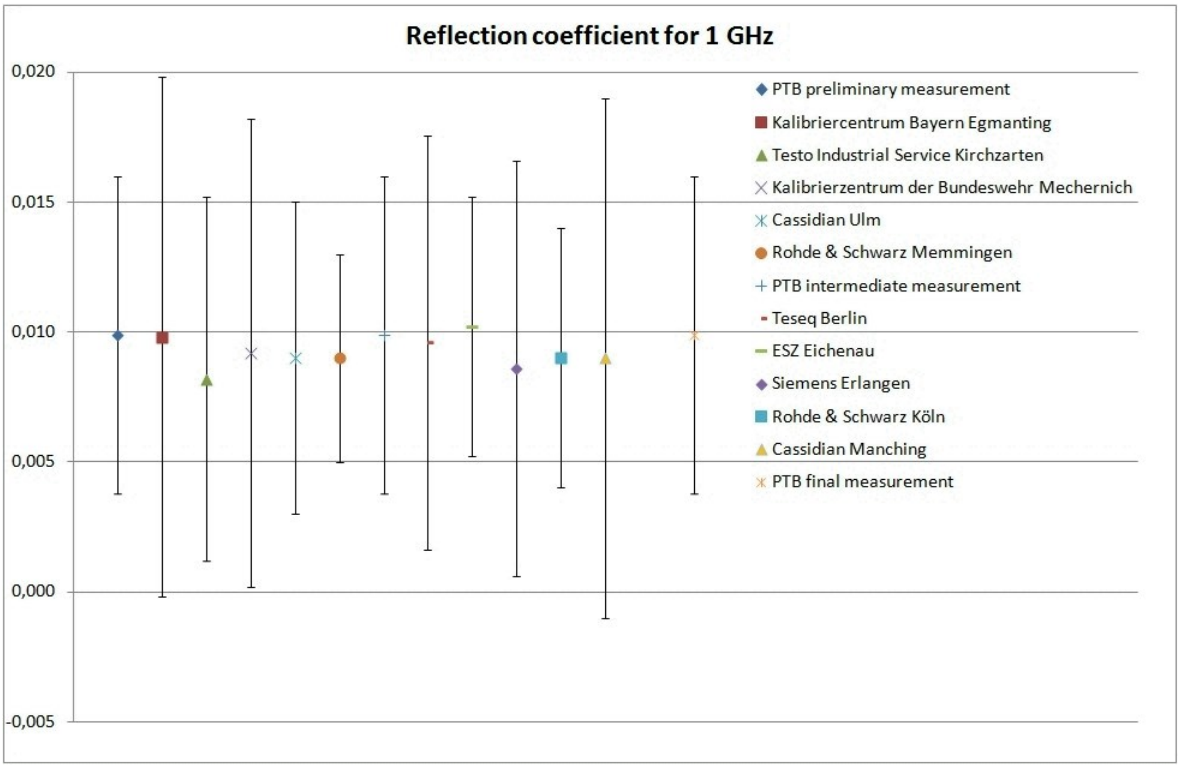

Figure 10.2.3: The magnitudes of the reflection coefficients at 1 GHz

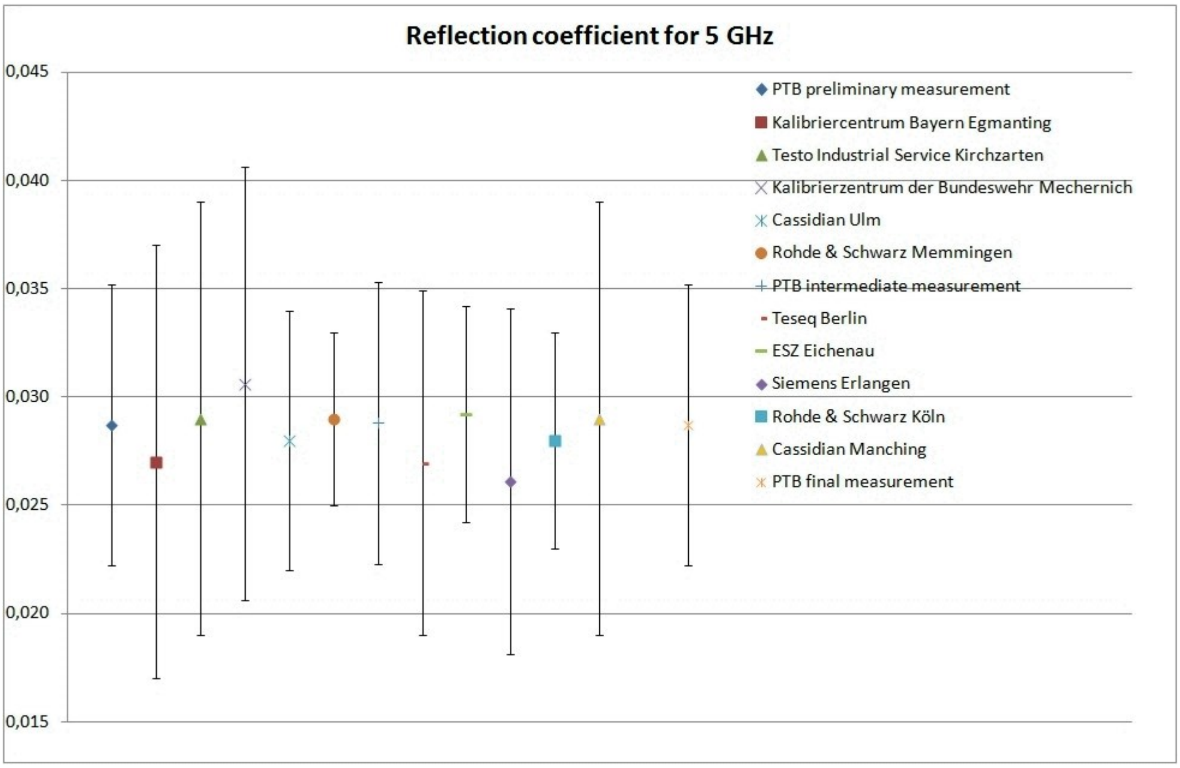

Figure 10.2.4: The magnitudes of the reflection coefficients at 5 GHz

Figure 10.2.5: The magnitudes of the reflection coefficients at 10 GHz

Figure 10.2.6: The magnitudes of the reflection coefficients at 15 GHz

Figure 10.2.7: The magnitudes of the reflection coefficients at 18 GHz

10.3 Phase of the reflection coefficient

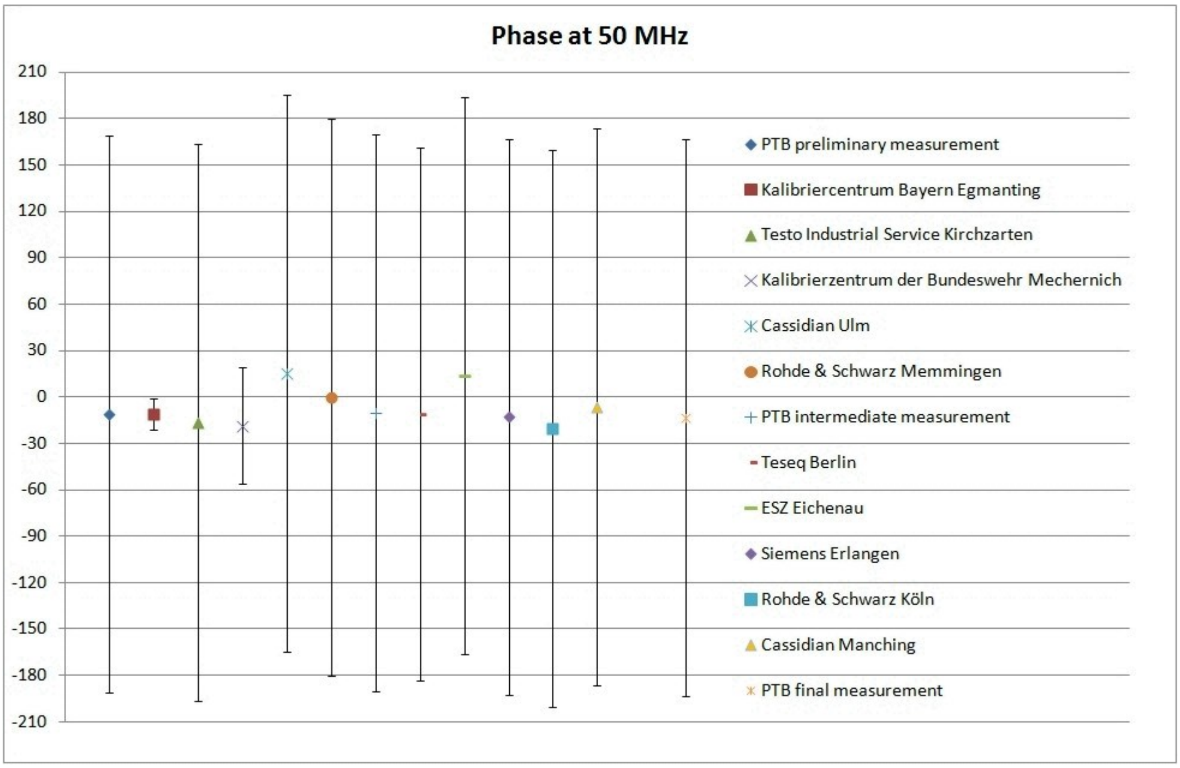

Figure 10.3.1: The phases of the reflection coefficients at 50 MHz

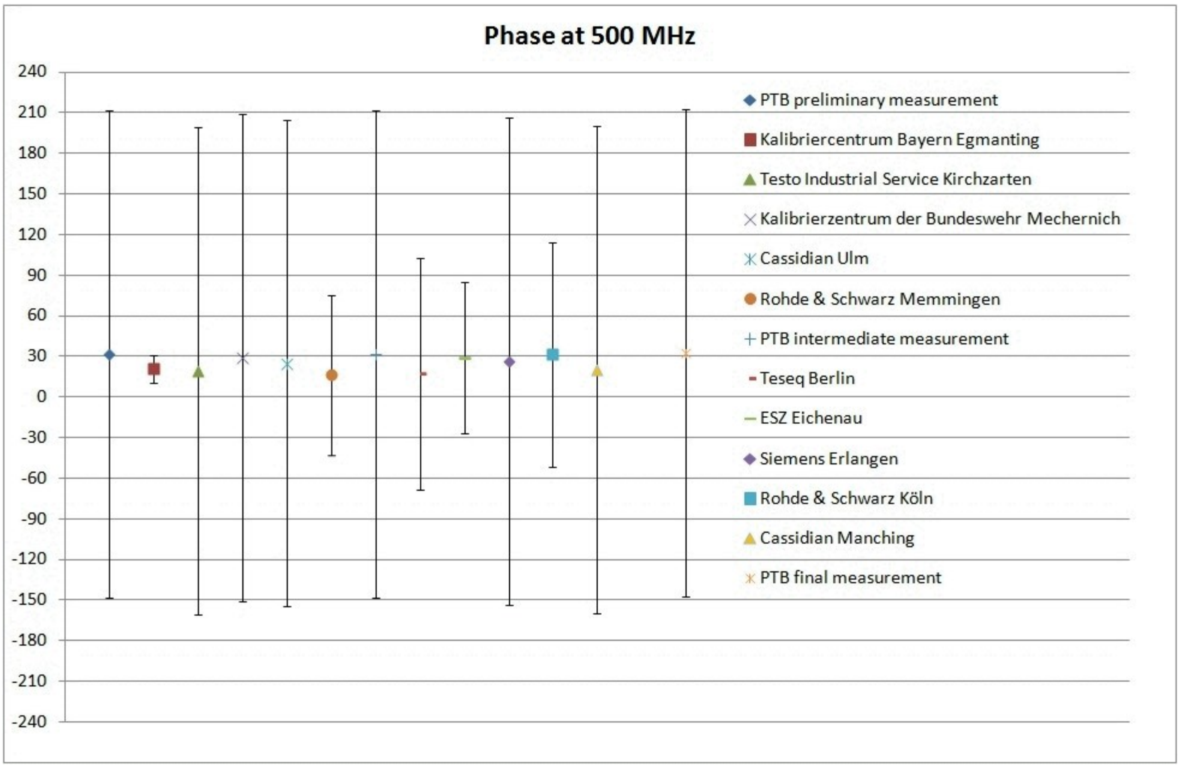

Figure 10.3.2: The phases of the reflection coefficients at 500 MHz

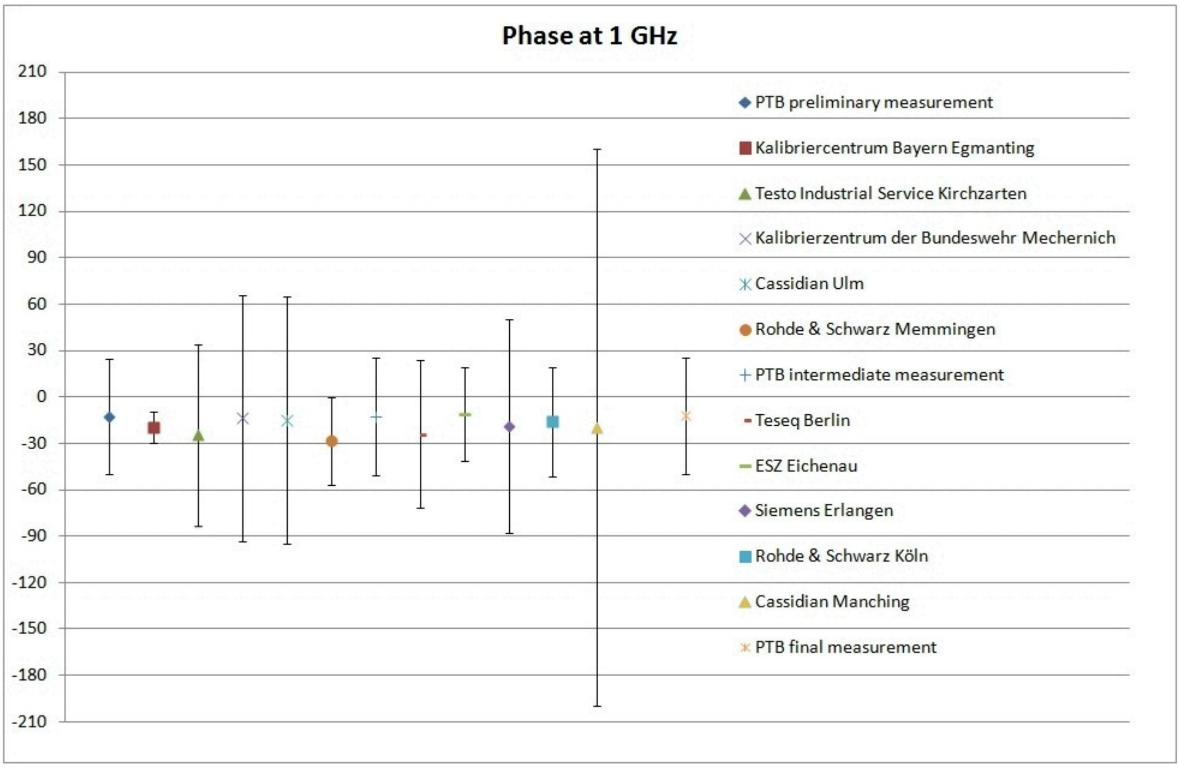

Figure 10.3.3: The phases of the reflection coefficients at 1 GHz

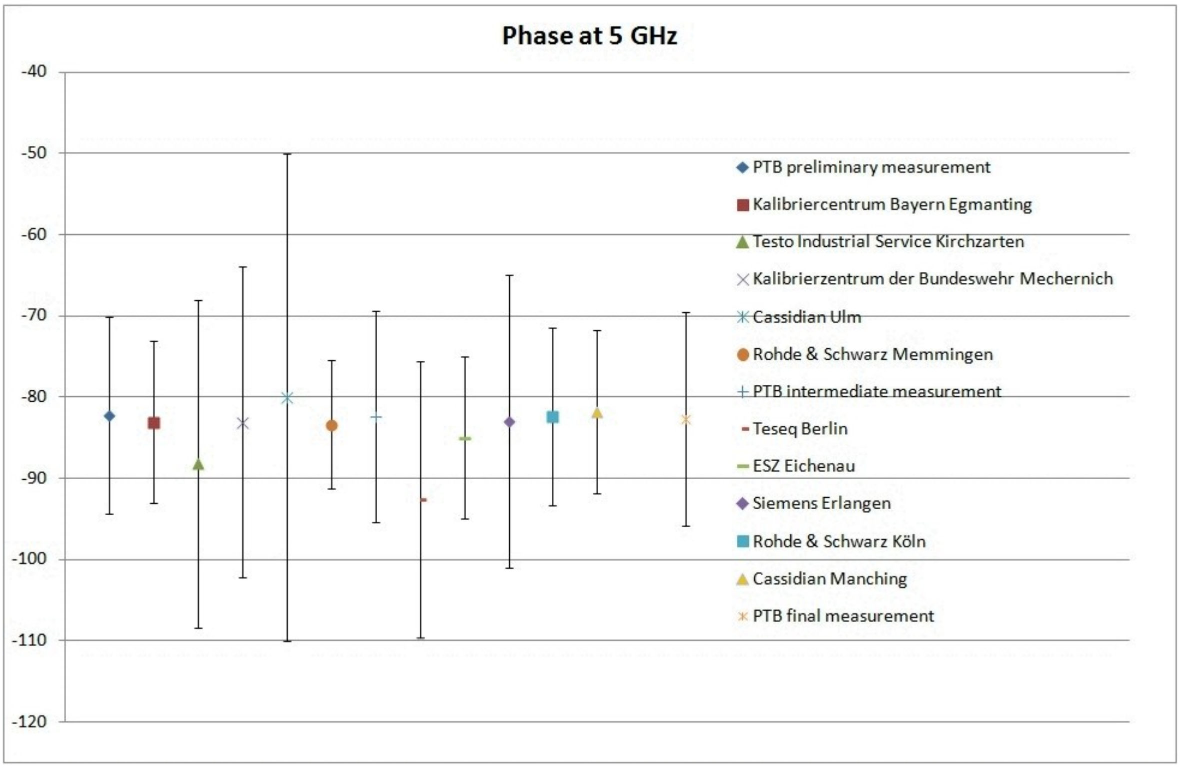

Figure 10.3.4: The phases of the reflection coefficients at 5 GHz

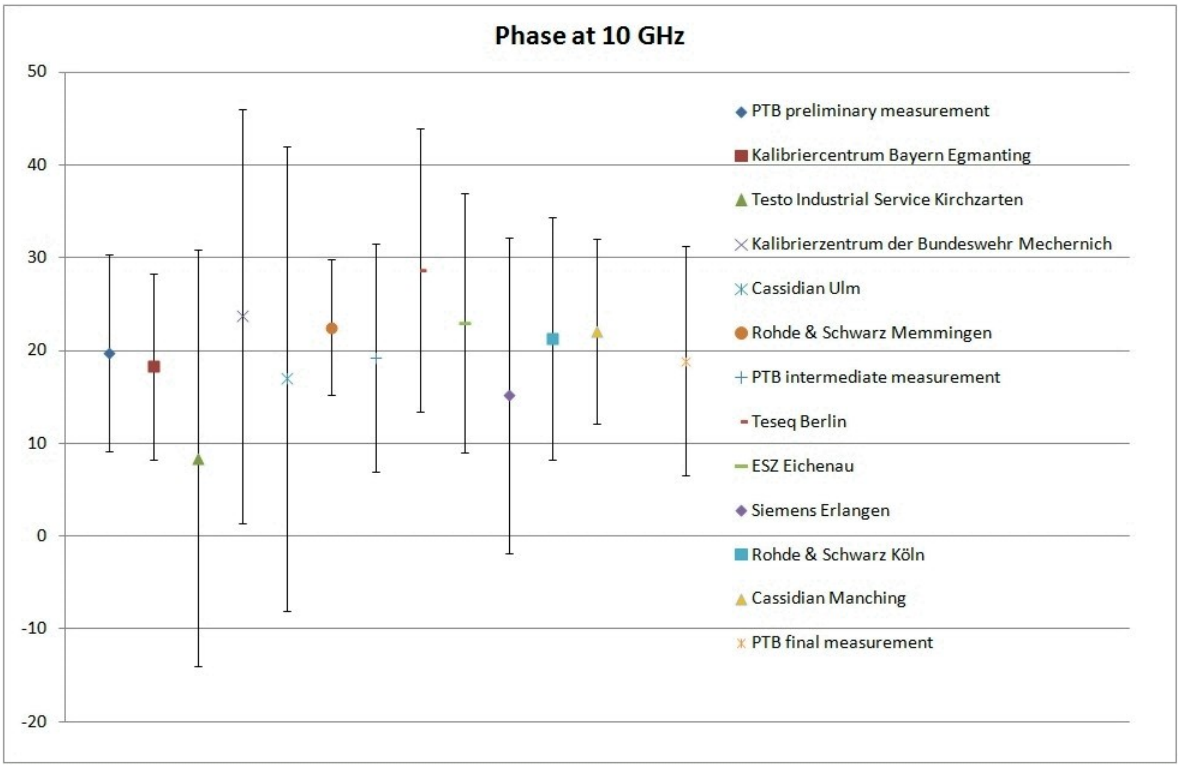

Figure 10.3.5: The phases of the reflection coefficients at 10 GHz

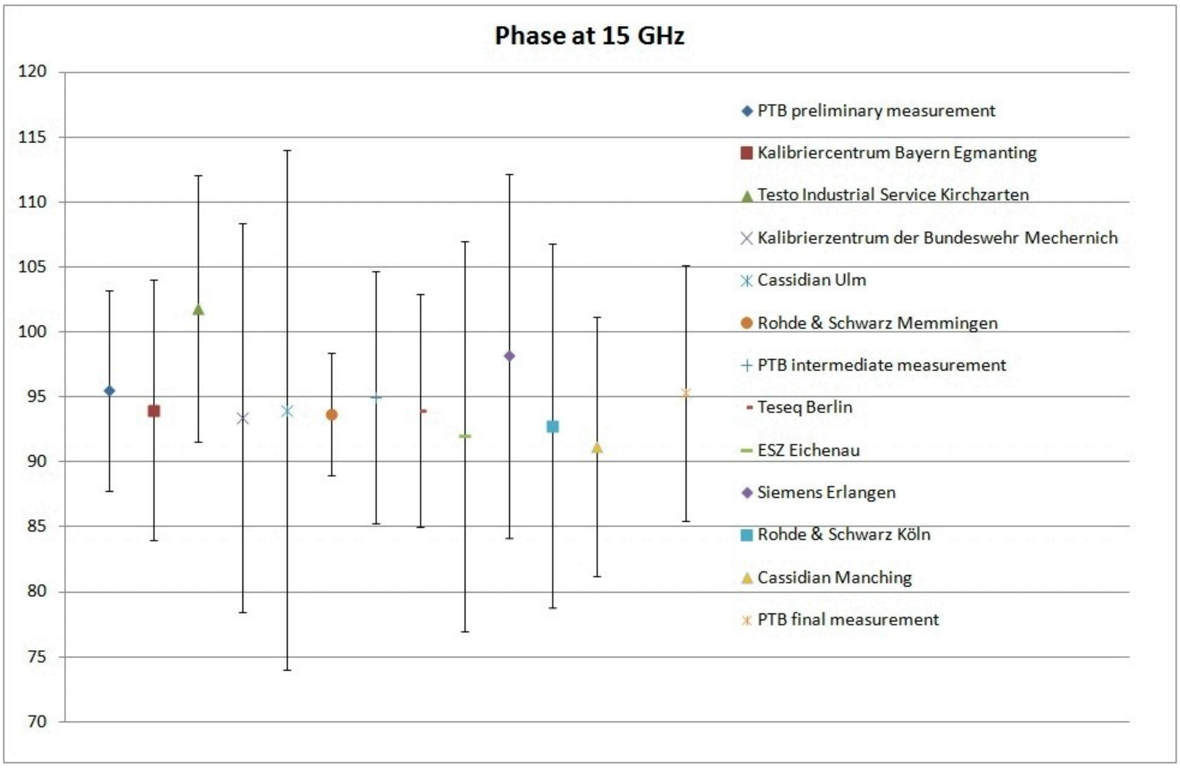

Figure 10.3.6: The phases of the reflection coefficients at 15 GHz

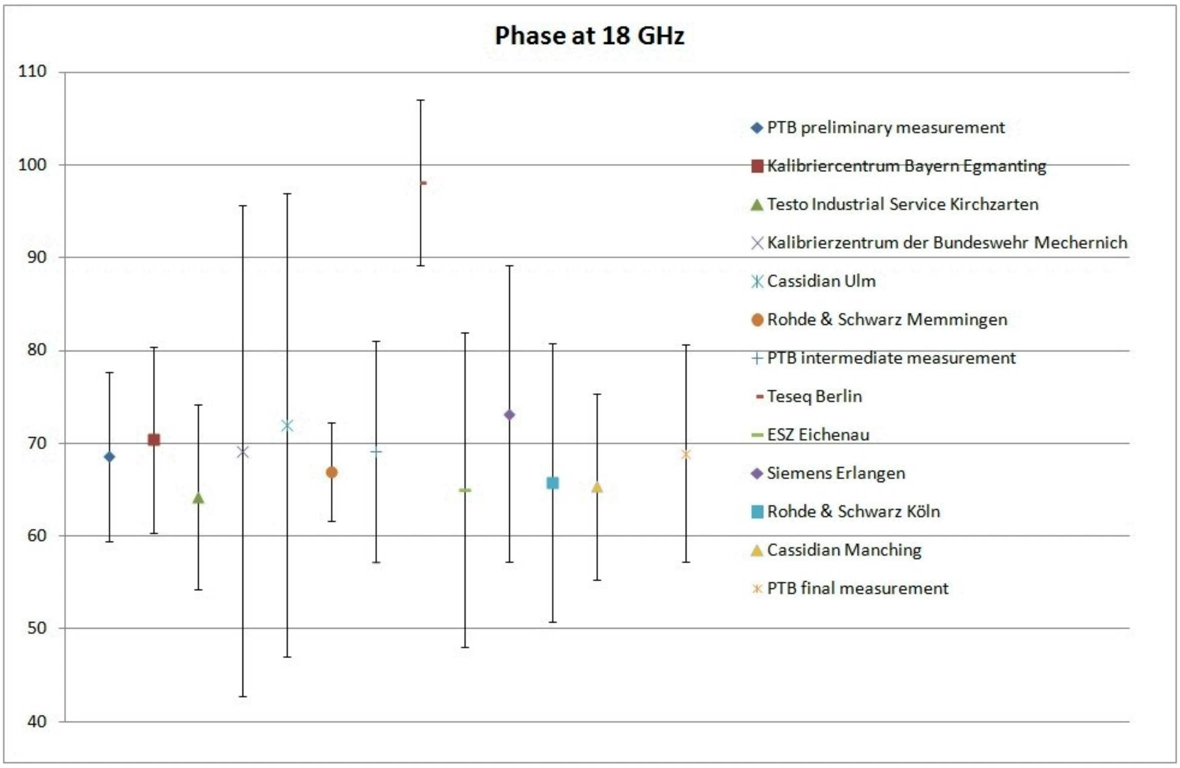

Figure 10.3.7: The phases of the reflection coefficients at 18 GHz

10.4 Pin depth

	Pin depth		U (k=2)
PTB, preliminary measurement		-43 µm	5 µm
Kalibriercentrum Bayern, Egmating	5294 µm	-> -36 µm	10 µm
Testo Industrial Services, Kirchzarten		-36.1 µm	5 µm
Kalibrierzentrum der Bundeswehr, Mechernich	5300.98 µm	-> -43 µm	2.54 µm
Cassidian, Ulm		-38.1 µm	10 µm
Rohde & Schwarz, Memmingen		-37 µm	4 µm
PTB, intermediate measurement		-45 µm	5 µm
Teseq, Berlin	5730 µm	-> -472 µm	30 µm
esz AG, Eichenau	5291 µm	-> -33 µm	19 µm
Siemens, Erlangen		--35 µm	10 µm
Rohde & Schwarz, Köln		-45 µm	5 µm
Cassidian, Manching	5307 µm	-> -49 µm	10 µm
Systems Engineering, Stolberg		-	-
PTB, final measurement		-43 µm	5 µm

Table 10.4.1: Measured pin depths of the calibration laboratories

PTB mean value		-44 µm	5 µm

Table 10.4.2: PTB mean value of the pin depths

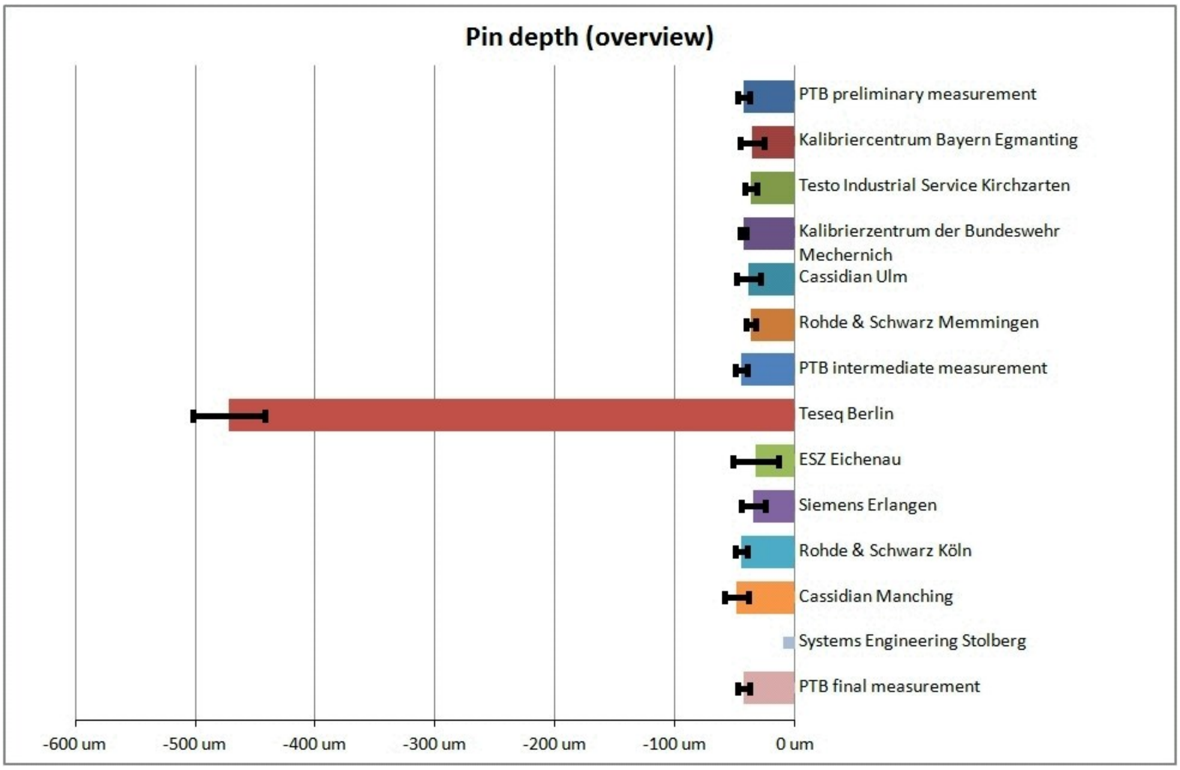

Figure 10.4.1: Measured pin depths

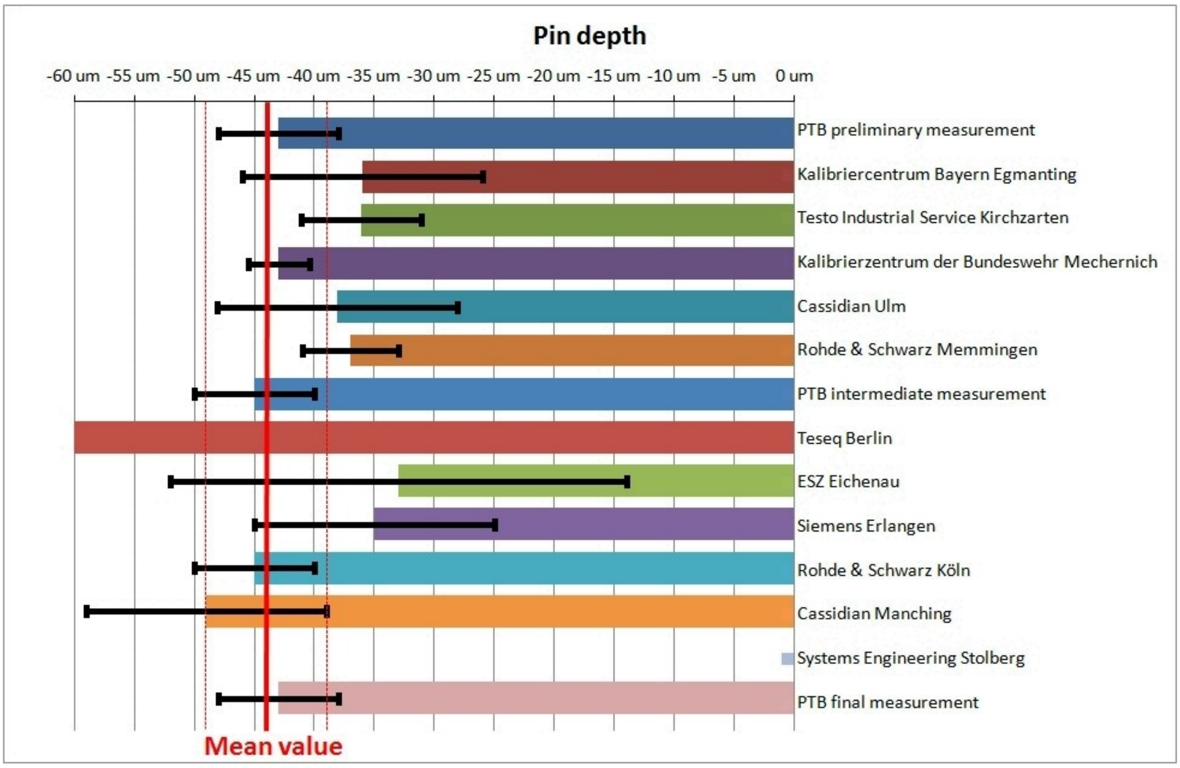

Figure 10.4.2: Pin depths with a mean value of -44 µm and an expanded uncertainty of ± 5 µm, determined from the measurements of PTB (enlarged)

11 Evaluation of the interlaboratory comparison

11.1 Summary

The absolute values of the E_N values of the calibration factor of all calibration laboratories are below 1.

The absolute values of the E_N values of the reflection coefficient of almost all calibration laboratories are below 1. Only in case of two calibration laboratories, these absolute values are above 1.

Almost all amounts of the E_N values of the phases of the reflection coefficients are below 1. Only one calibration laboratory was way off the mark, having obtained an E_N value of 2.3.

Almost all calibration laboratories reached good results regarding the values of the pin depth. Only one calibration laboratory had indicated a value which was too high.

The time schedule for calibration was followed by all participants, and also the shipment of the standard went along very well. Generally, the result reports were returned very quickly. Only one of the calibration laboratories required more time (three months) for the transmission of the result report.

11.2 Final remark

This national interlaboratory comparison "RF power in N-type coaxial connector systems up to 18 GHz" has shown good results.

At **all** frequencies, **all** of the participants reached an absolute value of the E_N value smaller than 1 for the main measurand – **the calibration factor**. In the lower frequency range, the E_N values of one of the participants ranged from 0.80 to 0.93, which was probably due to the very small estimated uncertainties. All other absolute values of the E_N values were lower than 0.62.

The E_N value for the **magnitude of the reflection coefficient** obtained by two of the participants at 18 GHz was 1.57 and 1.32. The absolute value of all the other participants was below 1.

The E_N value for the **phase of the reflection coefficient** obtained at 18 GHz by one of the participants was 2.3. The E_N values obtained by the rest of the participants were below 0.51.

As to the calibration factor, the calibration laboratories obtained the measurement values of their standards almost exclusively from calibrations carried out at PTB or from DAkkS-accredited calibration laboratories which have their standards calibrated at PTB. Only one calibration laboratory had its traceability established by another metrology institute (METAS).

12 The standard

Figure 11.2.1: Measurement object *NRP-Z51* with serial number 104095

Figure 11.2.2: Contents of the package

https://doi.org/10.7795/550.20190513A

13 Technical protocol

Technical protocol

(01.10.2013)

13.1 General information

13.1.1 Introduction

The aim of the national intercomparison is to give the accredited DAkkS laboratories an opportunity to participate in interlaboratory comparisons (according to DIN EN ISO/IEC 17025:2005 Point 5.9.1).

For this purpose, the PTB working group "High Frequency Measuring Techniques" organises a national interlaboratory comparison in the field of high frequency power, using a *NRP-Z51* power sensor with N connector up to 18 GHz.

13.1.2 Pilot laboratory

The PTB working group 2.22, "High Frequency Measuring Techniques", acts as pilot laboratory of this comparison and will perform three control measurements. The first measurement will be carried out at the beginning, the second in the middle and the final measurement at the end of the comparison. The contact address is:

Physikalisch-Technische Bundesanstalt	Tel.:	+49 531 592 - 22 23
Working Group 2.22; Jürgen Rühaak	FAX:	+49 531 592 - 22 28
Bundesallee 100	E-Mail:	juergen.ruehaak@ptb.de
38116 Braunschweig		

13.1.3 Transport of the reference standard

The RF power sensor *NRP-Z51* with the serial number 104095, which serves as measurement object, as well as an USB adapter and a CD with software for reading out the measurement data are packed for shipping in a carrying case weighing approximately 3.5 kg; the carrying case is then packed in a cardboard box.

The costs of shipment to the next participant or back to PTB have to be borne by the respective calibration laboratory.

The receipt and dispatch of the measurement object has to be confirmed immediately by e-mail to the pilot laboratory.

13.1.4 Circulation of the measurement object

The calibration of the measurement object is carried out according to the order set out in the circulation scheme (see section 13.5). The starting date is the **14th of October 2013**, date of arrival of the measurement object in the first calibration laboratory.

A period of one week was scheduled for each laboratory to carry out the measurement, and another week for further transport. In case a calibration laboratory should not be able to maintain the scheduled dates of the measuring period, we (in our role as pilot laboratory) ask for timely notification to be able to find an alternative solution.

If a calibration laboratory should not be able to stick to the schedule, there will be a second chance to measure the measurement object at the end of the round. However, this should remain an exception.

13.1.5 Defects in the measurement object

If disturbances or damages to the measurement object or the auxiliary components should be detected, the pilot laboratory has to be informed immediately so that, if necessary, a replacement standard can be provided.

13.2 Measurements

13.2.1 Measurement object

The box contains:

- *NRP-Z51* sensor head with N connector and serial number 104095
- USB adapter cable
- CD with driver and software
- Operating manual of the NRP power sensors
- Technical protocol
- CD with technical protocol, template for the result report, list of the participants and schedule

The *NRP-Z51* power sensor has an input impedance of approximately 50 Ω and is equipped with a precision N-connector. The connector can either be connected to an existing NRP basic device or, by means of the USB adapter cable, directly to a PC. A corresponding driver and the software required for the representation of the measured value can be found on the enclosed CD. The software can also be downloaded from http://www.rohde-schwarz.com/en/software/nrpz/.

13.2.2 Ambient conditions

The room temperature during the measurement should be 23 °C and has to be documented. The current values must be indicated in the calibration report. Prior to the measurement, a sufficiently long warm-up period should be guaranteed for the sensor.

13.2.3 Inspection prior to the measurement and control of the connector

Before starting the measurement, it should be ensured that there are no visible signs of damage on the measurement object. The connector of the measurement object should be

1. cleaned,
2. checked for damage, and
3. it should be checked whether the distance between the reference plane of the outer connector and the shoulder of the inner connector (pin depth) is within specification.

13.2.4 Connection of the sensor

The sensor should be connected to the measuring system by tightening with a matching torque wrench.

The power during measurement should be approximately 1 mW.

13.2.5 Measurands

The following measurement quantities are to be determined for the frequencies of 50 MHz, 500 MHz, 1 GHz, 5 GHz, 10 GHz, 15 GHz and 18 GHz:

a. the absolute calibration factor *K*, using the equation

$$K = \frac{P_{\text{indication}}}{P_{\text{incident}}}$$

$P_{\text{indication}}$: indicated power

P_{incident} : incident power

b. the magnitude of the input reflection coefficient $|\Gamma|$ and the phase φ; moreover,
c. the pin depth, i.e. the distance between reference plane and the shoulder of the inner connector, should be measured.

13.2.6 Documentation of the measurement results

The calibration laboratories must indicate the measurement results in a result report.

The following information is required:

a. absolute calibration factor
b. measurement power and
c. number of measurements,
d. brief description of the measurement procedure,
e. traceability of the standard (to PTB, another national institute or another calibration laboratory)
f. magnitude and phase of the reflection factor,
g. brief description of the measurement procedure of the reflection measurement and the standards used (Autocal, SOL...)
h. pin depth,
i. brief explanation regarding the measurement procedure of the pin depth, e.g. manufacturer of the dial gauge ...
j. temperature and relative humidity during measurement
k. calibration date

13.3 Evaluation of the interlaboratory comparison

The evaluation is carried out after the end of the return measurement at PTB. A report on the complete results of this national intercomparison will be prepared and distributed among the participants.

In the draft of the final report, the measurement results will be allocated anonymously.

Whether the participants' names are mentioned in the final report or not, will be decided after consultation with and consent of the participants.

13.4 Costs

All costs incurred are to be borne by the participants, weighted according to the measured frequency points.

As things stand at present, the costs per participant and for the calibration of all seven measuring points amount to approximately 1200 EUR + VAT.

13.5 Participants and schedule

Planned schedule for calibration:

		Week number	Start (Mon)	End (Fri)
PTB	Preliminary measurement	40	30.09.2013	11.10.2013
Kalibriercentrum Bayern	Egmating	42	14.10.2013	25.10.2013
testo industrial services	Kirchzarten	44	28.10.2013	08.11.2013
Kalibrierzentrum der Bundeswehr	Mechernich	46	11.11.2013	22.11.2013
Cassidian	Ulm	48	25.11.2013	06.12.2013
Rohde & Schwarz	Memmingen	50	09.12.2013	20.12.2013
PTB	Intermediate measurement	2	06.01.2014	17.01.2014
Teseq GmbH	Berlin	4	20.01.2014	31.01.2014
esz AG	Eichenau	6	03.02.2014	14.02.2014
Siemens	Erlangen	8	17.02.2014	28.02.2014
Rohde & Schwarz	Köln	10	03.03.2014	14.03.2014
Cassidian	Manching	12	17.03.2014	28.03.2014
Systems Engineering	Stolberg	14	31.03.2014	11.04.2014
PTB	Return measurement	16	14.04.2014	25.04.2014

In case of deviations from the schedule due to time constraints, the pilot laboratory asks for immediate notification.

13.6 List of addresses and contact persons

Address	**Contact person**
Cassidian Department COPMO2 Rechliner Straße 85077 **Manching**	Paul Winkler (0 84 59) 81 - 64 083 paul.winkler@cassidian.com
Cassidian Department COPLL6 Tester & Calibration Support Wörthstraße 85 89077 **Ulm**	Ingo Hallitzky (07 31) 392 - 53 31 ingo.hallitzky@cassidian.com
esz AG calibration & metrology Max-Planck-Strasse 16 82223 **Eichenau**	Andreas C. Böck (0 81 41) 8 88 87 - 79 a.boeck@esz-ag.de
Kalibriercentrum Bayern Keltenring 28 85658 **Egmating**	Christine Huber (0 80 95) 87 23 - 0 c.huber@kalibriercentrum.de
Kalibrierzentrum der Bundeswehr Calibration laboratory “Standards“ D-K-15072-01-00 Bleibergstraße 1 53894 **Mechernich**	Bruno Groß (0 24 43) 4 96 - 55 13 brunogross@bundeswehr.org Rolf Mösbauer (0 24 43) 4 96 - 55 13 rolfmoesbauer@bundeswehr.org
Phys.-Techn. Bundesanstalt Working Group 2.22 Bundesallee 100 38116 **Braunschweig**	Jürgen Rühaak (05 31) 592 - 22 23 Juergen.ruehaak@ptb.de
Rohde & Schwarz GmbH & Co. KG Service Centre Cologne Abt. 5TST1 / DKD-Labor D-K-15012 Graf-Zeppelin-Straße 18 51147 **Köln**	Bernhard Kistinger (0 22 03) 49 51 433 Bernhard.Kistinger@rohde-schwarz.com
Rohde & Schwarz Messgerätebau GmbH Rohde-und-Schwarz-Straße 1 87700 **Memmingen**	Gerhard Rösel (0 83 31) 10 - 81 676 Gerhard.Roesel@rohde-schwarz.com
Siemens AG Industry Sector I CS LS OP ITM TP CA Günther-Scharowsky-Straße 2 91058 **Erlangen**	Heinz Gerber (0 91 31) 74 30 50 heinz.gerber@siemens.com
Systems Engineering Kalibrierlaboratorium GmbH & Co. KG Leimberg 9 52222 **Stolberg**	Josef Hahn (024 02) 90 01 81 j.hahn@systems-engineering.eu

Teseq GmbH Landsberger Str. 255 12623 **Berlin**	Uwe Karsten (0 30) 56 59 88 14 uwe.karsten@teseq.com
Testo industrial services GmbH Gewerbestraße 3 79199 **Kirchzarten**	Eugen Sander (0 76 61) 90 901 - 84 12 esander@testo.de

When calling from abroad, use the international call prefix plus country code (+49 for Germany) and omit the zero in the area code.