Add: No.52 HuaYuanBei Road, Haidian District, Beijing, 100191, China
Tel: +86-10-62304633-2117
E-mail: emf@caict.ac.cn http://www.caict.ac.cn

10958	AAB	5G NR DL (CP-OFDM, TM 3.1, 15 MHz, 64-QAM, 30 kHz)	5G NR FR1 FDD	8.61	± 9.6 %
10959	AAB	5G NR DL (CP-OFDM, TM 3.1, 20 MHz, 64-QAM, 30 kHz)	5G NR FR1 FDD	8.33	± 9.6 %
10960	AAB	5G NR DL (CP-OFDM, TM 3.1, 5 MHz, 64-QAM, 15 kHz)	5G NR FR1 TDD	9.32	± 9.6 %
10961	AAB	5G NR DL (CP-OFDM, TM 3.1, 10 MHz, 64-QAM, 15 kHz)	5G NR FR1 TDD	9.36	± 9.6 %
10962	AAB	5G NR DL (CP-OFDM, TM 3.1, 15 MHz, 64-QAM, 15 kHz)	5G NR FR1 TDD	9.40	± 9.6 %
10963	AAB	5G NR DL (CP-OFDM, TM 3.1, 20 MHz, 64-QAM, 15 kHz)	5G NR FR1 TDD	9.55	± 9.6 %
10964	AAB	5G NR DL (CP-OFDM, TM 3.1, 5 MHz, 64-QAM, 30 kHz)	5G NR FR1 TDD	9.29	± 9.6 %
10965	AAB	5G NR DL (CP-OFDM, TM 3.1, 10 MHz, 64-QAM, 30 kHz)	5G NR FR1 TDD	9.37	± 9.6 %
10966	AAB	5G NR DL (CP-OFDM, TM 3.1, 15 MHz, 64-QAM, 30 kHz)	5G NR FR1 TDD	9.55	± 9.6 %
10967	AAB	5G NR DL (CP-OFDM, TM 3.1, 20 MHz, 64-QAM, 30 kHz)	5G NR FR1 TDD	9.42	± 9.6 %
10968	AAB	5G NR DL (CP-OFDM, TM 3.1, 100 MHz, 64-QAM, 30 kHz)	5G NR FR1 TDD	9.49	± 9.6 %
10972	AAB	5G NR (CP-OFDM, 1 RB, 20 MHz, QPSK, 15 kHz)	5G NR FR1 TDD	11.59	± 9.6 %
10973	AAB	5G NR (DFT-s-OFDM, 1 RB, 100 MHz, QPSK, 30 kHz)	5G NR FR1 TDD	9.06	± 9.6 %
10974	AAB	5G NR (CP-OFDM, 100% RB, 100 MHz, 256-QAM, 30 kHz)	5G NR FR1 TDD	10.28	± 9.6 %
10978	AAA	ULLA BDR	ULLA	1.16	± 9.6 %
10979	AAA	ULLA HDR4	ULLA	8.58	± 9.6 %
10980	AAA	ULLA HDR8	ULLA	10.32	± 9.6 %
10981	AAA	ULLA HDRp4	ULLA	3.19	± 9.6 %
10982	AAA	ULLA HDRp8	ULLA	3.43	± 9.6 %
10983	AAC	5G NR DL (CP-OFDM, TM 3.1, 40 MHz, 64-QAM, 15 kHz)	5G NR FR1 TDD	9.31	± 9.6 %
10984	AAB	5G NR DL (CP-OFDM, TM 3.1, 50 MHz, 64-QAM, 15 kHz)	5G NR FR1 TDD	9.42	± 9.6 %
10985	AAC	5G NR DL (CP-OFDM, TM 3.1, 40 MHz, 64-QAM, 30 kHz)	5G NR FR1 TDD	9.54	± 9.6 %
10986	AAB	5G NR DL (CP-OFDM, TM 3.1, 50 MHz, 64-QAM, 30 kHz)	5G NR FR1 TDD	9.50	± 9.6 %
10987	AAC	5G NR DL (CP-OFDM, TM 3.1, 60 MHz, 64-QAM, 30 kHz)	5G NR FR1 TDD	9.53	± 9.6 %
10988	AAB	5G NR DL (CP-OFDM, TM 3.1, 70 MHz, 64-QAM, 30 kHz)	5G NR FR1 TDD	9.38	± 9.6 %
10989	AAC	5G NR DL (CP-OFDM, TM 3.1, 80 MHz, 64-QAM, 30 kHz)	5G NR FR1 TDD	9.33	± 9.6 %
10990	AAB	5G NR DL (CP-OFDM, TM 3.1, 90 MHz, 64-QAM, 30 kHz)	5G NR FR1 TDD	9.52	± 9.6 %
11003	AAA	5G NR DL (CP-OFDM, TM 3.1, 30 MHz, 64-QAM, 15 kHz)	5G NR FR1 TDD	10.24	± 9.6 %
11004	AAA	5G NR DL (CP-OFDM, TM 3.1, 30 MHz, 64-QAM, 30 kHz)	5G NR FR1 TDD	10.73	± 9.6 %
11005	AAA	5G NR DL (CP-OFDM, TM 3.1, 25 MHz, 64-QAM, 15 kHz)	5G NR FR1 FDD	8.70	± 9.6 %
11006	AAA	5G NR DL (CP-OFDM, TM 3.1, 30 MHz, 64-QAM, 15 kHz)	5G NR FR1 FDD	8.55	± 9.6 %
11007	AAA	5G NR DL (CP-OFDM, TM 3.1, 40 MHz, 64-QAM, 15 kHz)	5G NR FR1 FDD	8.46	± 9.6 %
11008	AAA	5G NR DL (CP-OFDM, TM 3.1, 50 MHz, 64-QAM, 15 kHz)	5G NR FR1 FDD	8.51	± 9.6 %
11009	AAA	5G NR DL (CP-OFDM, TM 3.1, 25 MHz, 64-QAM, 30 kHz)	5G NR FR1 FDD	8.76	± 9.6 %
11010	AAA	5G NR DL (CP-OFDM, TM 3.1, 30 MHz, 64-QAM, 30 kHz)	5G NR FR1 FDD	8.95	± 9.6 %
11011	AAA	5G NR DL (CP-OFDM, TM 3.1, 40 MHz, 64-QAM, 30 kHz)	5G NR FR1 FDD	8.96	± 9.6 %
11012	AAA	5G NR DL (CP-OFDM, TM 3.1, 50 MHz, 64-QAM, 30 kHz)	5G NR FR1 FDD	8.68	± 9.6 %
11013	AAB	IEEE 802.11be (320MHz, MCS1, 99pc duty cycle)	WLAN	8.47	± 9.6 %
11014	AAB	IEEE 802.11be (320MHz, MCS2, 99pc duty cycle)	WLAN	8.45	± 9.6 %
11015	AAB	IEEE 802.11be (320MHz, MCS3, 99pc duty cycle)	WLAN	8.44	± 9.6 %
11016	AAB	IEEE 802.11be (320MHz, MCS4, 99pc duty cycle)	WLAN	8.44	± 9.6 %
11017	AAB	IEEE 802.11be (320MHz, MCS5, 99pc duty cycle)	WLAN	8.41	± 9.6 %
11018	AAB	IEEE 802.11be (320MHz, MCS6, 99pc duty cycle)	WLAN	8.40	± 9.6 %
11019	AAB	IEEE 802.11be (320MHz, MCS7, 99pc duty cycle)	WLAN	8.29	± 9.6 %
11020	AAB	IEEE 802.11be (320MHz, MCS8, 99pc duty cycle)	WLAN	8.27	± 9.6 %
11021	AAB	IEEE 802.11be (320MHz, MCS9, 99pc duty cycle)	WLAN	8.46	± 9.6 %
11022	AAB	IEEE 802.11be (320MHz, MCS10, 99pc duty cycle)	WLAN	8.36	± 9.6 %
11023	AAB	IEEE 802.11be (320MHz, MCS11, 99pc duty cycle)	WLAN	8.09	± 9.6 %
11024	AAB	IEEE 802.11be (320MHz, MCS12, 99pc duty cycle)	WLAN	8.42	± 9.6 %
11025	AAB	IEEE 802.11be (320MHz, MCS13, 99pc duty cycle)	WLAN	8.37	± 9.6 %
11026	AAB	IEEE 802.11be (320MHz, MCS0, 99pc duty cycle)	WLAN	8.39	± 9.6 %

[E] Uncertainty is determined using the max. deviation from linear response applying rectangular distribution and is expressed for the square of the field value.

Calibration Laboratory of
Schmid & Partner
Engineering AG
Zeughausstrasse 43, 8004 Zurich, Switzerland

S Schweizerischer Kalibrierdienst
C Service suisse d'étalonnage
Servizio svizzero di taratura
S Swiss Calibration Service

Accredited by the Swiss Accreditation Service (SAS)
The Swiss Accreditation Service is one of the signatories to the EA Multilateral Agreement for the recognition of calibration certificates

Accreditation No.: SCS 0108

Client **WSCT**
Shenzhen

Certificate No: **OCP-DAK3.5-1363_Nov24**

CALIBRATION CERTIFICATE

Object	DAK-3.5 - SN: 1363
Calibration procedure(s)	QA CAL-33.v3 Calibration of dielectric parameter probes
Calibration date:	November 5, 2024

This calibration certificate documents the traceability to national standards, which realize the physical units of measurements (SI).
The measurements and the uncertainties with confidence probability are given on the following pages and are part of the certificate.

All calibrations have been conducted in the closed laboratory facility: environment temperature (22 ± 3)°C and humidity < 70%.

Calibration Equipment used (M&TE critical for calibration)

Primary Standards	ID #	Cal Date (Certificate No.)	Scheduled Calibration
OCP DAK-3.5 (weighted)	SN: 1249	23-Sep-24 (OCP-DAK3.5-1249_Sep24)	Sep-25

Secondary Standards	ID #	Check Date (in house)	Scheduled Check
Rohde & Schwarz ZVA67	T4383	1-Oct-24 (in house check Oct-24)	Oct-25
Digital Thermometer DTM3000	4026	07-Feb-24 (DTM-4026_Feb24)	Feb-25
Methanol 99.9% Type 34860	STBH5818	06-May-19 (bottle opened, check May-24)	May-25
Ethanol 99.9% Type 1.0983	241014-1	14-Oct-20 (bottle opened, check Oct-24)	Oct-25
Head Liquid, HBBL U16	200311-0	11-Mar-20 (in house check May-24)	May-25
0.1 mol/L NaCl solution	190926-1	20-Sep-19 (in house check May-24)	May-25
0.05 mol/L NaCl solution	190926-0	20-Sep-19 (in house check May-24)	May-25
Head Gel, SLAGH U08 AA-B	200227-1	07-Apr-20 (in house check Apr-24)	Apr-25
Eccostock0005	1507101	01-Jul-15 (in house check May-24)	May-25

	Name	Function	Signature
Calibrated by:	Cindy Karina	External Engineer	*(signature)*
Approved by:	Sven Kühn	Technical Manager	*(signature)*

Issued: November 5, 2024

References

[1] IEEE Std 1528-2013, "IEEE Recommended Practice for Determining the Peak Spatial-Averaged Specific Absorption Rate (SAR) in the Human Head from Wireless Communications Devices: Measurement Techniques", June 2013

[2] IEC 62209-1, "Measurement procedure for the assessment of Specific Absorption Rate (SAR) from hand-held and body-mounted devices used next to the ear (frequency range of 300 MHz to 6 GHz)", July 2016

[3] IEC 62209-2 Ed.1, "Human Exposure to Radio Frequency Fields from Handheld and Body-Mounted Wireless Communication Devices – Human models, Instrumentation, and Procedures Part 2: Procedure to determine the specific absorption rate (SAR) for mobile wireless communication devices used in close proximity to the human body (frequency range of 30 MHz to 6 GHz)", March 2010

[4] A. P. Gregory and R. N. Clarke, "NPL Report MAT 23", January 2012
Tables of the Complex Permittivity of Dielectric Reference Liquids at Frequencies up to 5 GHz

[5] DAK Professional Handbook, SPEAG, September 2018

[6] A. Toropainen et al, "Method for accurate measurement of complex permittivity of tissue equivalent liquids", Electronics Letters 36 (1) 2000 pp32-34

[7] J. Hilland, "Simple sensor system for measuring the dielectric properties of saline solutions", Meas. Sci. Technol. 8 pp901–910 (1997)

[8] K. Nörtemann, J. Hilland and U. Kaatze, "Dielectric Properties of Aqueous NaCl Solutions at Microwave Frequencies", J. Phys. Chem. A 101 pp6864-6869 (1997)

[9] R. Buchner, G. T. Hefter and Peter M. May, "Dielectric Relaxation of Aqueous NaCl Solutions", J. Phys. Chem. A 103 (1) (1999)

Description of the dielectric probe

Dielectric probes are used to measure the dielectric parameters of tissue simulating media in a wide frequency range. The complex permittivity $\varepsilon_r^* = (\varepsilon'/\varepsilon_0) - j(\varepsilon''/\varepsilon_0)$ is determined from the S parameters measured with a vector network analyzer (VNA) with software specific to the probe type. The parameters of interest e.g. in standards [1, 2, 3] and for other applications are presented are calculated as follows:
(Relative) permittivity ε' (real part of $\varepsilon_r^* = (\varepsilon'/\varepsilon_0) - j(\varepsilon''/\varepsilon_0)$ where ε_0 = 8.854 pF/m is the permittivity in free space)
Conductivity $\sigma = 2\,\pi\, f\, \varepsilon''\, \varepsilon_0$,
Loss Tangent = $(\varepsilon''/\varepsilon')$

The **OCP** (open ended coaxial) is a cut off section of 50 Ohm transmission line, similar to the system described in [1, 2, 3, 5], used for contact measurement. The material is measured either by touching the probe to the surface of a solid/gel or by immersing it into a liquid media. The electromagnetic fields at the probe end fringe into the material to be measured, and its parameters are determined from the change of the S_{11} parameters. With larger diameter of the dielectrics, the probe can be used down to lower frequencies.
The flange surrounding the active area shapes the near field similar to a semi-infinite geometry and is inserted fully into the measured lossy liquid.

The probe is connected with a phase and amplitude stable cable to a VNA which is then calibrated with Open, Short and a Liquid with well-known parameters.
All parts in the setup influencing the amplitude and phase of the signal are important and shall remain stable.

Handling of the item

Before usage, the active probe area has to be cleaned from any material residuals potentially contaminating the reference standards. The metal and dielectric surface must be protected to keep the precision of the critical mechanical dimensions. The connector and cable quality are critical; any movements between calibration and measurement shall be avoided.
The temperature must be stable and must not differ from the material temperature.

Methods Applied and Interpretation of Parameters

The calibration of the dielectric probe system is done in the steps described below for the desired frequency range and calibration package (SAR/MRI liquids, Semi-solid/solid material). Because the standard calibration in step 3 is critical for the results in steps 4 to 8, the sequence 3 to 8 is repeated 3 times. As a result, the result from these 3 sets is represented.

1. Configuration and mechanical / optical status.
2. Measurement resolution is 5 MHz from 10 to 300 MHz, 50 MHz from 300 to 6000 MHz and 250 MHz from 6 to 20 GHz.
3. Standard calibration uses Air / Short / Liquid. 1 liter liquid quantity is used to reduce the influence the reflections. The liquid type is selected depending on the lowest frequency and probe diameter:
   DAK-1.2, DAK-3.5, Agilent OCP: de-ionized water (approx. 22 °C)
   DAK-12: saline solution with static conductivity 1 S/m (approx. 22 °C)
   NPL OCP: pure ethanol (approx. 22 °C)
4. The cable used in the setup stays in a fixed position, i.e. the probe is fixed and measuring from the top in an angle of typ. 20° from the vertical axis. For DAK and Agilent probes, the refresh function (air standard) is used previous to the individual measurements in order to compensate for possible deviations from cable movements. After insertion of the probe into a liquid, the possible air bubbles are removed from the active surface.
5. Measurement of multiple shorts if not already available from the calibration in the previous step (NPL). Evaluation of the deviation from the previous calibration short with graphical representation of the complex quantities and magnitude over the frequency range. Probe specific short is used. This assessment shows ability to define a short circuit at the end of the probe for the VNA calibration in the setup which is essential at high frequencies and depends on the probe surface quality.
6. Measurement of validation liquids in a quantity of 1 liter at well defined temperature. Evaluation of the deviations from the target. The targets base on traceable data from reference sources. The deviation of the measurement is graphically presented for permittivity and conductivity (for lossy liquids) or loss tangent (for low losses at low frequencies).
7. Measurement of lossy liquids in a quantity of 1 liter at well defined temperature. Head tissue simulating liquid or saline solution with 0.5 S/m static conductivity are representative. The target data base on traceable data from reference sources or from multiple measurements with precision reference probes or different evaluations such as transmission line or slotted line methods. Evaluation of the deviation from the target and graphical representation for permittivity and conductivity over the frequency range
8. Semi-solid / solid material calibration:
   Measurements of an elastic lossy broadband semi-solid gel with parameters close to the head tissue target. Measurements of a planar very low loss solid microwave-substrate. The average of 4 measurements of the same sample at different location is shown as a single result. The deviation of the permittivity and conductivity from the reference data is evaluated.
   Measurements of a planar very low loss solid microwave-substrate. The average of 4 measurements of the same sample at different location is shown as a single result. The relative deviation of the permittivity and the absolute deviation of the loss tangent is evaluated.
   The targets base on multiple measurements (on the same material batch at identical temperature) on convex and planar surfaces with precision reference OCP.

The measurement on semi-solid / solid materials is sensitive to the quality and planarity of the probe contact area, such as air gaps due to imperfect probes (resulting lower permittivity values).

9. Table for the probe uncertainty: The uncertainty of the probe depending on probe type, size, material parameter range and frequency is given in a table. It represents the best measurement capability of the specific probe but does not include the material (deviation from the target values).
10. Appendix with detailed results of all measurements with the uncertainties for the specific measurement. In addition to the probe uncertainty (see above), it includes the uncertainty of the reference material used for the measurement. A set of results from independent calibrations represents the capability of the setup and the lossy materials used, including the precision of the measured material and the influence of temperature deviations. Temperature and operator influence was minimized and gives a good indication of the achievable repeatability of a measurement.
11. Summary assessment of the measured deviations and detailed comments if not typical for the probe type.

Dielectric probe identification and configuration data

Item description

Probe type	**OCP** Open-ended coaxial probe
Probe name	SPEAG Dielectric Assessment Kit DAK-3.5
Type No	**SM DAK 040 CA**
Serial No	**1363**
Description	Open-ended coaxial probe with flange Flange diameter: 19.0 mm Dielectric diameter: 3.5 mm Material: stainless steel
Connector 1	PC 3.5 pos.
Software version	**DAK Measurement Solver 3.0.6.34** Calibration Type: Air / short / water (set to measured water temp.) Probe type: "DAK3.5" (software setting)
Further settings	VNA bandwidth setting: 50 Hz

SCS 0108 Accessories used for customer probe calibration

Cable	Huber & Suhner Sucoflex 100, SN: 512046/126, length 1 m, PC3.5 neg. – PC3.5 neg.
Short	DAK-3.5 shorting block, type SM DAK 200 BA Contact area covered with cleaned Cu stripe

Additional items used during measurements

Adapter 1	PC3.5 pos. – PC1.85 (VNA side)
Adapter 2	PC3.5 pos. – PC3.5 neg. (probe side)

Notes

- Before the calibration, the connectors of the probe and cable were inspected and cleaned.
- Probe visual inspection: according to requirements
- Short inspection: according to the requirements

Probe Uncertainty

The following tables provide material and frequency specific uncertainties (k=2) for the dielectric probe. The values in the tables represent the measurement capability for the probe when measuring a material in the indicated parameter range. They include all uncertainties of

- probe system
- possible systematic errors due to the design
- calibration
- temperature differences during the calibration and measurements, as described,
- VNA noise

Apart from the material used for the calibration (de-ionized water), material uncertainties of the reference materials used during the measurement in Appendix A are not included in these tables.

DAK-3.5				
Permittivity range		Frequency range	(sigma / LT range)	Unc. (k=2)
	1 – 15	200 MHz - 3 GHz	LT < 0.1	2.4%
		3 GHz - 6 GHz	LT < 0.1	2.0%
		6 GHz - 20 GHz	LT < 0.1	2.1%
		6 GHz - 20 GHz	sigma > 1	3.5%
	10 – 40	200 MHz - 3 GHz	sigma : 1 – 10 S/m	1.9%
		3 GHz - 6 GHz	sigma : 1 – 10 S/m	2.3%
		6 GHz - 20 GHz	sigma > 10 S/m	3.5%
	35 – 100	200 MHz - 3 GHz	sigma : 1 – 10 S/m	1.8%
		3 GHz - 6 GHz	sigma : 1 – 10 S/m	1.9%
		6 GHz - 20 GHz	sigma > 10 S/m	2.4%
Conductivity range (S/m)		Frequency range	(epsilon / LT range)	Unc. (k=2)
	1 – 10	200 MHz - 3 GHz	eps : 35 - 100	2.7%
		3 GHz - 6 GHz	eps : 35 - 100	3.0%
		6 GHz - 20 GHz	eps : 10 - 40	3.0%
Loss tangent range		Frequency range	(epsilon / LT range)	Unc. (k=2)
	< 0.1	200 MHz - 3 GHz	eps : 1 - 15	0.03
		3 GHz - 6 GHz	eps : 1 - 15	0.03
		6 GHz - 20 GHz	eps : 1 - 15	0.03

Calibration Results

Uncertainty limits (k=2) for the material measurements in the figures of Appendix A are represented with red dashed lines. These uncertainties contain - in addition to probe uncertainty - the uncertainty of the material target parameter determination.
The measurements show the results obtained from independent calibrations for the same material. The differences between the individual measurement curves give therefore an indication for the obtainable repeatability and shall lie within the uncertainties stated in the tables.

Materials for DAK-3.5 calibration:
Appendix A with curves for Ethanol, HBBL, and 0.05 mol/L NaCl solution (200 MHz - 6 GHz, optional 20 GHz), HS gel and low loss solid substrate are optional.*

** Effective immediately, methanol will be replaced with the safer and more environmentally-friendly ethanol as the validation liquid. Each batch of ethanol is calibrated using a methanol reference, ensuring that the validation process is both traceable and consistent with prior measurements.*

Appendix A: Detailed Results

A.1 Probe appearance and calibration sequence

A.1.1 Appearance

The OCP appearance is fully according to the expectations:

- the flange surface is intact

A.1.2 Calibration sequence

The following sequence was repeated 3 times in the low frequency range from 200 – 300 MHz in 5 MHz steps and in the high frequency range from 300 to 6000 MHz in 50 MHz steps, and from 6 GHz to 20 GHz in 250 MHz steps.

- Air
- Short 1 short, then immediate verification with a second short (with eventual repetition)
- Water De-ionized water, temperature measured and set in the software (for DAK-12 0.1 mol/L saline solution, temperature measured and set in the software)
- Methanol Pure methanol, temperature measured and set in the software
- Ethanol Pure ethanol, temperature measured and set in the software
- Liquids Measurement of further liquids (e.g. Head tissue simulating liquid and 0.05 mol/l saline)
- Cleaning Probe washed with water and isopropanol at the end of the sequence.
- Shorts 4 additional separate short measurements to determine the deviation from the original
- Refresh Refresh with Air
- Solid 4 separate solid low loss planar substrate measurements to determine one average (optional)
- Semisolid 4 separate head gel measurements on fresh intact surface to determine one average (optional)
- Cleaning Probe washed with water and isopropanol at the end of the sequence

Evaluation of the additional shorts from the calibrated (ideal) short point at the left edge of the Smith Chart, represented as magnitude over the frequency range (fig. 2.1.x) and in polar representation (fig. 2.2.x).

Evaluation of the Liquid measurements and representation of the permittivity and conductivity deviation from their reference data at the measurement temperature. The results of each of the 3 calibrations is shown in the appendix for each material (fig. 3ff) in black, red, blue. The red dashed line shows the uncertainty of the reference material parameter determination.

Evaluation of the Semisolid measurements (optional) by representing the 3 average deviations (each resulting from the 4 separate measurements per set), equivalent to the liquid measurement. Representation of the permittivity and conductivity deviation from their reference data at the nominal temperature.

Evaluation of the Solid measurements (optional) by representing the 3 average deviations (each resulting from the 4 separate measurements per set), equivalent to the liquid measurement. Representation of the permittivity deviation from their reference data and the loss tangent at the nominal temperature.

A.2 Short residual magnitudes

After each of the 3 calibrations with a single short (as per the DAK software), 4 additional separate, short measurements were performed after the liquid measurements and evaluated from the S11 data. The residuals in the graphs represent the deviation from the ideal short point on the polar representation on the VNA screen.

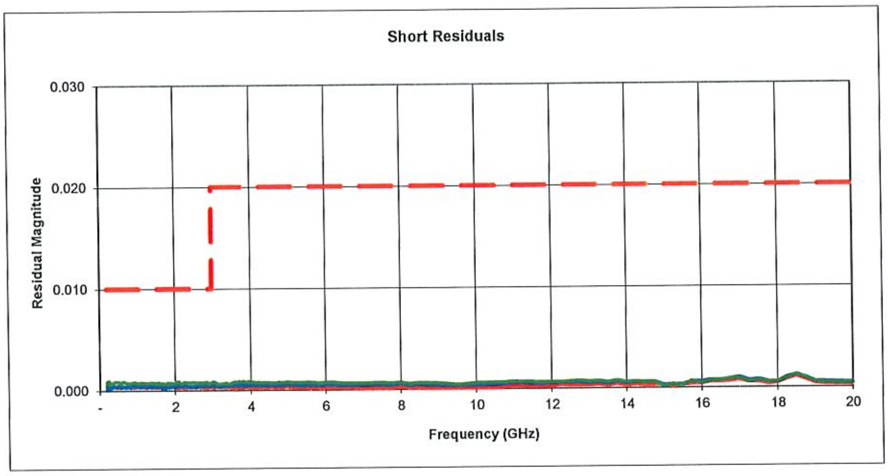

Fig. 2.1a Magnitude of the residual of the shorts, 200 MHz – 20 GHz, after calibration a)

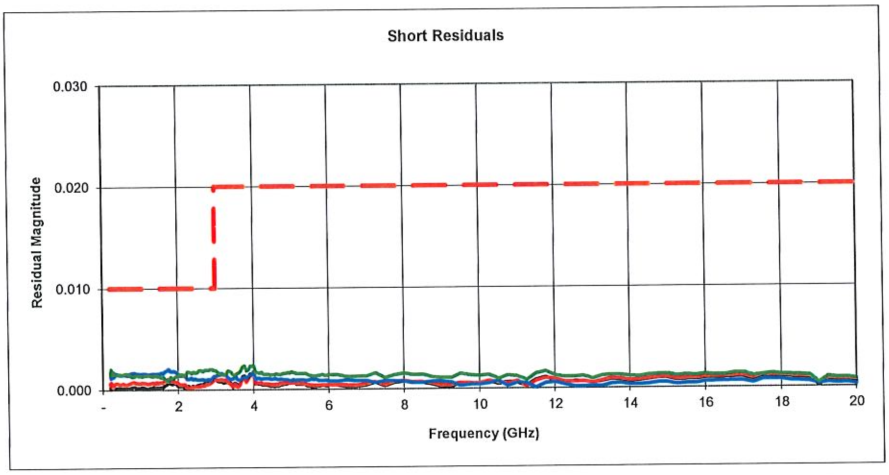

Fig. 2.1b Magnitude of the residual of the shorts, 200 MHz – 20 GHz, after calibration b)

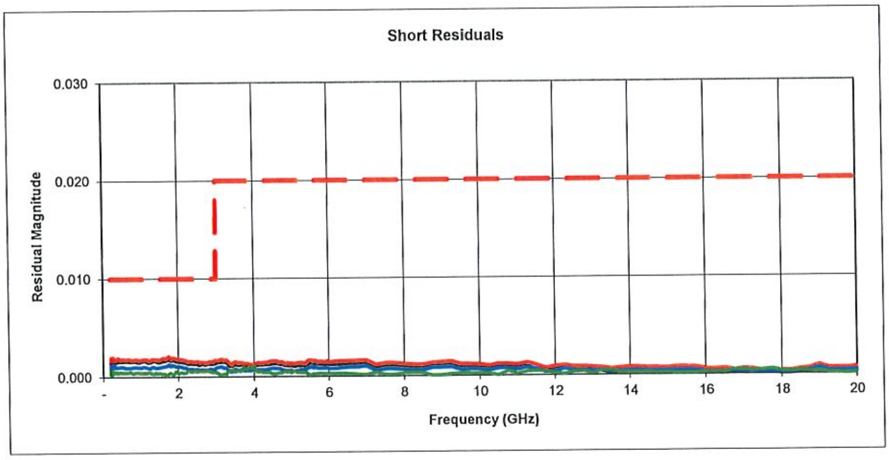

Fig. 2.1c Magnitude of the residual of the shorts, 200 MHz – 20 GHz, after calibration c)

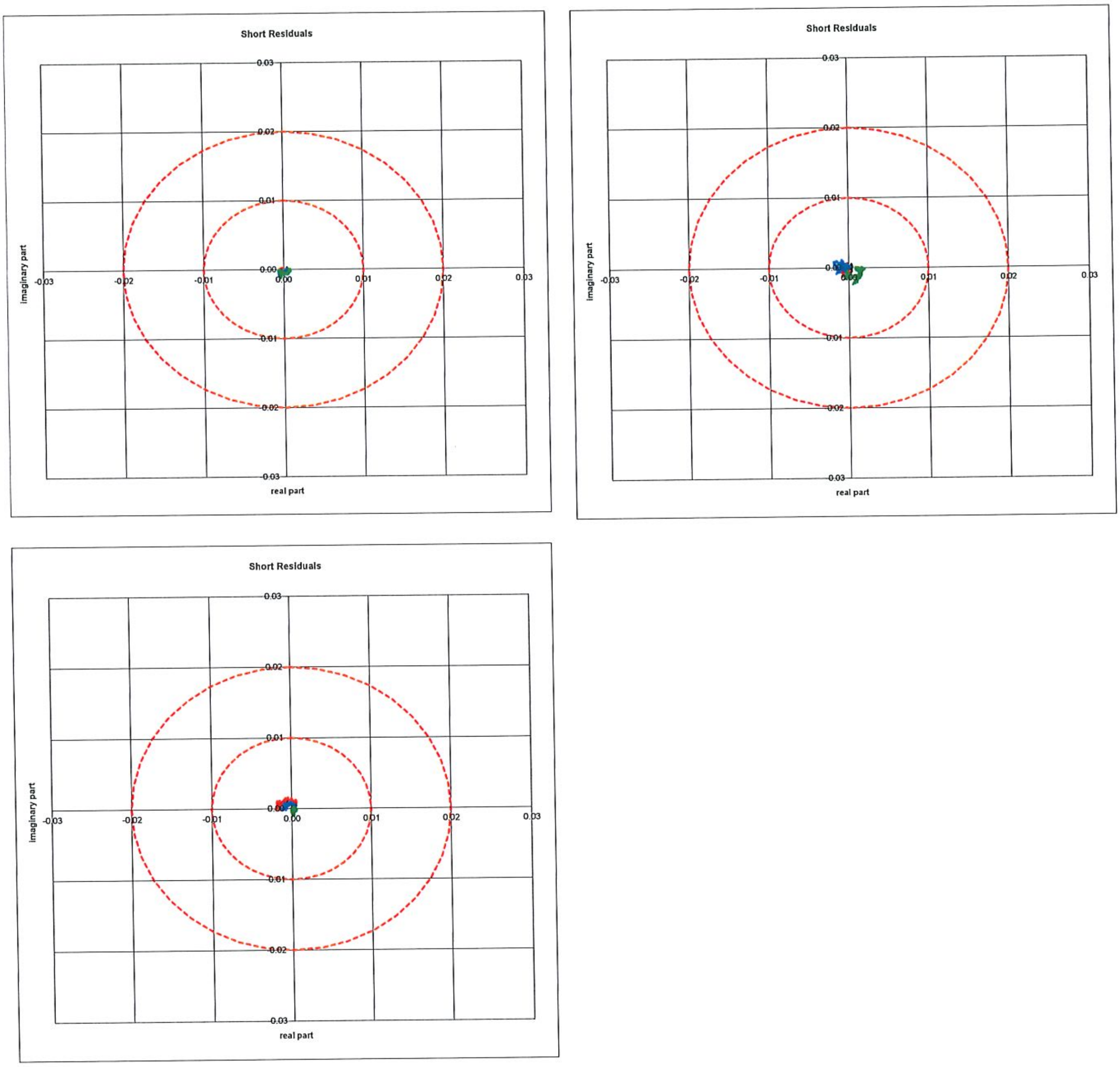

Fig. 2.2a-c Complex representation of the residuals of the shorts, 200 MHz - 20 GHz, after calibrations a)-b) in the top and c) in the bottom

All shorts have good quality. Some minor deviations might be visible from contact quality (left - right).

A.3 Ethanol

Ethanol (99.9% pure) was measured at a temperature of 22 +/- 2 °C. The liquid temperature was stabilized within 0.05 °C of the desired temperature. Deviations are presented relative to the reference data for this material. Those parameters have been evaluated from multiple measurements on the used bath with precision reference OCP and further methods. For the measurements the Noise Filter was activated in the software.

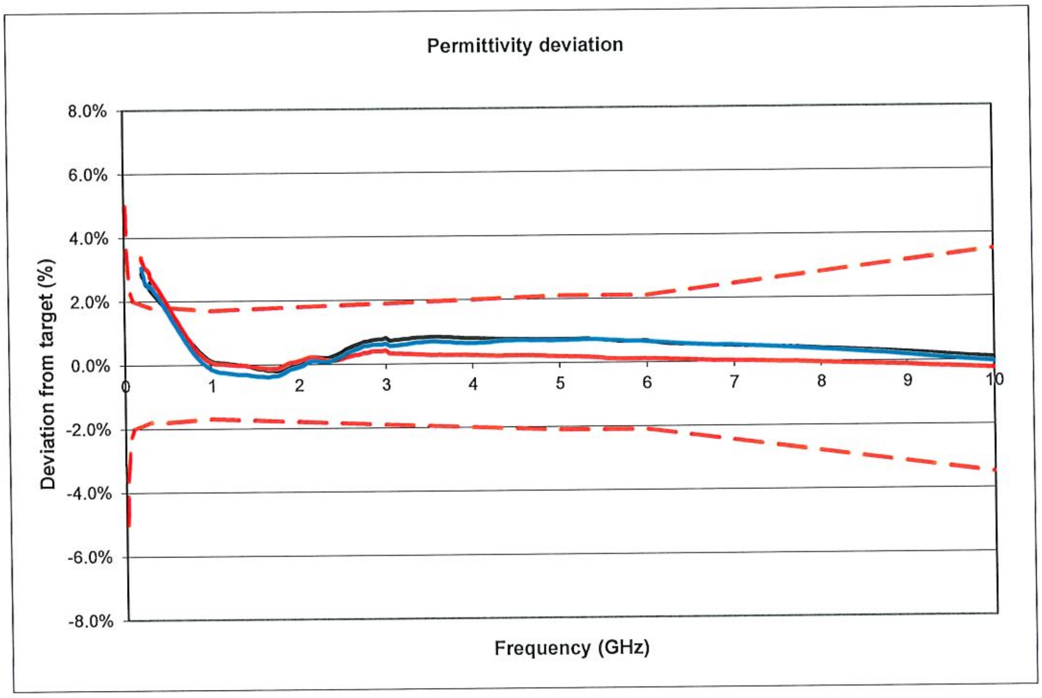

Fig. 3.1 Ethanol permittivity deviation from target, 200 MHz – 10 GHz

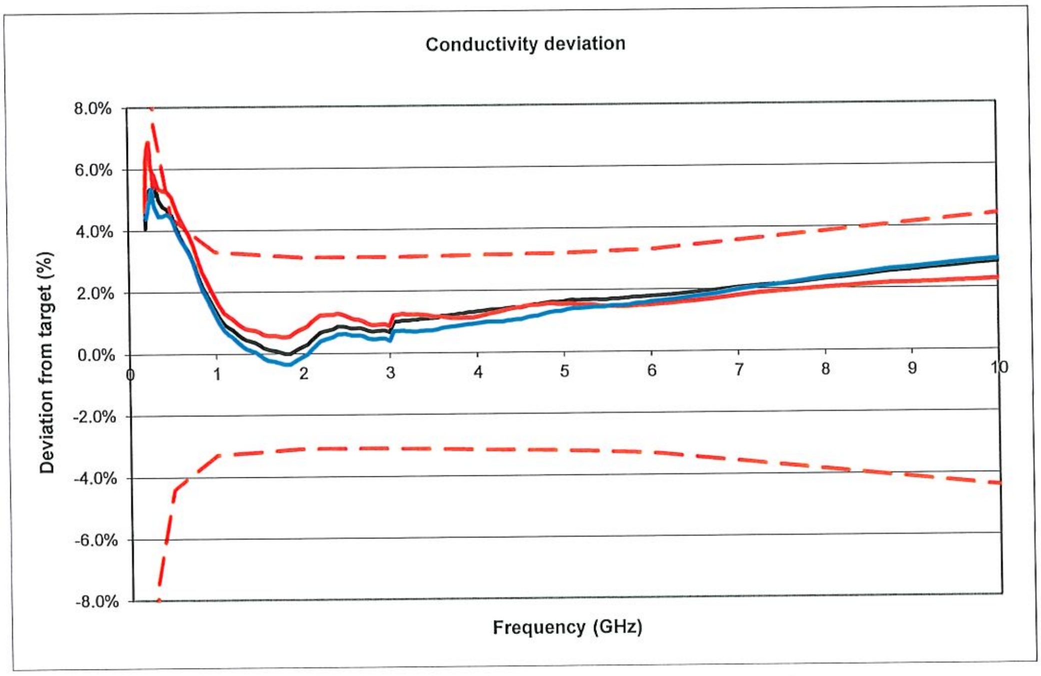

Fig. 3.2 Ethanol conductivity deviation from target, 200 MHz – 10 GHz

Note: Conductivity error can be high at low frequencies due to the low absolute conductivity values.

A.4 Head Tissue

Broadband head simulating liquid was measured at a temperature of 22 +/- 2 °C. The liquid temperature was stabilized within 0.05 °C of the desired temperature. Deviations are presented relative to the reference data for this material. Those parameters have been evaluated from multiple measurements on the used bath with precision reference OCP and further methods. For the measurements the Noise Filter was activated in the software.

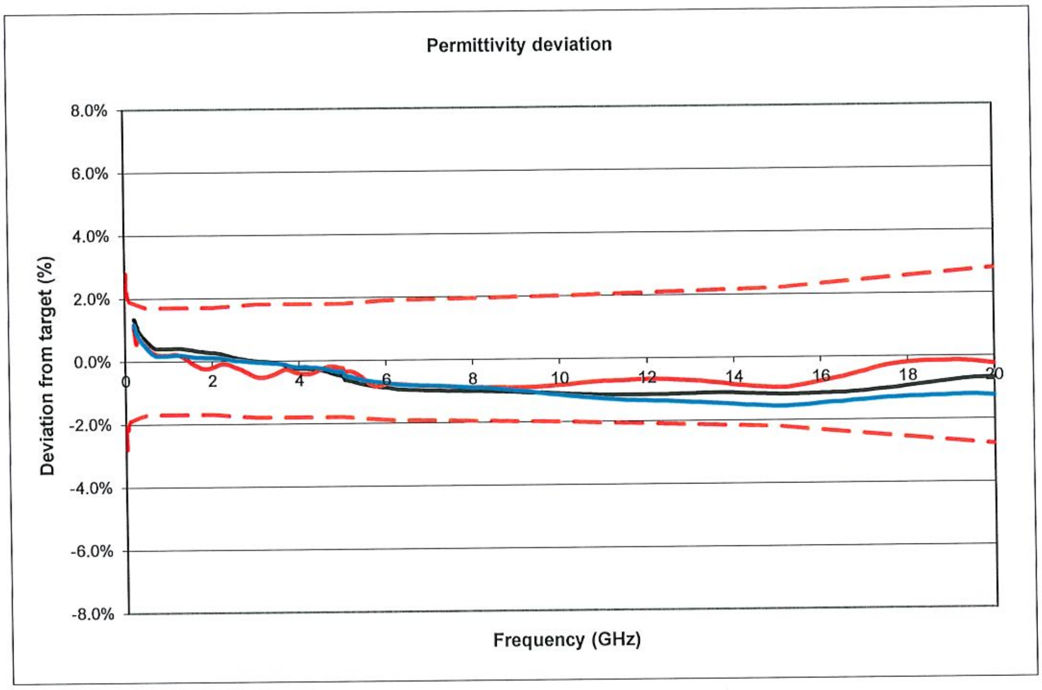

Fig. 4.1 HBBL permittivity deviation from target, 200 MHz – 20 GHz

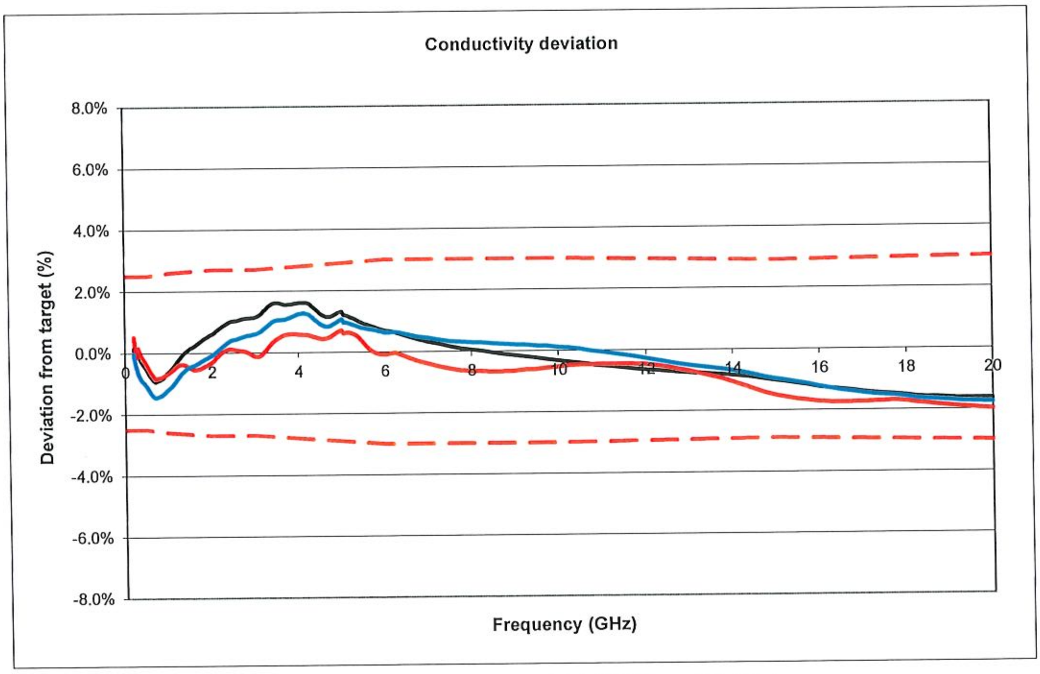

Fig. 4.2 HBBL conductivity deviation from target, 200 MHz – 20 GHz

A.5 0.05 mol/L NaCl solution

0.05 mol/L NaCl / water solution has a static conductivity of 0.5 S/m, similar to MRI HCL (High Conductivity Liquid). It was measured at a temperature of 22 +/- 2 °C. The liquid temperature was stabilized within 0.05 °C of the desired temperature. Deviations are presented relative to the reference data for this material. These parameters have been derived from the theoretical model according to [7], matched to the measurements from reference probes and other sources.
A quantity of 1 liter was used for the measurement. For the measurements the Noise Filter was activated in the software.

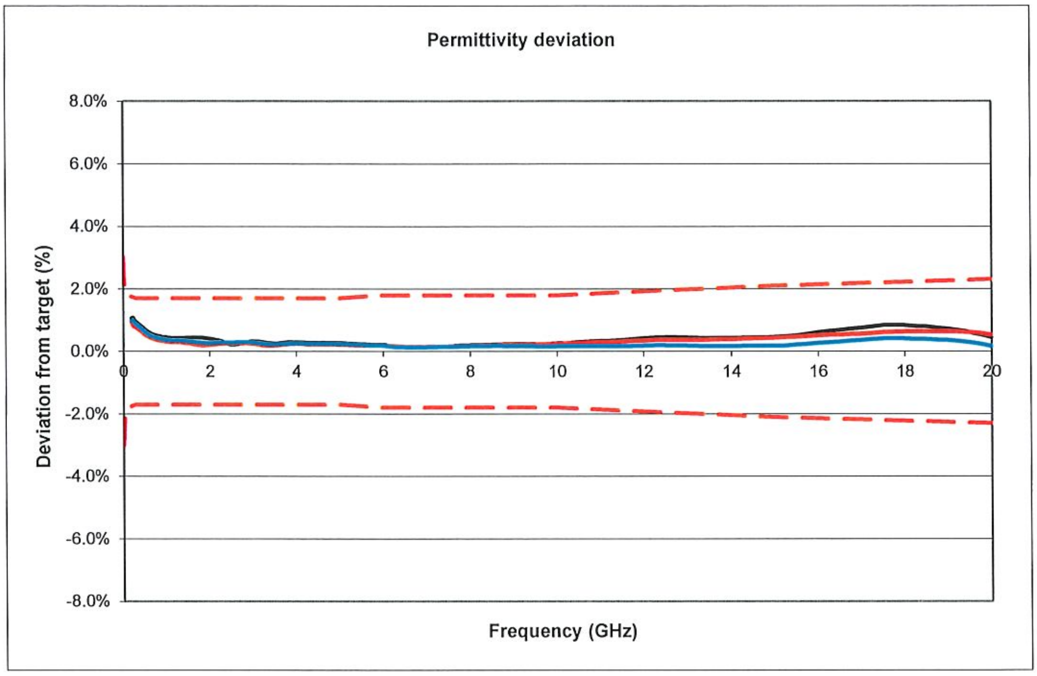

Fig. 5.1 0.05 mol/L solution permittivity deviation from target, 200 MHz – 20 GHz

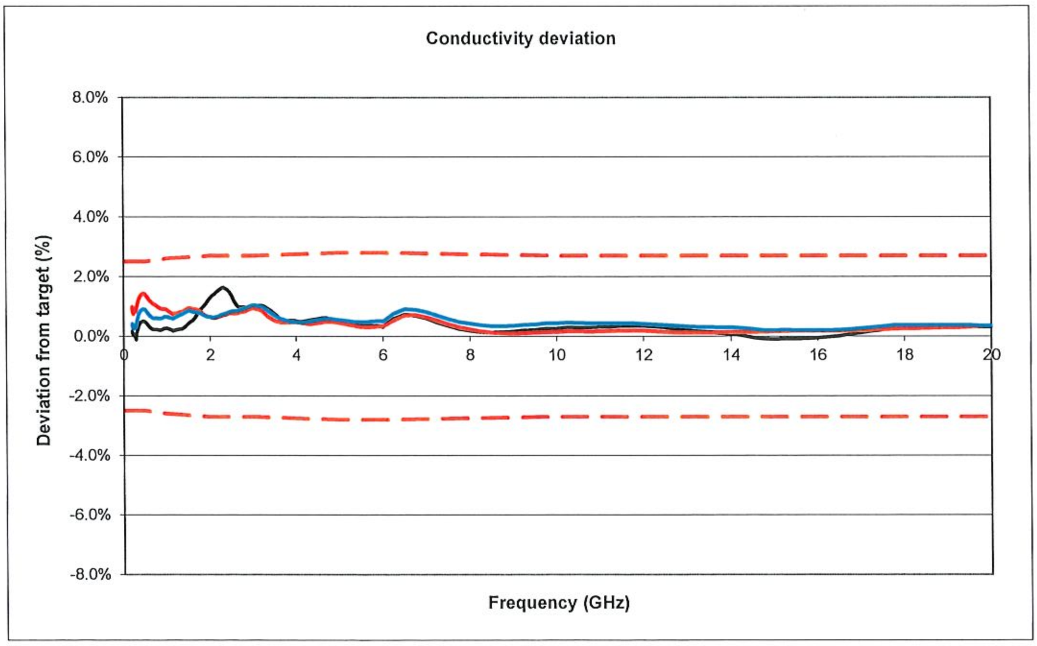

Fig. 5.2 0.05 mol/L solution conductivity deviation from target, 200 MHz – 20 GHz

Appendix B: Nominal parameters of reference materials used for calibration (additional assessments outside the scope of SCS0108)

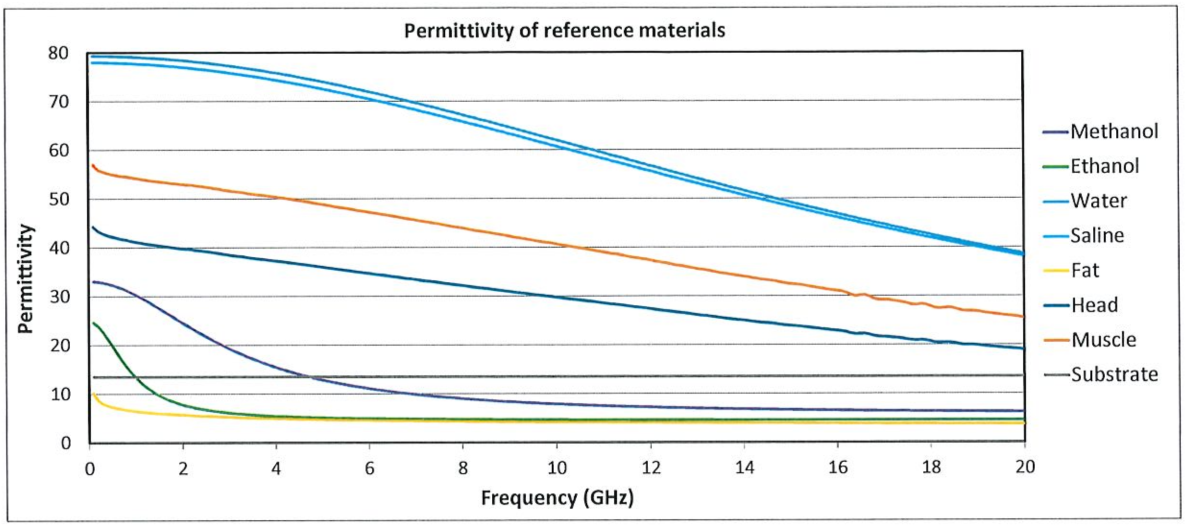

Fig. B.1 Permittivity of reference materials

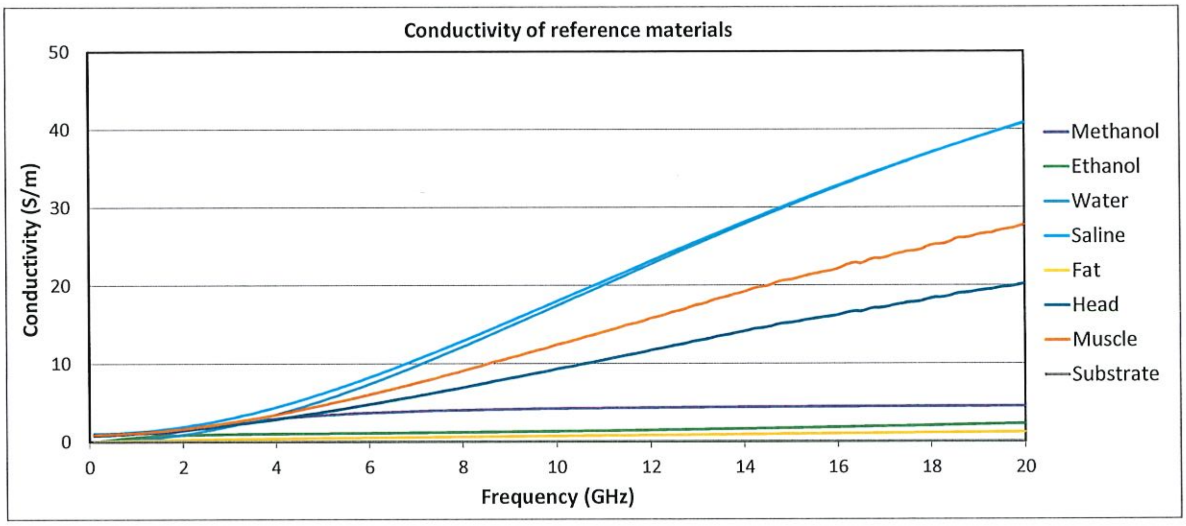

Fig. B.2 Conductivity of reference materials

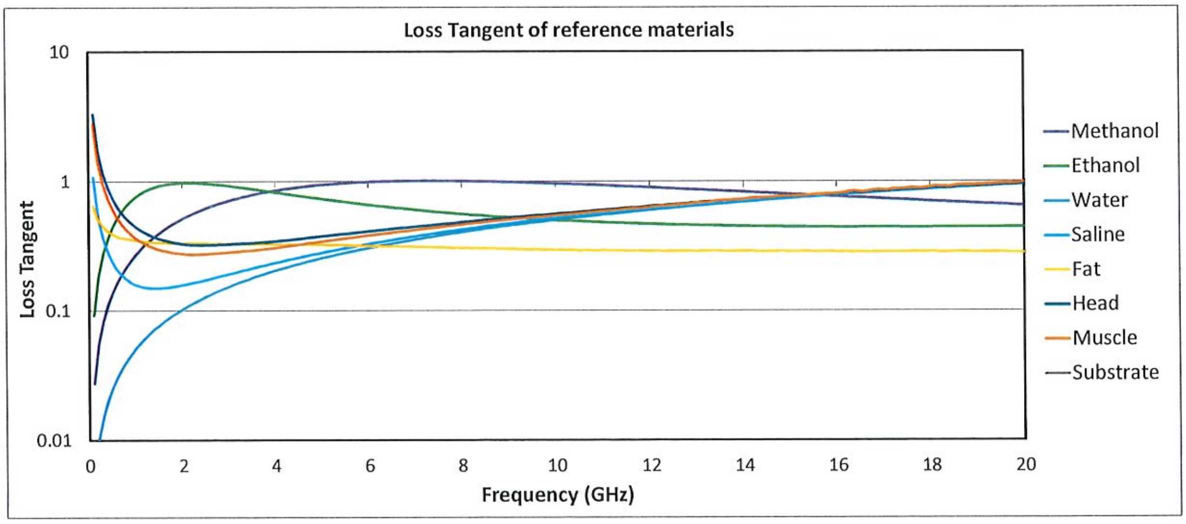

Fig. B.3 Loss tangent of reference materials

Calibration Laboratory of
Schmid & Partner
Engineering AG
Zeughausstrasse 43, 8004 Zurich, Switzerland

S **Schweizerischer Kalibrierdienst**
C **Service suisse d'étalonnage**
S **Servizio svizzero di taratura**
S **Swiss Calibration Service**

Accredited by the Swiss Accreditation Service (SAS)
The Swiss Accreditation Service is one of the signatories to the EA Multilateral Agreement for the recognition of calibration certificates

Accreditation No.: SCS 0108

Client **WSCT**
Shenzhen

Certificate No. **MAGPy-8H3D-3087_Nov24**

CALIBRATION CERTIFICATE

Object	MAGPy-8H3D+E3DV2 SN:3087 MAGPy-DASV2 SN:3116
Calibration procedure(s)	QA CAL-46.v1 Calibration Procedure for MAGPy–8H3D+E3D Near-field Electric and Magnetic Field Sensor System
Calibration date	November 01, 2024

This calibration certificate documents the traceability to national standards, which realize the physical units of measurements (SI).
The measurements and the uncertainties with confidence probability are given on the following pages and are part of the certificate.

All calibrations have been conducted in the closed laboratory facility: environment temperature (22 ± 3)°C and humidity < 70%.

Calibration Equipment used (M&TE critical for calibration)

Primary Standards	ID	Cal Date (Certificate No.)	Scheduled Calibration
Oscilloscope	SN: 110918	03-Sep-24 (No. 4030A315008835)	Sep-25
Reference 20 dB Attenuator	SN: CC2552 (20x)	26-Mar-24 (No. 217-04046)	Mar-25
Type-N mismatch	SN: 310982 / 06327	26-Mar-24 (No. 217-04047)	Mar-25

Secondary Standards	ID	Check Date (in house)	Scheduled Check
Network Analyzer E5061B	SN: MY49810822	In house check: Nov-23	In house check: Nov-24
TEM Cell	SN: S6029i	In house check: Nov-23	In house check: Nov-24
Plate Capacitor	SN: 6028i	In house check: Nov-23	In house check: Nov-24
Resonator (160kHz)	SN: 6030i	In house check: Nov-23	In house check: Nov-24

	Name	Function	Signature
Calibrated by	Aidonia Georgiadou	Laboratory Engineer	
Approved by	Sven Kühn	Technical Manager	

Issued: November 01, 2024

Calibration Laboratory of
Schmid & Partner
Engineering AG
Zeughausstrasse 43, 8004 Zurich, Switzerland

S Schweizerischer Kalibrierdienst
C Service suisse d'étalonnage
 Servizio svizzero di taratura
S Swiss Calibration Service

Accredited by the Swiss Accreditation Service (SAS)
The Swiss Accreditation Service is one of the signatories to the EA Multilateral Agreement for the recognition of calibration certificates

Accreditation No.: SCS 0108

Glossary

MAGPy-8H3D-E3D	Magnetic Amplitude and Gradient Probe – Eight H-field Sensors, Single E-field sensor
MAGPy-DAS	Magnetic Amplitude and Gradient Data Acquisition System

Calibration is Performed According to the Following Standards:

a) IEEE Std 1309-2013, "IEEE Standard for calibration of electromagnetic field sensors and probes, excluding antennas, from 9 kHz to 40 GHz", November 2013

Methods Applied and Interpretation of Parameters

- Calibration has been performed after the adjustment of the device.
- *Linearity*: Calibration of the linearity of the field reading over the specified dynamic range at 161.75 kHz. Influence of offset voltage is included in this measurement.
- *Frequency response*: Calibration of the field reading over the specified frequency range from 3.0 kHz to 10.0 MHz.
- Receiving Pattern: Assessed for H-field polarizations ϑ, and $\phi = 0° \ldots 360°$; $\vartheta = 90°$, and $\phi = 0° \ldots 360°$; for the XYZ sensors (in TEM-Cell at 4 kHz, 40 kHz, 400 kHz and 4 MHz).
- Receiving Pattern: Assessed for E-field polarizations ϑ, and $\phi = 0° \ldots 360°$; $\vartheta = 90°$, and $\phi = 0° \ldots 360°$; for the XYZ sensor (in parallel plate capacitor at 4 kHz, 40 kHz, 400 kHz and 4 MHz).

Calibration Uncertainty

The calibration uncertainty is 0.7 dB for the H-field readings and 1.06 dB for the E-field readings. The calibration uncertainty is specified over the frequency range from 3.0 kHz to 10.0 MHz and a dynamic range from 0.1 A/m to 3200 A/m and from 0.08 V/m to 2000 V/m respectively.

The reported uncertainty of measurement is stated as the standard uncertainty of measurement multiplied by the coverage factor k=2, which for a normal distribution corresponds to a coverage probability of approximately 95%.

Measurement Conditions

Unit Type	MAGPy–8H3D+E3DV2 (SP MGY 303 AA)	3087
	MAGPy–DASV2 (SE UMS 303 AF)	3116
	MAGPy FPGA Board	WP000270
Adjustment Date	Last MAGPy Adjustment	November 01, 2024
Firmware SW Version	MAGPy Firmware	Ver. 1.00
Backend SW Version	MAGPy Backend	Ver. 1.0.2
Calibration SW Version	MAGACAP	Ver. 1.0

Dynamic Range

Dynamic Range, H-field, Channel 0

H-field/(A/m) Applied			H-field/(A/m) Reading			Difference/(dB)			
x	y	z	x	y	z	x	y	z	Tolerance/(dB)
0.390	0.370	0.370	0.400	0.380	0.380	0.22	0.23	0.23	±1.00
0.520	0.510	0.500	0.530	0.510	0.520	0.17	0.00	0.34	±1.00
0.720	0.700	0.690	0.710	0.700	0.700	−0.12	0.00	0.12	±1.00
0.940	0.910	0.900	0.940	0.910	0.900	0.00	0.00	0.00	±1.00
1.28	1.24	1.22	1.28	1.25	1.20	0.00	0.07	−0.14	±1.00
1.75	1.70	1.67	1.75	1.69	1.66	0.00	−0.05	−0.05	±1.00
2.33	2.26	2.23	2.32	2.27	2.22	−0.04	0.04	−0.04	±0.20
3.12	3.02	2.97	3.11	3.03	2.95	−0.03	0.03	−0.06	±0.20
4.23	4.10	4.03	4.23	4.12	4.03	0.00	0.04	0.00	±0.20
5.73	5.55	5.46	5.72	5.60	5.46	−0.02	0.08	0.00	±0.20
7.69	7.46	7.34	7.69	7.53	7.34	0.00	0.08	0.00	±0.20
10.3	9.96	9.79	10.3	10.0	9.81	0.00	0.03	0.02	±0.20
13.9	13.5	13.2	13.8	13.5	13.2	−0.06	0.00	0.00	±0.20
18.7	18.2	17.8	18.7	18.2	17.9	0.00	0.00	0.05	±0.20
25.3	24.5	24.1	25.3	24.6	24.1	0.00	0.04	0.00	±0.20
33.8	32.8	32.2	33.9	32.9	32.4	0.03	0.03	0.05	±0.20
45.6	44.3	43.5	45.9	44.5	43.7	0.06	0.04	0.04	±0.20
62.0	60.1	59.0	62.2	60.3	59.3	0.03	0.03	0.04	±0.20
85.1	82.5	81.1	84.9	82.2	80.7	−0.02	−0.03	−0.04	±0.20
111	108	106	111	108	106	0.00	0.00	0.00	±0.20
153	148	146	153	148	145	0.00	0.00	−0.06	±0.20
212	206	202	212	205	202	0.00	−0.04	0.00	±0.20
294	285	280	296	280	274	0.06	−0.15	−0.19	±0.20
434	420	412	429	414	406	−0.10	−0.12	−0.13	±0.20
599	579	567	596	575	563	−0.04	−0.06	−0.06	±0.20
894	864	845	899	867	848	0.05	0.03	0.03	±0.20
1350	1310	1280	1380	1330	1300	0.19	0.13	0.13	±0.30
1840	1780	1740	1900	1830	1780	0.28	0.24	0.20	±0.30
3030	2920	2850	3150	3030	2950	0.34	0.32	0.30	±0.50
3690	3540	3450	3850	3700	3600	0.37	0.38	0.37	±0.50

SPEAG H-field linearity tolerance criteria[1]:
- ±1.0 dB for applied H-fields < 2.0 A/m
- ±0.2 dB for applied H-fields ≥ 2.0 A/m and < 1000 A/m
- ±0.3 dB for applied H-fields ≥ 1000 A/m and < 2000 A/m
- ±0.4 dB for applied H-fields ≥ 2000 A/m and < 3000 A/m
- ±0.5 dB for applied H-fields ≥ 3000 A/m

[1] Calibration uncertainty not taken into account (shared risk 50%).

Dynamic Range, H-field, Channel 1

H-field/(A/m) Applied			H-field/(A/m) Reading			Difference/(dB)			
x	y	z	x	y	z	x	y	z	Tolerance/(dB)
0.390	0.380	0.380	0.400	0.400	0.390	0.22	0.45	0.23	±1.00
0.530	0.520	0.520	0.530	0.540	0.510	0.00	0.33	−0.17	±1.00
0.730	0.710	0.710	0.730	0.710	0.700	0.00	0.00	−0.12	±1.00
0.950	0.930	0.930	0.950	0.920	0.930	0.00	−0.09	0.00	±1.00
1.29	1.26	1.26	1.28	1.26	1.25	−0.07	0.00	−0.07	±1.00
1.76	1.72	1.73	1.79	1.71	1.72	0.15	−0.05	−0.05	±1.00
2.35	2.30	2.30	2.37	2.30	2.29	0.07	0.00	−0.04	±0.20
3.14	3.07	3.07	3.17	3.07	3.06	0.08	0.00	−0.03	±0.20
4.26	4.16	4.17	4.28	4.17	4.17	0.04	0.02	0.00	±0.20
5.77	5.64	5.64	5.78	5.64	5.65	0.02	0.00	0.02	±0.20
7.75	7.58	7.59	7.77	7.59	7.59	0.02	0.01	0.00	±0.20
10.4	10.1	10.1	10.4	10.1	10.2	0.00	0.00	0.09	±0.20
14.0	13.7	13.7	14.0	13.7	13.7	0.00	0.00	0.00	±0.20
18.9	18.4	18.4	18.9	18.5	18.5	0.00	0.05	0.05	±0.20
25.5	24.9	24.9	25.5	24.9	25.0	0.00	0.00	0.03	±0.20
34.1	33.3	33.3	34.2	33.5	33.5	0.03	0.05	0.05	±0.20
46.0	45.0	45.0	46.2	45.2	45.2	0.04	0.04	0.04	±0.20
62.5	61.0	61.0	62.7	61.3	61.3	0.03	0.04	0.04	±0.20
85.8	83.8	83.9	85.5	83.5	83.5	−0.03	−0.03	−0.04	±0.20
112	110	110	112	109	109	0.00	−0.08	−0.08	±0.20
154	151	151	154	150	150	0.00	−0.06	−0.06	±0.20
214	209	209	214	209	208	0.00	0.00	−0.04	±0.20
296	290	289	298	284	284	0.06	−0.18	−0.15	±0.20
438	427	426	432	421	421	−0.12	−0.12	−0.10	±0.20
603	588	587	600	584	583	−0.04	−0.06	−0.06	±0.20
901	877	874	905	879	878	0.04	0.02	0.04	±0.20
1360	1330	1320	1390	1350	1340	0.19	0.13	0.13	±0.30
1860	1800	1790	1910	1850	1850	0.23	0.24	0.29	±0.30
3050	2960	2940	3170	3070	3060	0.34	0.32	0.35	±0.50
3720	3600	3570	3880	3750	3730	0.37	0.35	0.38	±0.50

SPEAG H-field linearity tolerance criteria[1]:
- ±1.0 dB for applied H-fields < 2.0 A/m
- ±0.2 dB for applied H-fields ≥ 2.0 A/m and < 1000 A/m
- ±0.3 dB for applied H-fields ≥ 1000 A/m and < 2000 A/m
- ±0.4 dB for applied H-fields ≥ 2000 A/m and < 3000 A/m
- ±0.5 dB for applied H-fields ≥ 3000 A/m

[1] Calibration uncertainty not taken into account (shared risk 50%).

Dynamic Range, H-field, Channel 2

H-field/(A/m) Applied			H-field/(A/m) Reading			Difference/(dB)			
x	y	z	x	y	z	x	y	z	Tolerance/(dB)
0.380	0.380	0.380	0.400	0.400	0.400	0.45	0.45	0.45	±1.00
0.520	0.510	0.520	0.530	0.530	0.550	0.17	0.33	0.49	±1.00
0.710	0.710	0.710	0.690	0.710	0.730	−0.25	0.00	0.24	±1.00
0.930	0.920	0.930	0.920	0.910	0.930	−0.09	−0.09	0.00	±1.00
1.26	1.25	1.26	1.26	1.24	1.26	0.00	−0.07	0.00	±1.00
1.72	1.71	1.72	1.72	1.72	1.74	0.00	0.05	0.10	±1.00
2.30	2.29	2.30	2.30	2.27	2.31	0.00	−0.08	0.04	±0.20
3.07	3.05	3.07	3.08	3.04	3.08	0.03	−0.03	0.03	±0.20
4.16	4.14	4.17	4.19	4.16	4.18	0.06	0.04	0.02	±0.20
5.64	5.61	5.63	5.64	5.61	5.67	0.00	0.00	0.06	±0.20
7.57	7.54	7.58	7.58	7.55	7.62	0.01	0.01	0.05	±0.20
10.1	10.1	10.1	10.1	10.1	10.2	0.00	0.00	0.09	±0.20
13.7	13.6	13.7	13.7	13.6	13.7	0.00	0.00	0.00	±0.20
18.4	18.3	18.4	18.4	18.4	18.4	0.00	0.05	0.00	±0.20
24.9	24.8	24.9	24.9	24.8	24.9	0.00	0.00	0.00	±0.20
33.3	33.1	33.2	33.4	33.2	33.4	0.03	0.03	0.05	±0.20
44.9	44.7	44.9	45.2	45.0	45.1	0.06	0.06	0.04	±0.20
61.0	60.7	61.0	61.2	60.9	61.3	0.03	0.03	0.04	±0.20
83.8	83.4	83.8	83.5	83.1	83.4	−0.03	−0.03	−0.04	±0.20
110	109	110	109	109	109	−0.08	0.00	−0.08	±0.20
151	150	151	150	149	150	−0.06	−0.06	−0.06	±0.20
209	208	209	209	207	208	0.00	−0.04	−0.04	±0.20
290	288	289	291	283	283	0.03	−0.15	−0.18	±0.20
428	425	426	422	419	420	−0.12	−0.12	−0.12	±0.20
589	585	586	586	582	583	−0.04	−0.04	−0.04	±0.20
880	873	873	884	876	877	0.04	0.03	0.04	±0.20
1330	1320	1320	1350	1340	1340	0.13	0.13	0.13	±0.30
1810	1790	1790	1860	1840	1840	0.24	0.24	0.24	±0.30
2980	2950	2940	3100	3060	3050	0.34	0.32	0.32	±0.40
3630	3580	3570	3790	3740	3720	0.37	0.38	0.36	±0.50

SPEAG H-field linearity tolerance criteria[1]:
±1.0dB for applied H-fields < 2.0 A/m
±0.2dB for applied H-fields ≥ 2.0 A/m and < 1000 A/m
±0.3dB for applied H-fields ≥ 1000 A/m and < 2000 A/m
±0.4dB for applied H-fields ≥ 2000 A/m and < 3000 A/m
±0.5dB for applied H-fields ≥ 3000 A/m

[1] Calibration uncertainty not taken into account (shared risk 50%).

Dynamic Range, H-field, Channel 3

H-field/(A/m) Applied			H-field/(A/m) Reading			Difference/(dB)			
x	y	z	x	y	z	x	y	z	Tolerance/(dB)
0.380	0.380	0.380	0.420	0.400	0.350	0.87	0.45	−0.71	±1.00
0.520	0.510	0.510	0.550	0.540	0.500	0.49	0.50	−0.17	±1.00
0.710	0.710	0.710	0.730	0.720	0.700	0.24	0.12	−0.12	±1.00
0.930	0.920	0.920	0.950	0.920	0.930	0.18	0.00	0.09	±1.00
1.26	1.25	1.25	1.29	1.25	1.25	0.20	0.00	0.00	±1.00
1.72	1.71	1.71	1.75	1.73	1.70	0.15	0.10	−0.05	±1.00
2.30	2.28	2.28	2.31	2.29	2.28	0.04	0.04	0.00	±0.20
3.07	3.05	3.05	3.08	3.06	3.04	0.03	0.03	−0.03	±0.20
4.16	4.13	4.14	4.17	4.14	4.14	0.02	0.02	0.00	±0.20
5.64	5.60	5.60	5.65	5.61	5.60	0.02	0.02	0.00	±0.20
7.57	7.52	7.53	7.58	7.55	7.53	0.01	0.03	0.00	±0.20
10.1	10.0	10.0	10.1	10.1	10.1	0.00	0.09	0.09	±0.20
13.7	13.6	13.6	13.7	13.6	13.6	0.00	0.00	0.00	±0.20
18.4	18.3	18.3	18.4	18.3	18.4	0.00	0.00	0.05	±0.20
24.9	24.7	24.7	24.9	24.8	24.8	0.00	0.04	0.04	±0.20
33.3	33.0	33.0	33.4	33.2	33.2	0.03	0.05	0.05	±0.20
44.9	44.6	44.6	45.2	44.9	44.8	0.06	0.06	0.04	±0.20
61.0	60.6	60.6	61.2	60.8	60.9	0.03	0.03	0.04	±0.20
83.8	83.2	83.2	83.5	82.9	82.9	−0.03	−0.03	−0.03	±0.20
110	109	109	109	109	108	−0.08	0.00	−0.08	±0.20
151	150	150	150	149	149	−0.06	−0.06	−0.06	±0.20
209	207	207	209	207	207	0.00	0.00	0.00	±0.20
290	287	287	291	282	282	0.03	−0.15	−0.15	±0.20
427	424	423	422	418	417	−0.10	−0.12	−0.12	±0.20
589	584	582	586	580	579	−0.04	−0.06	−0.04	±0.20
880	871	867	883	873	871	0.03	0.02	0.04	±0.20
1330	1320	1310	1350	1340	1330	0.13	0.13	0.13	±0.30
1810	1790	1780	1860	1840	1830	0.24	0.24	0.24	±0.30
2980	2940	2920	3100	3030	3030	0.34	0.26	0.32	±0.40
3630	3570	3540	3790	3690	3700	0.37	0.29	0.38	±0.50

SPEAG H-field linearity tolerance criteria[1]:

- ±1.0 dB for applied H-fields < 2.0 A/m
- ±0.2 dB for applied H-fields ≥ 2.0 A/m and < 1000 A/m
- ±0.3 dB for applied H-fields ≥ 1000 A/m and < 2000 A/m
- ±0.4 dB for applied H-fields ≥ 2000 A/m and < 3000 A/m
- ±0.5 dB for applied H-fields ≥ 3000 A/m

[1] Calibration uncertainty not taken into account (shared risk 50%).