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**
Swiss Calibration Service

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Accreditation No.: SCS 0108

Client **UL CCS USA**

Certificate No: EX3-7356_Apr15

CALIBRATION CERTIFICATE

Object	EX3DV4 - SN:7356
Calibration procedure(s)	QA CAL-01.v9, QA CAL-12.v9, QA CAL-14.v4, QA CAL-23.v5, QA CAL-25.v6 Calibration procedure for dosimetric E-field probes
Calibration date:	April 22, 2015

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
Power meter E4419B	GB41293874	01-Apr-15 (No. 217-02128)	Mar-16
Power sensor E4412A	MY41498087	01-Apr-15 (No. 217-02128)	Mar-16
Reference 3 dB Attenuator	SN: S5054 (3c)	01-Apr-15 (No. 217-02129)	Mar-16
Reference 20 dB Attenuator	SN: S5277 (20x)	01-Apr-15 (No. 217-02132)	Mar-16
Reference 30 dB Attenuator	SN: S5129 (30b)	01-Apr-15 (No. 217-02133)	Mar-16
Reference Probe ES3DV2	SN: 3013	30-Dec-14 (No. ES3-3013_Dec14)	Dec-15
DAE4	SN: 660	14-Jan-15 (No. DAE4-660_Jan15)	Jan-16
Secondary Standards	ID	Check Date (in house)	Scheduled Check
RF generator HP 8648C	US3642U01700	4-Aug-99 (in house check Apr-13)	In house check: Apr-16
Network Analyzer HP 8753E	US37390585	18-Oct-01 (in house check Oct-14)	In house check: Oct-15

	Name	Function	Signature
Calibrated by:	Israe Elnaouq	Laboratory Technician	
Approved by:	Katja Pokovic	Technical Manager	

Issued: April 23, 2015

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Glossary:

TSL	tissue simulating liquid
NORMx,y,z	sensitivity in free space
ConvF	sensitivity in TSL / NORMx,y,z
DCP	diode compression point
CF	crest factor (1/duty_cycle) of the RF signal
A, B, C, D	modulation dependent linearization parameters
Polarization φ	φ rotation around probe axis
Polarization ϑ	ϑ rotation around an axis that is in the plane normal to probe axis (at measurement center), i.e., ϑ = 0 is normal to probe axis
Connector Angle	information used in DASY system to align probe sensor X to the robot coordinate system

Calibration is Performed According to the Following Standards:

a) 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
b) IEC 62209-1, "Procedure to measure the Specific Absorption Rate (SAR) for hand-held devices used in close proximity to the ear (frequency range of 300 MHz to 3 GHz)", February 2005

Methods Applied and Interpretation of Parameters:

- *NORMx,y,z:* Assessed for E-field polarization ϑ = 0 (f ≤ 900 MHz in TEM-cell; f > 1800 MHz: R22 waveguide). NORMx,y,z are only intermediate values, i.e., the uncertainties of NORMx,y,z does not affect the E^2-field uncertainty inside TSL (see below *ConvF*).
- *NORM(f)x,y,z = NORMx,y,z * frequency_response* (see Frequency Response Chart). This linearization is implemented in DASY4 software versions later than 4.2. The uncertainty of the frequency response is included in the stated uncertainty of *ConvF*.
- *DCPx,y,z:* DCP are numerical linearization parameters assessed based on the data of power sweep with CW signal (no uncertainty required). DCP does not depend on frequency nor media.
- *PAR:* PAR is the Peak to Average Ratio that is not calibrated but determined based on the signal characteristics
- *Ax,y,z; Bx,y,z; Cx,y,z; Dx,y,z; VRx,y,z*: *A, B, C, D* are numerical linearization parameters assessed based on the data of power sweep for specific modulation signal. The parameters do not depend on frequency nor media. *VR* is the maximum calibration range expressed in RMS voltage across the diode.
- *ConvF and Boundary Effect Parameters:* Assessed in flat phantom using E-field (or Temperature Transfer Standard for f ≤ 800 MHz) and inside waveguide using analytical field distributions based on power measurements for f > 800 MHz. The same setups are used for assessment of the parameters applied for boundary compensation (alpha, depth) of which typical uncertainty values are given. These parameters are used in DASY4 software to improve probe accuracy close to the boundary. The sensitivity in TSL corresponds to *NORMx,y,z * ConvF* whereby the uncertainty corresponds to that given for *ConvF*. A frequency dependent *ConvF* is used in DASY version 4.4 and higher which allows extending the validity from ± 50 MHz to ± 100 MHz.
- *Spherical isotropy (3D deviation from isotropy)*: in a field of low gradients realized using a flat phantom exposed by a patch antenna.
- *Sensor Offset*: The sensor offset corresponds to the offset of virtual measurement center from the probe tip (on probe axis). No tolerance required.
- *Connector Angle*: The angle is assessed using the information gained by determining the *NORMx* (no uncertainty required).

Probe EX3DV4

SN:7356

Manufactured: February 5, 2015
Calibrated: April 22, 2015

Calibrated for DASY/EASY Systems
(Note: non-compatible with DASY2 system!)

DASY/EASY - Parameters of Probe: EX3DV4 - SN:7356

Basic Calibration Parameters

	Sensor X	Sensor Y	Sensor Z	Unc (k=2)
Norm ($\mu V/(V/m)^2$)[A]	0.37	0.55	0.58	± 10.1 %
DCP (mV)[B]	98.7	98.6	97.8	

Modulation Calibration Parameters

UID	Communication System Name		A dB	B dB$\sqrt{\mu V}$	C	D dB	VR mV	Unc[E] (k=2)
0	CW	X	0.0	0.0	1.0	0.00	138.6	±3.0 %
		Y	0.0	0.0	1.0		142.4	
		Z	0.0	0.0	1.0		154.0	

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%.

[A] The uncertainties of NormX,Y,Z do not affect the E^2-field uncertainty inside TSL (see Pages 5 and 6).
[B] Numerical linearization parameter: uncertainty not required.
[E] Uncertainty is determined using the max. deviation from linear response applying rectangular distribution and is expressed for the square of the field value.

DASY/EASY - Parameters of Probe: EX3DV4 - SN:7356

Calibration Parameter Determined in Head Tissue Simulating Media

f (MHz) [C]	Relative Permittivity [F]	Conductivity (S/m) [F]	ConvF X	ConvF Y	ConvF Z	Alpha [G]	Depth [G] (mm)	Unct. (k=2)
450	43.5	0.87	11.11	11.11	11.11	0.15	1.20	± 13.3 %
750	41.9	0.89	10.78	10.78	10.78	0.24	1.34	± 12.0 %
900	41.5	0.97	9.96	9.96	9.96	0.21	1.60	± 12.0 %
1450	40.5	1.20	9.30	9.30	9.30	0.22	1.27	± 12.0 %
1750	40.1	1.37	8.87	8.87	8.87	0.38	0.80	± 12.0 %
1900	40.0	1.40	8.61	8.61	8.61	0.27	0.80	± 12.0 %
2300	39.5	1.67	8.23	8.23	8.23	0.34	0.80	± 12.0 %
2450	39.2	1.80	7.89	7.89	7.89	0.25	0.89	± 12.0 %
2600	39.0	1.96	7.67	7.67	7.67	0.27	0.88	± 12.0 %
3500	37.9	2.91	7.36	7.36	7.36	0.38	1.05	± 13.1 %
3700	37.7	3.12	7.19	7.19	7.19	0.39	1.01	± 13.1 %
4950	36.3	4.40	6.32	6.32	6.32	0.30	1.80	± 13.1 %
5250	35.9	4.71	5.55	5.55	5.55	0.30	1.80	± 13.1 %
5600	35.5	5.07	5.15	5.15	5.15	0.35	1.80	± 13.1 %
5750	35.4	5.22	5.26	5.26	5.26	0.40	1.80	± 13.1 %

[C] Frequency validity above 300 MHz of ± 100 MHz only applies for DASY v4.4 and higher (see Page 2), else it is restricted to ± 50 MHz. The uncertainty is the RSS of the ConvF uncertainty at calibration frequency and the uncertainty for the indicated frequency band. Frequency validity below 300 MHz is ± 10, 25, 40, 50 and 70 MHz for ConvF assessments at 30, 64, 128, 150 and 220 MHz respectively. Above 5 GHz frequency validity can be extended to ± 110 MHz.
[F] At frequencies below 3 GHz, the validity of tissue parameters (ε and σ) can be relaxed to ± 10% if liquid compensation formula is applied to measured SAR values. At frequencies above 3 GHz, the validity of tissue parameters (ε and σ) is restricted to ± 5%. The uncertainty is the RSS of the ConvF uncertainty for indicated target tissue parameters.
[G] Alpha/Depth are determined during calibration. SPEAG warrants that the remaining deviation due to the boundary effect after compensation is always less than ± 1% for frequencies below 3 GHz and below ± 2% for frequencies between 3-6 GHz at any distance larger than half the probe tip diameter from the boundary.

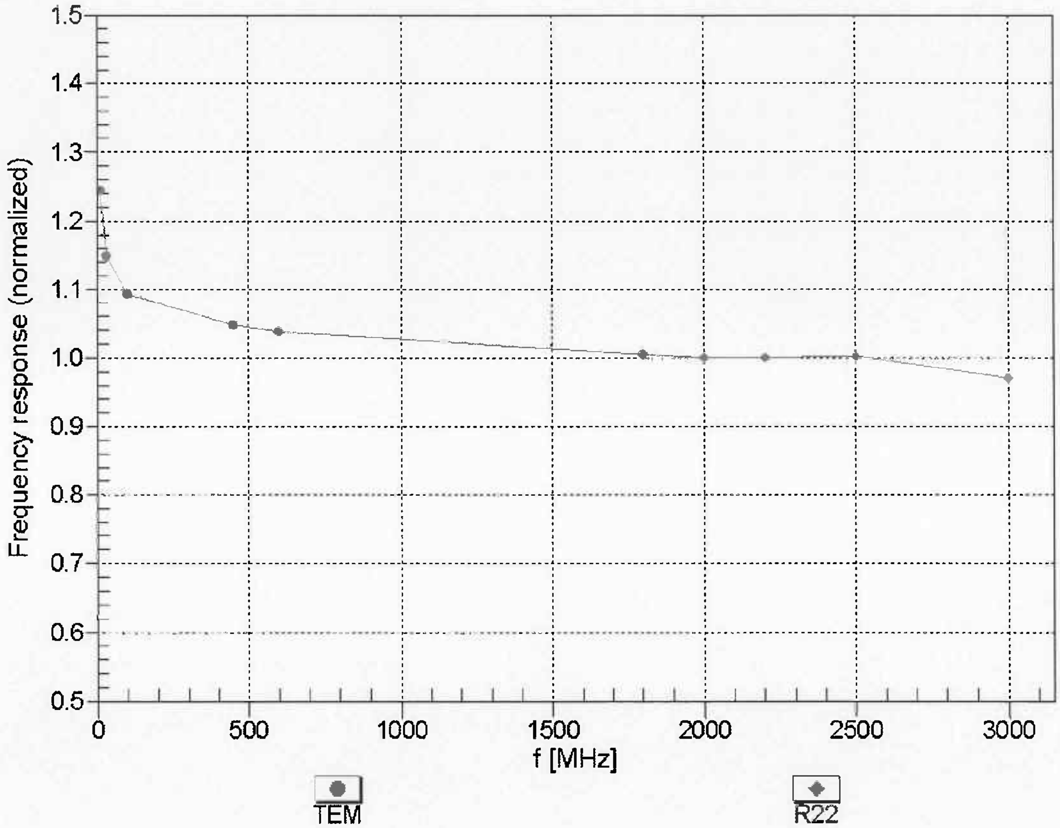
DASY/EASY - Parameters of Probe: EX3DV4 - SN:7356

Calibration Parameter Determined in Body Tissue Simulating Media

f (MHz) [C]	Relative Permittivity [F]	Conductivity (S/m) [F]	ConvF X	ConvF Y	ConvF Z	Alpha [G]	Depth [G] (mm)	Unct. (k=2)
450	56.7	0.94	11.41	11.41	11.41	0.10	1.15	± 13.3 %
750	55.5	0.96	10.31	10.31	10.31	0.19	1.51	± 12.0 %
900	55.0	1.05	9.97	9.97	9.97	0.42	0.86	± 12.0 %
1450	54.0	1.30	8.78	8.78	8.78	0.22	1.54	± 12.0 %
1750	53.4	1.49	8.47	8.47	8.47	0.42	0.81	± 12.0 %
1900	53.3	1.52	7.94	7.94	7.94	0.24	1.06	± 12.0 %
2300	52.9	1.81	7.83	7.83	7.83	0.31	0.80	± 12.0 %
2450	52.7	1.95	7.54	7.54	7.54	0.29	0.94	± 12.0 %
2600	52.5	2.16	7.27	7.27	7.27	0.30	0.99	± 12.0 %
3500	51.3	3.31	6.79	6.79	6.79	0.30	1.30	± 13.1 %
3700	51.0	3.55	6.81	6.81	6.81	0.32	1.37	± 13.1 %
4950	49.4	5.01	5.19	5.19	5.19	0.50	1.90	± 13.1 %
5250	48.9	5.36	4.89	4.89	4.89	0.50	1.90	± 13.1 %
5600	48.5	5.77	4.17	4.17	4.17	0.55	1.90	± 13.1 %
5750	48.3	5.94	4.52	4.52	4.52	0.55	1.90	± 13.1 %

[C] Frequency validity above 300 MHz of ± 100 MHz only applies for DASY v4.4 and higher (see Page 2), else it is restricted to ± 50 MHz. The uncertainty is the RSS of the ConvF uncertainty at calibration frequency and the uncertainty for the indicated frequency band. Frequency validity below 300 MHz is ± 10, 25, 40, 50 and 70 MHz for ConvF assessments at 30, 64, 128, 150 and 220 MHz respectively. Above 5 GHz frequency validity can be extended to ± 110 MHz.
[F] At frequencies below 3 GHz, the validity of tissue parameters (ε and σ) can be relaxed to ± 10% if liquid compensation formula is applied to measured SAR values. At frequencies above 3 GHz, the validity of tissue parameters (ε and σ) is restricted to ± 5%. The uncertainty is the RSS of the ConvF uncertainty for indicated target tissue parameters.
[G] Alpha/Depth are determined during calibration. SPEAG warrants that the remaining deviation due to the boundary effect after compensation is always less than ± 1% for frequencies below 3 GHz and below ± 2% for frequencies between 3-6 GHz at any distance larger than half the probe tip diameter from the boundary.

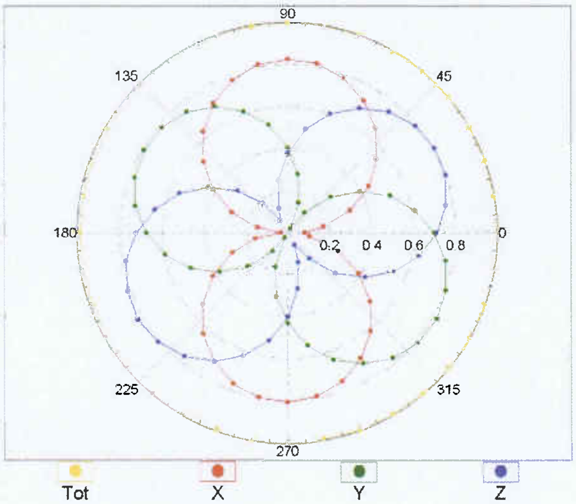
Frequency Response of E-Field
(TEM-Cell:ifi110 EXX, Waveguide: R22)



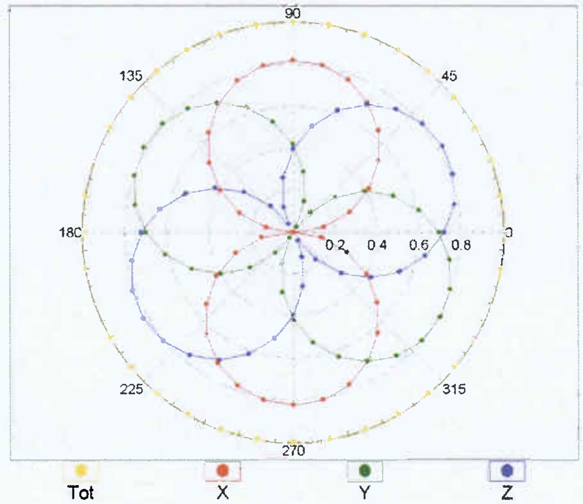
Uncertainty of Frequency Response of E-field: ± 6.3% (k=2)

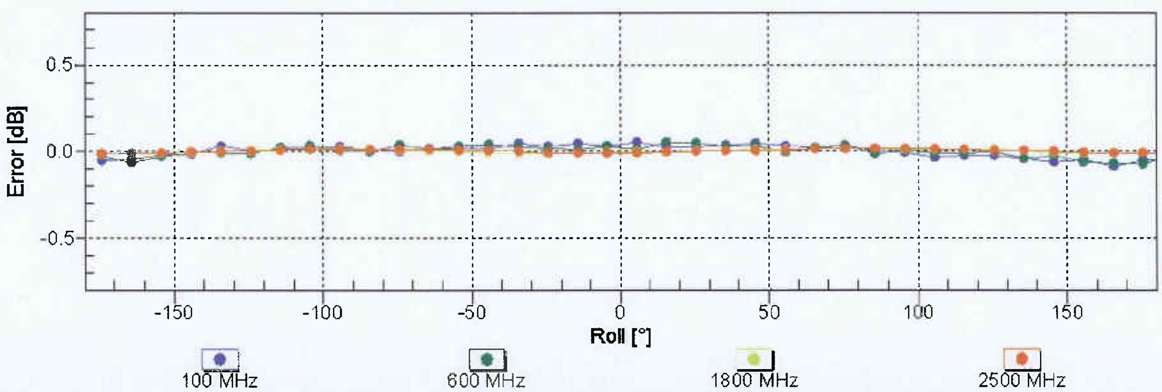
Receiving Pattern (ϕ), ϑ = 0°

f=600 MHz,TEM



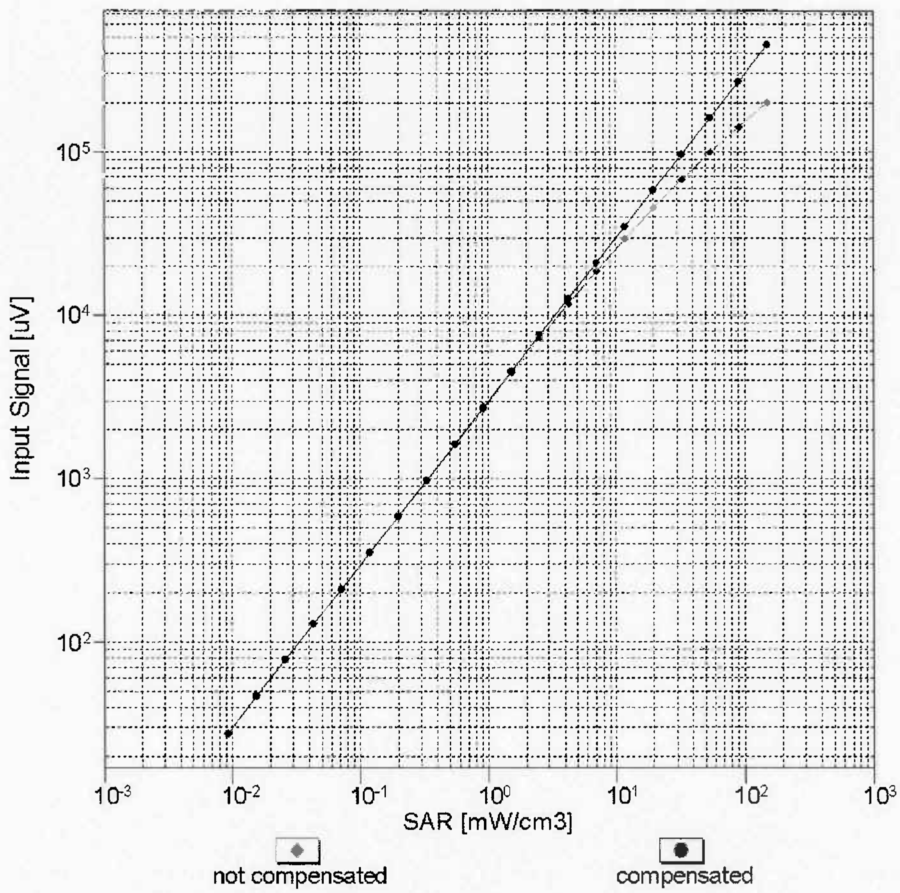
f=1800 MHz,R22

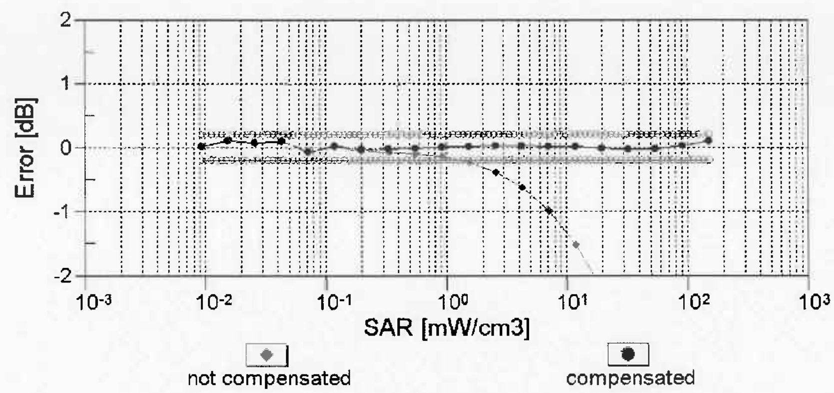




Uncertainty of Axial Isotropy Assessment: ± 0.5% (k=2)

Dynamic Range f(SAR_{head})
(TEM cell , f_{eval}= 1900 MHz)

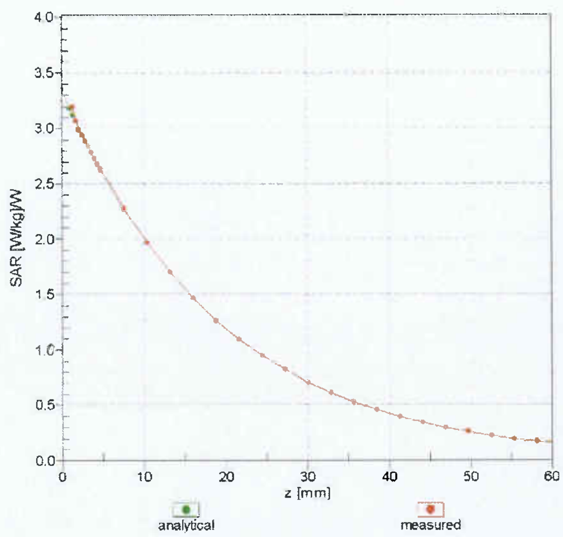




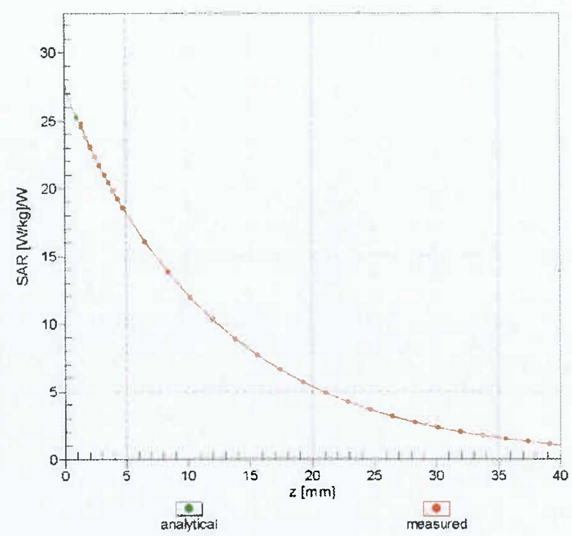
Uncertainty of Linearity Assessment: ± 0.6% (k=2)

Conversion Factor Assessment

f = 900 MHz,WGLS R9 (H_convF)

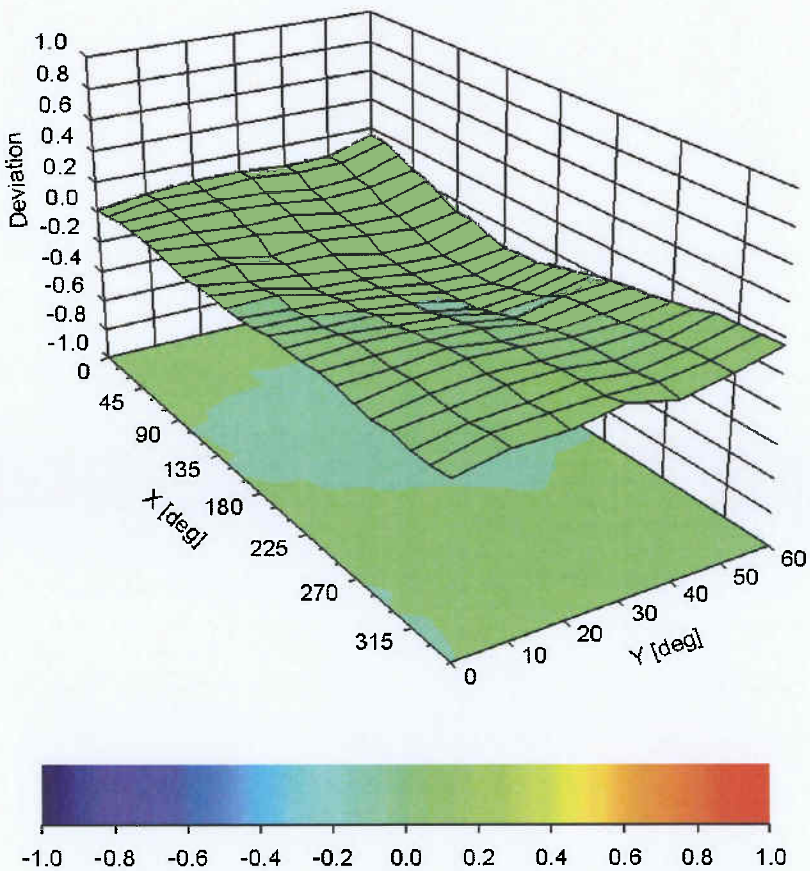


f = 1900 MHz,WGLS R22 (H_convF)



Deviation from Isotropy in Liquid

Error (ϕ, ϑ), f = 900 MHz



Uncertainty of Spherical Isotropy Assessment: ± 2.6% (k=2)

DASY/EASY - Parameters of Probe: EX3DV4 - SN:7356

Other Probe Parameters

Sensor Arrangement	Triangular
Connector Angle (°)	-4.3
Mechanical Surface Detection Mode	enabled
Optical Surface Detection Mode	disabled
Probe Overall Length	337 mm
Probe Body Diameter	10 mm
Tip Length	9 mm
Tip Diameter	2.5 mm
Probe Tip to Sensor X Calibration Point	1 mm
Probe Tip to Sensor Y Calibration Point	1 mm
Probe Tip to Sensor Z Calibration Point	1 mm
Recommended Measurement Distance from Surface	1.4 mm

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PHANTOM MATERIAL COMPATIBILTIY WITH SPEAG LIQUIDS

INTRODUCTION

SPEAG offers a wide range of tissue simulating liquids. These liquids are based on various ingredients depending on their frequency range. The below table shows compatibility of these tissue simulating liquids and various phantom materials.

COMPATIBILITY TABLE

Y= **fully compatible** with the tissue simulating liquid. Long time exposure is not critical.

P= **partially compatible**. It is essential to keep the exposure time to a minimum and to rinse and clean the item after exposure to the respective tissue simulating liquid. Liquids can have a softening effect on the material. Fiber reinforced material may reduce this effect. Continuous exposure will reduce the item life-time considerably.

R= **restricted** compatibility with the respective tissue simulating liquid. Liquids can enter and damage the material structure. Short time exposure (e.g. few hours) is possible given that the item is thoroughly rinsed and dried after each exposure.

N= **not compatible** with the respective tissue simulating liquid. Short time exposure can cause irreparable damage to the item exposed.

SPEAG MSDS	772-SLAAx0yy			772-SLAAx1yy		772-SLAAx4yy		772-SLAAx6yy		772-SLAAx6yy	
Phantom Material \ Liquid Type	B 900	HSL175V2 to HSL900V2	MSL300V2 to MSL900V2	HSL1450V2 to HSL2450V2	MSL1450V2 to MSL2450V2	HBBL3500-5800V5	MBBL3500-5800V5	HBBL1350-1850V3 to HBBL1900-3800V3	MBBL1350-1850V3 to MBBL1900-3800V3	HBBL30-250V3	MBBL125-250V3
PEEK	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
POM	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
PTFE	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Glass	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Phenol resin plates	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Silicone *	Y	Y	Y	Y*	Y*	Y	Y	Y	Y	Y	Y
Acrylic resin *	Y	Y	Y	Y*	Y*	Y	Y	Y	Y	Y	Y
Polyethylene	Y	Y	Y	P	P	Y	Y	Y	Y	Y	Y
Vinylester, glass fiber (VE-GF)	Y	Y	Y	P	P	Y	Y	Y	Y	Y	Y
Polypropylene, glass fiber (PP-GF)	Y	Y	Y	P	P	Y	Y	Y	Y	Y	Y
Epoxy resin, glass fiber reinforced	Y	Y	Y	R	R	Y	Y	Y	Y	Y	Y
PMMA (Acrylic glass, Plexiglass) **	Y	Y	Y	N	N	Y	Y	Y	Y	Y	Y

NOTES:
* Liquids may cause damage by entering adhesive joints or bonding surfaces.
** Damage of material macro structure possible.