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

ilac-MRA

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Accreditation No.: **SCS 108**

Client   **Motorola EME**

Certificate No: **ES3-3163_Apr13**

CALIBRATION CERTIFICATE

Object	ES3DV3 - SN:3163
Calibration procedure(s)	QA CAL-01.v8, QA CAL-12.v7, QA CAL-14.v3, QA CAL-23.v4, QA CAL-25.v4 Calibration procedure for dosimetric E-field probes
Calibration date:	April 26, 2013

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	04-Apr-13 (No. 217-01733)	Apr-14
Power sensor E4412A	MY41498087	04-Apr-13 (No. 217-01733)	Apr-14
Reference 3 dB Attenuator	SN: S5054 (3c)	04-Apr-13 (No. 217-01737)	Apr-14
Reference 20 dB Attenuator	SN: S5277 (20x)	04-Apr-13 (No. 217-01735)	Apr-14
Reference 30 dB Attenuator	SN: S5129 (30b)	04-Apr-13 (No. 217-01738)	Apr-14
Reference Probe ES3DV2	SN: 3013	28-Dec-12 (No. ES3-3013_Dec12)	Dec-13
DAE4	SN: 660	31-Jan-13 (No. DAE4-660_Jan13)	Jan-14
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-15
Network Analyzer HP 8753E	US37390585	18-Oct-01 (in house check Oct-12)	In house check: Oct-13

	Name	Function	Signature
Calibrated by:	Claudio Leubler	Laboratory Technician	
Approved by:	Katja Pokovic	Technical Manager	

Issued: April 27, 2013

This calibration certificate shall not be reproduced except in full without written approval of the laboratory.

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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

Calibration is Performed According to the Following Standards:

a) IEEE Std 1528-2003, "IEEE Recommended Practice for Determining the Peak Spatial-Averaged Specific Absorption Rate (SAR) in the Human Head from Wireless Communications Devices: Measurement Techniques", December 2003

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.

Probe ES3DV3

SN:3163

Manufactured: October 8, 2007
Calibrated: April 26, 2013

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

DASY/EASY - Parameters of Probe: ES3DV3 - SN:3163

Basic Calibration Parameters

	Sensor X	Sensor Y	Sensor Z	Unc (k=2)
Norm $(\mu V/(V/m)^2)^A$	1.32	1.13	1.04	± 10.1 %
DCP $(mV)^B$	100.5	100.6	103.7	

Modulation Calibration Parameters

UID	Communication System Name		A dB	B dB√µV	C	D dB	VR mV	Unc^E (k=2)
0	CW	X	0.0	0.0	1.0	0.00	157.2	±3.3 %
		Y	0.0	0.0	1.0		150.2	
		Z	0.0	0.0	1.0		133.8	
10108-CAA	LTE-FDD (SC-FDMA, 100% RB, 10 MHz, QPSK)	X	6.38	67.2	19.7	5.80	141.0	±1.4 %
		Y	6.27	66.7	19.3		132.1	
		Z	6.11	66.5	19.3		114.8	
10109-CAA	LTE-FDD (SC-FDMA, 100% RB, 10 MHz, 16-QAM)	X	6.80	65.8	19.1	6.43	104.1	±1.4 %
		Y	7.28	67.3	19.8		140.6	
		Z	7.08	67.2	19.9		122.4	
10110-CAA	LTE-FDD (SC-FDMA, 100% RB, 5 MHz, QPSK)	X	6.07	66.8	19.5	5.75	137.4	±1.2 %
		Y	5.93	66.1	19.0		123.8	
		Z	5.79	66.0	19.1		113.2	
10111-CAA	LTE-FDD (SC-FDMA, 100% RB, 5 MHz, 16-QAM)	X	7.15	67.6	20.2	6.44	145.2	±1.4 %
		Y	7.01	67.1	19.8		130.7	
		Z	6.85	67.1	19.9		119.6	
10112-CAA	LTE-FDD (SC-FDMA, 100% RB, 10 MHz, 64-QAM)	X	7.08	66.2	19.4	6.59	105.4	±1.4 %
		Y	7.49	67.5	20.0		136.0	
		Z	7.33	67.4	20.1		124.7	
10113-CAA	LTE-FDD (SC-FDMA, 100% RB, 5 MHz, 64-QAM)	X	7.40	67.9	20.4	6.62	147.4	±1.4 %
		Y	7.21	67.2	19.9		131.6	
		Z	7.07	67.2	20.1		121.4	
10142-CAA	LTE-FDD (SC-FDMA, 100% RB, 3 MHz, QPSK)	X	5.92	66.6	19.5	5.73	135.0	±1.2 %
		Y	5.75	65.9	18.9		121.1	
		Z	5.64	66.0	19.1		113.1	
10143-CAA	LTE-FDD (SC-FDMA, 100% RB, 3 MHz, 16-QAM)	X	6.91	67.5	20.1	6.35	142.2	±1.2 %
		Y	6.72	66.9	19.6		127.4	
		Z	6.64	67.2	20.0		118.2	
10145-CAA	LTE-FDD (SC-FDMA, 100% RB, 1.4 MHz, QPSK)	X	5.66	66.3	19.3	5.76	131.2	±1.2 %
		Y	5.50	65.6	18.8		117.2	
		Z	5.43	66.0	19.2		109.8	
10146-CAA	LTE-FDD (SC-FDMA, 100% RB, 1.4 MHz, 16-QAM)	X	6.66	67.6	20.2	6.41	136.2	±1.2 %
		Y	6.41	66.8	19.6		120.3	
		Z	6.29	67.0	19.9		111.4	
10154-CAA	LTE-FDD (SC-FDMA, 50% RB, 10 MHz, QPSK)	X	6.14	67.1	19.8	5.76	134.0	±1.2 %
		Y	5.92	66.1	19.0		122.4	
		Z	5.84	66.2	19.2		114.4	

10155-CAA	LTE-FDD (SC-FDMA, 50% RB, 10 MHz, 16-QAM)	X	7.21	68.0	20.5	6.43	141.4	±1.2 %
		Y	6.96	67.0	19.7		129.8	
		Z	6.83	67.0	19.8		120.1	
10156-CAA	LTE-FDD (SC-FDMA, 50% RB, 5 MHz, QPSK)	X	5.90	66.7	19.6	5.79	129.1	±1.2 %
		Y	5.72	65.9	18.9		120.0	
		Z	5.60	65.9	19.1		111.2	
10157-CAA	LTE-FDD (SC-FDMA, 50% RB, 5 MHz, 16-QAM)	X	6.94	67.8	20.4	6.49	135.2	±1.4 %
		Y	6.72	66.9	19.7		125.2	
		Z	6.58	67.0	19.9		114.6	
10158-CAA	LTE-FDD (SC-FDMA, 50% RB, 10 MHz, 64-QAM)	X	7.47	68.2	20.7	6.62	141.7	±1.4 %
		Y	7.22	67.3	19.9		130.9	
		Z	7.09	67.3	20.1		120.9	
10159-CAA	LTE-FDD (SC-FDMA, 50% RB, 5 MHz, 64-QAM)	X	7.05	67.9	20.5	6.56	135.9	±1.2 %
		Y	6.83	67.0	19.8		125.7	
		Z	6.70	67.1	20.0		115.7	
10163-CAA	LTE-FDD (SC-FDMA, 50% RB, 3 MHz, QPSK)	X	5.75	66.6	19.5	5.68	127.4	±1.2 %
		Y	5.54	65.7	18.8		118.2	
		Z	5.44	65.9	19.0		109.9	
10164-CAA	LTE-FDD (SC-FDMA, 50% RB, 3 MHz, 16-QAM)	X	6.80	67.8	20.4	6.44	132.4	±1.2 %
		Y	6.56	66.9	19.7		122.8	
		Z	6.42	67.0	19.9		112.3	
10166-CAA	LTE-FDD (SC-FDMA, 50% RB, 1.4 MHz, QPSK)	X	5.09	66.1	19.2	5.46	121.1	±0.9 %
		Y	4.92	65.3	18.5		112.1	
		Z	5.23	67.4	19.9		146.0	
10167-CAA	LTE-FDD (SC-FDMA, 50% RB, 1.4 MHz, 16-QAM)	X	6.06	67.4	20.1	6.21	123.7	±0.9 %
		Y	5.79	66.4	19.4		112.6	
		Z	5.75	67.0	19.9		109.0	
10175-CAA	LTE-FDD (SC-FDMA, 1 RB, 10 MHz, QPSK)	X	4.96	66.4	19.6	5.73	115.5	±0.9 %
		Y	4.75	65.4	18.8		108.7	
		Z	5.06	67.6	20.2		142.2	
10176-CAA	LTE-FDD (SC-FDMA, 1 RB, 10 MHz, 16-QAM)	X	5.71	67.4	20.5	6.52	115.6	±1.4 %
		Y	5.97	68.6	20.9		149.6	
		Z	5.86	68.9	21.3		140.8	
10177-CAA	LTE-FDD (SC-FDMA, 1 RB, 5 MHz, QPSK)	X	4.92	66.1	19.4	5.73	115.7	±1.2 %
		Y	5.11	67.1	19.8		145.6	
		Z	5.09	67.7	20.3		141.9	
10178-CAA	LTE-FDD (SC-FDMA, 1 RB, 5 MHz, 16-QAM)	X	5.76	67.6	20.6	6.52	115.8	±1.4 %
		Y	5.94	68.5	20.9		147.2	
		Z	5.86	68.9	21.3		140.7	
10179-CAA	LTE-FDD (SC-FDMA, 1 RB, 10 MHz, 64-QAM)	X	5.69	67.4	20.4	6.50	115.8	±1.4 %
		Y	5.93	68.6	20.9		144.8	
		Z	5.87	69.1	21.4		140.2	
10180-CAA	LTE-FDD (SC-FDMA, 1 RB, 5 MHz, 64-QAM)	X	5.72	67.5	20.5	6.51	116.6	±1.4 %
		Y	5.91	68.4	20.8		144.2	
		Z	5.86	69.0	21.4		140.8	

10184-CAA	LTE-FDD (SC-FDMA, 1 RB, 3 MHz, QPSK)	X	5.02	66.6	19.7	5.73	116.5	±1.2 %
		Y	5.09	67.0	19.7		143.7	
		Z	5.09	67.7	20.3		141.5	
10185-CAA	LTE-FDD (SC-FDMA, 1 RB, 3 MHz, 16-QAM)	X	5.71	67.3	20.4	6.51	116.8	±1.4 %
		Y	5.90	68.4	20.8		143.9	
		Z	5.85	68.9	21.3		140.8	
10187-CAA	LTE-FDD (SC-FDMA, 1 RB, 1.4 MHz, QPSK)	X	4.95	66.2	19.5	5.73	116.9	±0.9 %
		Y	5.09	67.0	19.7		143.5	
		Z	5.05	67.5	20.2		142.4	
10188-CAA	LTE-FDD (SC-FDMA, 1 RB, 1.4 MHz, 16-QAM)	X	5.75	67.5	20.5	6.52	116.6	±1.4 %
		Y	5.91	68.3	20.8		144.3	
		Z	5.79	68.5	21.0		141.4	

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: ES3DV3 - SN:3163

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	Depth (mm)	Unct. (k=2)
300	45.3	0.87	7.15	7.15	7.15	0.25	1.08	± 13.4 %
450	43.5	0.87	6.62	6.62	6.62	0.16	1.89	± 13.4 %
750	41.9	0.89	6.47	6.47	6.47	0.41	1.54	± 12.0 %
900	41.5	0.97	6.13	6.13	6.13	0.69	1.18	± 12.0 %
1810	40.0	1.40	5.13	5.13	5.13	0.49	1.49	± 12.0 %
1950	40.0	1.40	4.95	4.95	4.95	0.80	1.20	± 12.0 %
2300	39.5	1.67	4.80	4.80	4.80	0.78	1.26	± 12.0 %
2450	39.2	1.80	4.49	4.49	4.49	0.70	1.35	± 12.0 %
2600	39.0	1.96	4.39	4.39	4.39	0.65	1.43	± 12.0 %
3500	37.9	2.91	4.30	4.30	4.30	0.80	1.02	± 13.1 %
3700	37.7	3.12	4.10	4.10	4.10	0.75	1.23	± 13.1 %

^{c} Frequency validity 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.

^{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.

DASY/EASY - Parameters of Probe: ES3DV3 - SN:3163

## 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	Depth (mm)	Unct. (k=2)
300	58.2	0.92	7.11	7.11	7.11	0.22	1.50	± 13.4 %
450	56.7	0.94	7.14	7.14	7.14	0.10	1.20	± 13.4 %
750	55.5	0.96	6.09	6.09	6.09	0.30	1.95	± 12.0 %
900	55.0	1.05	6.04	6.04	6.04	0.49	1.43	± 12.0 %
1810	53.3	1.52	4.77	4.77	4.77	0.52	1.60	± 12.0 %
1950	53.3	1.52	4.69	4.69	4.69	0.67	1.37	± 12.0 %
2300	52.9	1.81	4.31	4.31	4.31	0.80	1.23	± 12.0 %
2450	52.7	1.95	4.15	4.15	4.15	0.80	1.10	± 12.0 %
2600	52.5	2.16	3.99	3.99	3.99	0.80	0.98	± 12.0 %
3500	51.3	3.31	3.69	3.69	3.69	0.85	1.27	± 13.1 %
3700	51.0	3.55	3.46	3.46	3.46	0.80	1.49	± 13.1 %

[c] Frequency validity 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.
[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.
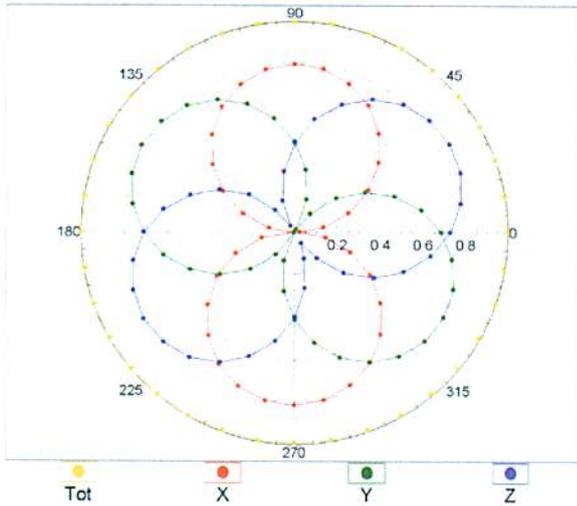
Frequency Response of E-Field
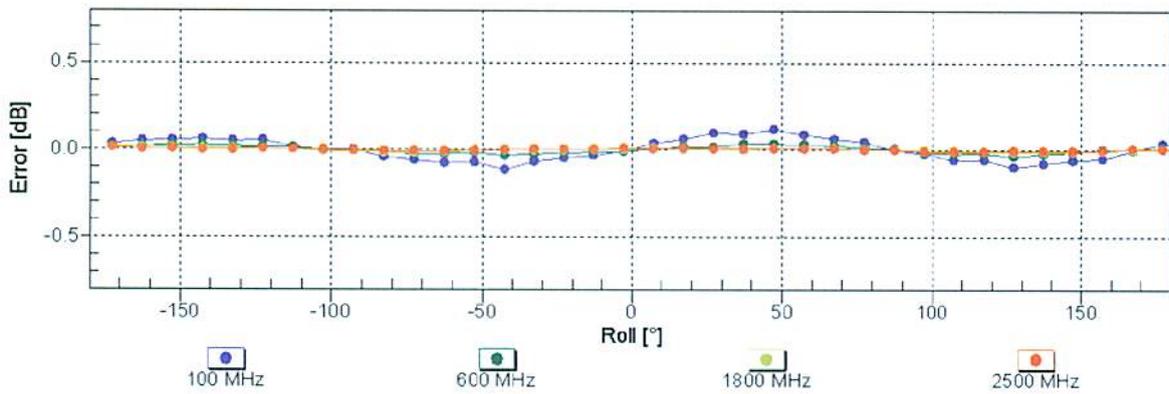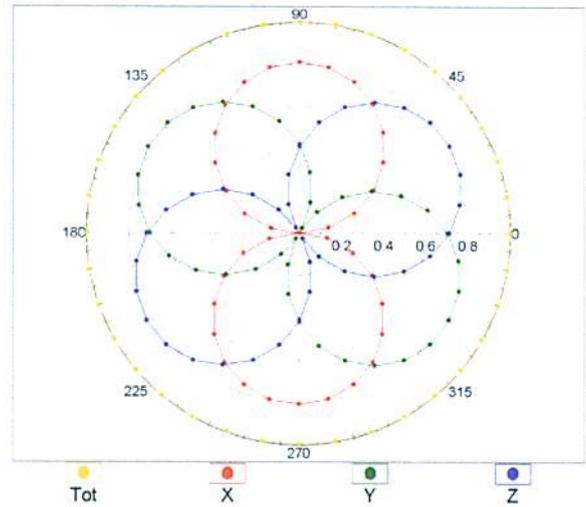## (TEM-Cell:ifi110 EXX, Waveguide: R22)
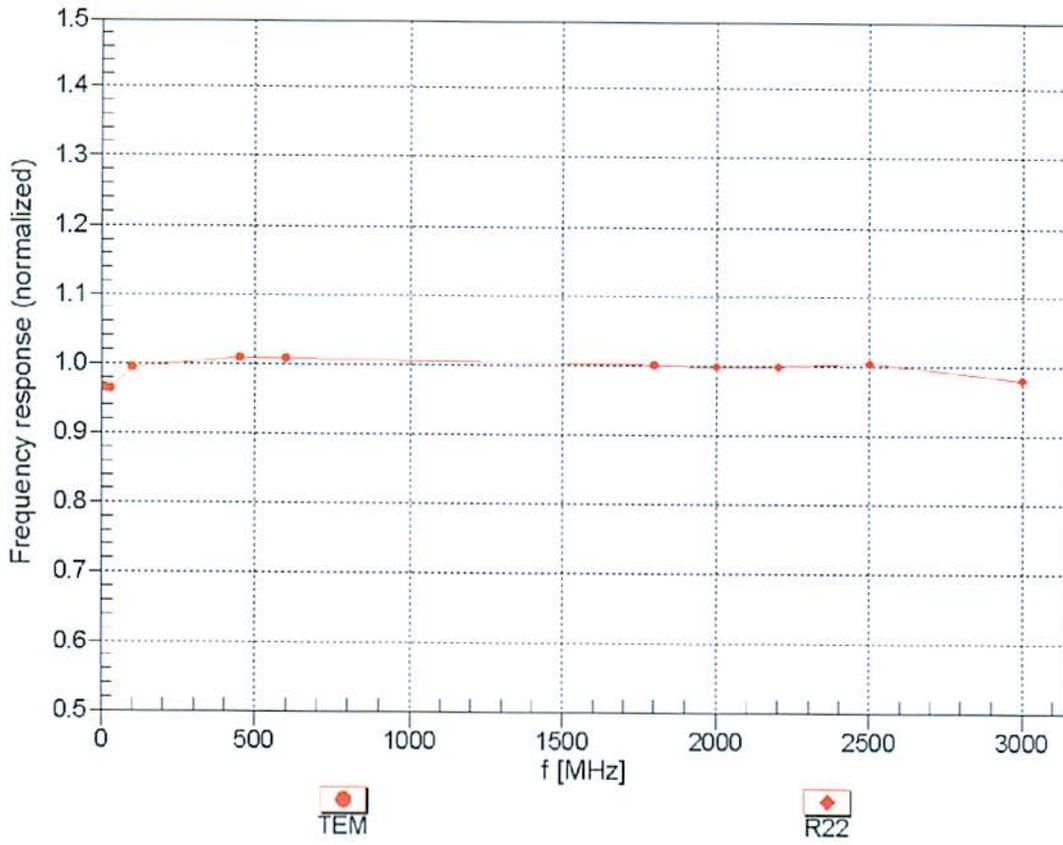
Uncertainty of Frequency Response of E-field: ± 6.3% (k=2)

Receiving Pattern (φ), θ = 0°

f=600 MHz,TEM

| Tot | X | Y | Z |

f=1800 MHz,R22
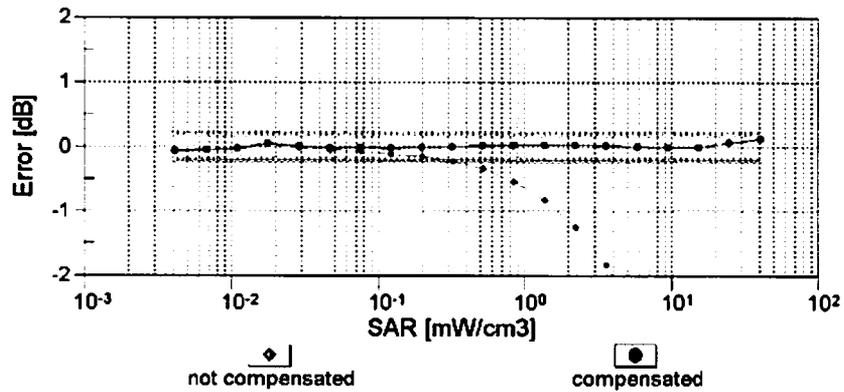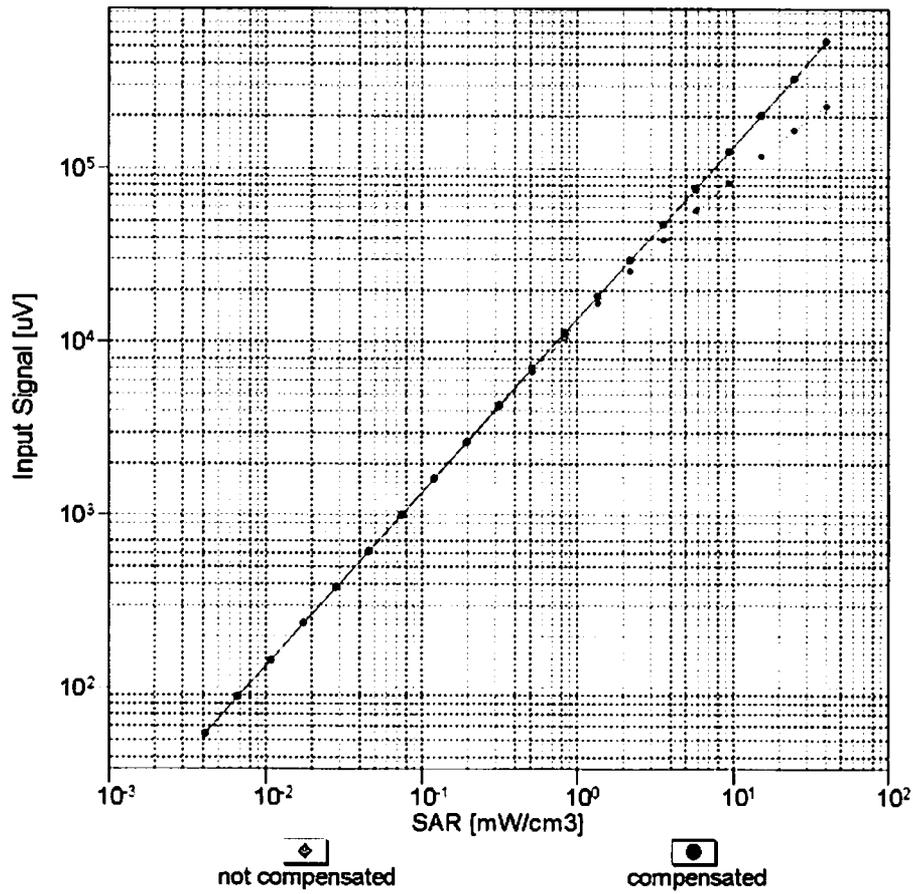

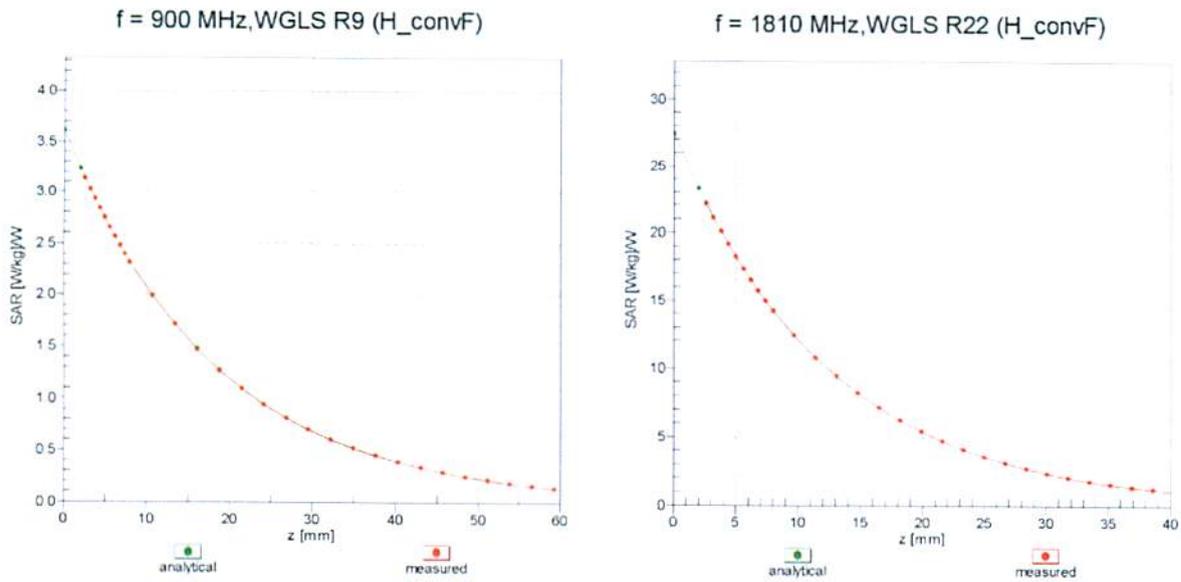| Tot | X | Y | Z |

| 100 MHz | 600 MHz | 1800 MHz | 2500 MHz |

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

Dynamic Range f(SAR$_{head}$)
(TEM cell , f = 900 MHz)

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

Conversion Factor Assessment

f = 900 MHz, WGLS R9 (H_convF)

f = 1810 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)
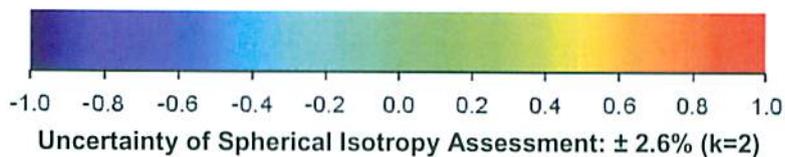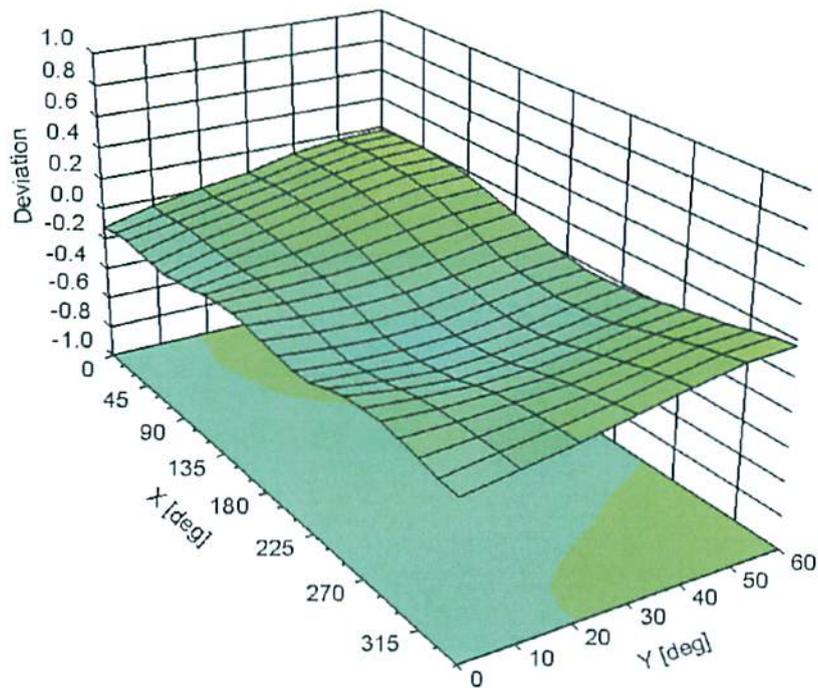
DASY/EASY - Parameters of Probe: ES3DV3 - SN:3163

Other Probe Parameters

Sensor Arrangement	Triangular
Connector Angle (°)	7.3
Mechanical Surface Detection Mode	enabled
Optical Surface Detection Mode	disabled
Probe Overall Length	337 mm
Probe Body Diameter	10 mm
Tip Length	10 mm
Tip Diameter	4 mm
Probe Tip to Sensor X Calibration Point	2 mm
Probe Tip to Sensor Y Calibration Point	2 mm
Probe Tip to Sensor Z Calibration Point	2 mm
Recommended Measurement Distance from Surface	3 mm

Additional Conversion Factors
for Dosimetric E-Field Probe

Type:	**ES3DV3**
Serial Number:	**3163**
Place of Assessment:	**Zurich**
Date of Assessment:	**April 29, 2013**
Probe Calibration Date:	**April 26, 2013**

Schmid & Partner Engineering AG hereby certifies that conversion factor(s) of this probe have been evaluated on the date indicated above. The assessment was performed using the FDTD numerical code SEMCAD of Schmid & Partner Engineering AG. Since the evaluation is coupled with measured conversion factors, it has to be recalculated yearly, i.e., following the re-calibration schedule of the probe. The uncertainty of the numerical assessment is based on the extrapolation from measured value at 300, 450 and 900 MHz.

Assessed by:

Dosimetric E-Field Probe ES3DV3 SN:3163

Conversion factor (± standard deviation)

150 ± 50 MHz	$ConvF$	**8.33 ± 10%**	$\varepsilon_r = 52.3 \pm 5\%$ $\sigma = 0.76 \pm 5\%$ mho/m (head tissue)
250 ± 50 MHz	$ConvF$	**7.77 ± 10%**	$\varepsilon_r = 47.6 \pm 5\%$ $\sigma = 0.83 \pm 5\%$ mho/m (head tissue)
150 ± 50 MHz	$ConvF$	**8.05 ± 10%**	$\varepsilon_r = 61.9 \pm 5\%$ $\sigma = 0.80 \pm 5\%$ mho/m (body tissue)
250 ± 50 MHz	$ConvF$	**7.62 ± 10%**	$\varepsilon_r = 59.4 \pm 5\%$ $\sigma = 0.88 \pm 5\%$ mho/m (body tissue)

Important Note:

For numerically assessed probe conversion factors, parameters Alpha and Delta in the DASY software must have the following entries: Alpha = 0 and Delta = 1.

Please see also DASY Manual.