

Appendix B - DAE & Probe Calibration Certificate

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



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Accreditation No.: SCS 0108

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Multilateral Agreement for the recognition of calibration certificates

Client **SGS-TW (Auden)**

Certificate No: **DAE4-877_Mar19**

CALIBRATION CERTIFICATE

Object **DAE4 - SD 000 D04 BM - SN: 877**

Calibration procedure(s) **QA CAL-06.v29
Calibration procedure for the data acquisition electronics (DAE)**

Calibration date: **March 22, 2019**

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 $(22 \pm 3)^{\circ}\text{C}$ and humidity $< 70\%$.

Calibration Equipment used (M&TE critical for calibration)

Primary Standards	ID #	Cal Date (Certificate No.)	Scheduled Calibration
Kathley Multimeter Type 2001	SN: 0810278	03-Sep-18 (No:23488)	Sep-19
Secondary Standards	ID #	Check Date (in house)	Scheduled Check
Auto DAE Calibration Unit	SE UWS 053 AA 1001	07-Jan-19 (in house check)	In house check: Jan-20
Calibrator Box V2.1	SE UMS 006 AA 1002	07-Jan-19 (in house check)	In house check: Jan-20

Calibrated by:	Name Dominique Steffen	Function Laboratory Technician	Signature
Approved by:	Name Sven Kühn	Function Deputy Manager	Signature

Issued: March 22, 2019

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Certificate No: DAE4-877_Mar19

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台灣檢驗科技股份有限公司

t (886-2) 2299-3279

f (886-2) 2298-0488

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**Calibration Laboratory of
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Engineering AG**
Zeughausstrasse 43, 8004 Zurich, Switzerland



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Accreditation No.: SCS 0108

Glossary

DAE data acquisition electronics
Connector angle information used in DASY system to align probe sensor X to the robot coordinate system.

Methods Applied and Interpretation of Parameters

- **DC Voltage Measurement:** Calibration Factor assessed for use in DASY system by comparison with a calibrated instrument traceable to national standards. The figure given corresponds to the full scale range of the voltmeter in the respective range.
- **Connector angle:** The angle of the connector is assessed measuring the angle mechanically by a tool inserted. Uncertainty is not required.
- The following parameters as documented in the Appendix contain technical information as a result from the performance test and require no uncertainty.
 - **DC Voltage Measurement Linearity:** Verification of the Linearity at +10% and -10% of the nominal calibration voltage. Influence of offset voltage is included in this measurement.
 - **Common mode sensitivity:** Influence of a positive or negative common mode voltage on the differential measurement.
 - **Channel separation:** Influence of a voltage on the neighbor channels not subject to an input voltage.
 - **AD Converter Values with inputs shorted:** Values on the internal AD converter corresponding to zero input voltage
 - **Input Offset Measurement:** Output voltage and statistical results over a large number of zero voltage measurements.
 - **Input Offset Current:** Typical value for information; Maximum channel input offset current, not considering the input resistance.
 - **Input resistance:** Typical value for information: DAE input resistance at the connector, during internal auto-zeroing and during measurement.
 - **Low Battery Alarm Voltage:** Typical value for information. Below this voltage, a battery alarm signal is generated.
 - **Power consumption:** Typical value for information. Supply currents in various operating modes.

Certificate No: DAE4-877_Mar19

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f (886-2) 2298-0488

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DC Voltage Measurement

A/D - Converter Resolution nominal

High Range: 1LSB = 8.1 μ V, full range = -100...+300 mV

Low Range: 1LSB = 61nV, full range = -1...+3mV

DASY measurement parameters: Auto Zero Time: 3 sec; Measuring time: 3 sec

Calibration Factors	X	Y	Z
High Range	405.009 $\pm$ 0.02% (k=2)	404.575 $\pm$ 0.02% (k=2)	404.999 $\pm$ 0.02% (k=2)
Low Range	3.98156 $\pm$ 1.50% (k=2)	3.98173 $\pm$ 1.50% (k=2)	3.97143 $\pm$ 1.50% (k=2)

Connector Angle

Connector Angle to be used in DASY system	324.0 $^{\circ}$ $\pm$ 1 $^{\circ}$
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Appendix (Additional assessments outside the scope of SCS0108)

1. DC Voltage Linearity

High Range	Reading (μV)	Difference (μV)	Error (%)
Channel X + Input	200032.98	-1.14	-0.00
Channel X + Input	20007.92	2.70	0.01
Channel X - Input	-20004.25	1.79	-0.01
Channel Y + Input	200036.80	2.70	0.00
Channel Y + Input	20007.07	1.87	0.01
Channel Y - Input	-20005.67	0.46	-0.00
Channel Z + Input	200029.76	-4.15	-0.00
Channel Z + Input	20005.98	1.01	0.01
Channel Z - Input	-20005.75	0.42	-0.00

Low Range	Reading (μV)	Difference (μV)	Error (%)
Channel X + Input	2000.31	-0.51	-0.03
Channel X + Input	200.71	-0.18	-0.09
Channel X - Input	-198.89	0.16	-0.08
Channel Y + Input	2000.66	-0.14	-0.01
Channel Y + Input	199.70	-1.15	-0.57
Channel Y - Input	-199.73	-0.70	0.35
Channel Z + Input	2000.33	-0.39	-0.02
Channel Z + Input	199.36	-1.50	-0.75
Channel Z - Input	-201.36	-2.21	1.11

2. Common mode sensitivity

DASY measurement parameters: Auto Zero Time: 3 sec; Measuring time: 3 sec

	Common mode Input Voltage (mV)	High Range Average Reading (μV)	Low Range Average Reading (μV)
Channel X	200	15.42	13.43
	-200	-11.67	-13.84
Channel Y	200	-18.90	-19.48
	-200	18.01	18.21
Channel Z	200	20.03	19.90
	-200	-23.15	-23.35

3. Channel separation

DASY measurement parameters: Auto Zero Time: 3 sec; Measuring time: 3 sec

	Input Voltage (mV)	Channel X (μV)	Channel Y (μV)	Channel Z (μV)
Channel X	200	-	0.30	-3.40
Channel Y	200	7.13	-	1.49
Channel Z	200	8.92	4.35	-

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4. AD-Converter Values with inputs shorted

DASY measurement parameters: Auto Zero Time: 3 sec; Measuring time: 3 sec

	High Range (LSB)	Low Range (LSB)
Channel X	16001	16135
Channel Y	15878	16754
Channel Z	15739	17168

5. Input Offset Measurement

DASY measurement parameters: Auto Zero Time: 3 sec; Measuring time: 3 sec

Input 10M Ω

	Average (μ V)	min. Offset (μ V)	max. Offset (μ V)	Std. Deviation (μ V)
Channel X	0.70	-0.90	2.31	0.60
Channel Y	0.66	-0.90	2.30	0.71
Channel Z	0.60	-1.31	2.66	0.79

6. Input Offset Current

Nominal input circuitry offset current on all channels: <25fA

7. Input Resistance (Typical values for information)

	Zeroing (k Ω m)	Measuring (M Ω m)
Channel X	200	200
Channel Y	200	200
Channel Z	200	200

8. Low Battery Alarm Voltage (Typical values for information)

Typical values	Alarm Level (VDC)
Supply (+ Vcc)	+7.9
Supply (- Vcc)	-7.6

9. Power Consumption (Typical values for information)

Typical values	Switched off (mA)	Stand by (mA)	Transmitting (mA)
Supply (+ Vcc)	+0.01	+6	+14
Supply (- Vcc)	-0.01	-8	-9

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Accreditation No.: **SCS 0108**

Client **SGS-TW (Auden)**

Certificate No: **DAE4-547_Mar19**

CALIBRATION CERTIFICATE

Object **DAE4 - SD 000 D04 BM - SN: 547**

Calibration procedure(s) **QA CAL-06.v29**
Calibration procedure for the data acquisition electronics (DAE)

Calibration date: **March 22, 2019**

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
Keithley Multimeter Type 2001	SN: 0810278	03-Sep-18 (No:23488)	Sep-19

Secondary Standards	ID #	Check Date (in house)	Scheduled Check
Auto DAE Calibration Unit	SE UWS 053 AA 1001	07-Jan-19 (in house check)	In house check: Jan-20
Calibrator Box V2.1	SE UMS 006 AA 1002	07-Jan-19 (in house check)	In house check: Jan-20

Calibrated by:	Name	Function	Signature
	Dominique Steffen	Laboratory Technician	

Approved by:	Name	Function	Signature
	Sven Kühn	Deputy Manager	

Issued: March 22, 2019

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Certificate No: DAE4-547_Mar19

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Accreditation No.: **SCS 0108**

Glossary

DAE data acquisition electronics
Connector angle information used in DASY system to align probe sensor X to the robot coordinate system.

Methods Applied and Interpretation of Parameters

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- **Connector angle:** The angle of the connector is assessed measuring the angle mechanically by a tool inserted. Uncertainty is not required.
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 - **DC Voltage Measurement Linearity:** Verification of the Linearity at +10% and -10% of the nominal calibration voltage. Influence of offset voltage is included in this measurement.
 - **Common mode sensitivity:** Influence of a positive or negative common mode voltage on the differential measurement.
 - **Channel separation:** Influence of a voltage on the neighbor channels not subject to an input voltage.
 - **AD Converter Values with inputs shorted:** Values on the internal AD converter corresponding to zero input voltage
 - **Input Offset Measurement:** Output voltage and statistical results over a large number of zero voltage measurements.
 - **Input Offset Current:** Typical value for information; Maximum channel input offset current, not considering the input resistance.
 - **Input resistance:** Typical value for information: DAE input resistance at the connector, during internal auto-zeroing and during measurement.
 - **Low Battery Alarm Voltage:** Typical value for information. Below this voltage, a battery alarm signal is generated.
 - **Power consumption:** Typical value for information. Supply currents in various operating modes.

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DC Voltage Measurement

A/D - Converter Resolution nominal

High Range: 1LSB = 6.1μV , full range = -100...+300 mV
Low Range: 1LSB = 61nV , full range = -1.....+3mV

DASY measurement parameters: Auto Zero Time: 3 sec; Measuring time: 3 sec

Calibration Factors	X	Y	Z
High Range	403.235 ± 0.02% (k=2)	403.136 ± 0.02% (k=2)	402.783 ± 0.02% (k=2)
Low Range	3.95448 ± 1.50% (k=2)	3.90479 ± 1.50% (k=2)	3.96245 ± 1.50% (k=2)

Connector Angle

Connector Angle to be used in DASY system	91.5 ° ± 1 °
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Appendix (Additional assessments outside the scope of SCS0108)

1. DC Voltage Linearity

High Range	Reading (μV)	Difference (μV)	Error (%)
Channel X + Input	199995.43	1.41	0.00
Channel X + Input	20002.84	1.52	0.01
Channel X - Input	-19996.87	4.76	-0.02
Channel Y + Input	199993.66	0.02	0.00
Channel Y + Input	19999.34	-2.02	-0.01
Channel Y - Input	-20003.96	-2.33	0.01
Channel Z + Input	199994.47	1.04	0.00
Channel Z + Input	20002.60	1.36	0.01
Channel Z - Input	-20001.47	0.29	-0.00

Low Range	Reading (μV)	Difference (μV)	Error (%)
Channel X + Input	2000.59	-0.23	-0.01
Channel X + Input	201.16	-0.10	-0.05
Channel X - Input	-199.09	-0.45	0.23
Channel Y + Input	2000.65	-0.10	-0.01
Channel Y + Input	200.83	-0.37	-0.18
Channel Y - Input	-199.37	-0.70	0.35
Channel Z + Input	2000.46	-0.35	-0.02
Channel Z + Input	199.75	-1.50	-0.75
Channel Z - Input	-200.47	-1.80	0.90

2. Common mode sensitivity

DASY measurement parameters: Auto Zero Time: 3 sec; Measuring time: 3 sec

	Common mode Input Voltage (mV)	High Range Average Reading (μV)	Low Range Average Reading (μV)
Channel X	200	-3.65	-5.24
	- 200	5.24	3.62
Channel Y	200	-0.39	-1.02
	- 200	0.24	-0.55
Channel Z	200	5.61	5.22
	- 200	-7.68	-8.11

3. Channel separation

DASY measurement parameters: Auto Zero Time: 3 sec; Measuring time: 3 sec

	Input Voltage (mV)	Channel X (μV)	Channel Y (μV)	Channel Z (μV)
Channel X	200	-	3.67	-2.18
Channel Y	200	9.88	-	4.13
Channel Z	200	4.62	8.17	-

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4. AD-Converter Values with inputs shorted

DASY measurement parameters: Auto Zero Time: 3 sec; Measuring time: 3 sec

	High Range (LSB)	Low Range (LSB)
Channel X	16357	14727
Channel Y	16459	15185
Channel Z	16084	17210

5. Input Offset Measurement

DASY measurement parameters: Auto Zero Time: 3 sec; Measuring time: 3 sec

Input 10M Ω

	Average (μ V)	min. Offset (μ V)	max. Offset (μ V)	Std. Deviation (μ V)
Channel X	-1.59	-2.60	-0.90	0.32
Channel Y	0.54	-0.42	1.60	0.34
Channel Z	0.95	-0.46	2.89	0.59

6. Input Offset Current

Nominal Input circuitry offset current on all channels: <25fA

7. Input Resistance (Typical values for information)

	Zeroing (kOhm)	Measuring (MOhm)
Channel X	200	200
Channel Y	200	200
Channel Z	200	200

8. Low Battery Alarm Voltage (Typical values for information)

Typical values	Alarm Level (VDC)
Supply (+ Vcc)	+7.9
Supply (- Vcc)	-7.6

9. Power Consumption (Typical values for information)

Typical values	Switched off (mA)	Stand by (mA)	Transmitting (mA)
Supply (+ Vcc)	+0.01	+6	+14
Supply (- Vcc)	-0.01	-8	-9

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Schmid & Partner
Engineering AG
Zeughausstrasse 43, 8004 Zurich, Switzerland



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Accreditation No.: **SCS 0108**

Client **SGS (Auden)**

Certificate No: **EX3-7509_Mar19**

CALIBRATION CERTIFICATE

Object **EX3DV4 - SN:7509**

Calibration procedure(s) **QA CAL-01.v9, QA CAL-14.v5, QA CAL-23.v5, QA CAL-25.v7**
Calibration procedure for dosimetric E-field probes

Calibration date: **March 25, 2019**

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 NRP	SN: 104778	04-Apr-18 (No. 217-02672/02673)	Apr-19
Power sensor NRP-Z91	SN: 103244	04-Apr-18 (No. 217-02672)	Apr-19
Power sensor NRP-Z91	SN: 103245	04-Apr-18 (No. 217-02673)	Apr-19
Reference 20 dB Attenuator	SN: S5277 (20x)	04-Apr-18 (No. 217-02682)	Apr-19
DAE4	SN: 660	19-Dec-18 (No. DAE4-660_Dec18)	Dec-19
Reference Probe ES3DV2	SN: 3013	31-Dec-18 (No. ES3-3013_Dec18)	Dec-19
Secondary Standards	ID	Check Date (in house)	Scheduled Check
Power meter E4419B	SN: GB41293874	06-Apr-16 (in house check Jun-18)	In house check: Jun-20
Power sensor E4412A	SN: MY41498067	06-Apr-16 (in house check Jun-18)	In house check: Jun-20
Power sensor E4412A	SN: 000110210	06-Apr-16 (in house check Jun-18)	In house check: Jun-20
RF generator HP 8648C	SN: US3642U01700	04-Aug-99 (in house check Jun-18)	In house check: Jun-20
Network Analyzer E5358A	SN: US41080477	31-Mar-14 (in house check Oct-18)	In house check: Oct-19

Calibrated by:	Name Claudio Leubler	Function Laboratory Technician	Signature
Approved by:	Name Katja Pokovic	Function Technical Manager	Signature
This calibration certificate shall not be reproduced except in full without written approval of the laboratory.			Issued: March 26, 2019

Certificate No: EX3-7509_Mar19

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t (886-2) 2299-3279

f (886-2) 2298-0488

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



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Glossary:

TSL	tissue simulating liquid
NORM _{x,y,z}	sensitivity in free space
ConvF	sensitivity in TSL / NORM _{x,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., $\theta = 0$ 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:

- 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
- 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
- IEC 62209-2, "Procedure to determine the Specific Absorption Rate (SAR) for wireless communication devices used in close proximity to the human body (frequency range of 30 MHz to 6 GHz)", March 2010
- KDB 865664, "SAR Measurement Requirements for 100 MHz to 6 GHz"

Methods Applied and Interpretation of Parameters:

- NORM_{x,y,z}**: Assessed for E-field polarization $\theta = 0$ ($f \leq 900$ MHz in TEM-cell; $f > 1800$ MHz: R22 waveguide). NORM_{x,y,z} are only intermediate values, i.e., the uncertainties of NORM_{x,y,z} does not affect the E^2 -field uncertainty inside TSL (see below ConvF).
- NORM(f)_{x,y,z}** = NORM_{x,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.
- DCP_{x,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.
- A_{x,y,z}; B_{x,y,z}; C_{x,y,z}; D_{x,y,z}; VR_{x,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 $f \leq 800$ 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 NORM_{x,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 NORM_x (no uncertainty required).

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EX3DV4 – SN:7509

March 25, 2019

DASY/EASY - Parameters of Probe: EX3DV4 - SN:7509**Basic Calibration Parameters**

	Sensor X	Sensor Y	Sensor Z	Unc (k=2)
Norm ($\mu\text{V}/(\text{V}/\text{m})^2$) ^A	0.47	0.49	0.47	$\pm 10.1 \%$
DCP (mV) ^B	99.6	98.6	102.3	

Calibration Results for Modulation Response

UID	Communication System Name		A dB	B dB $\sqrt{\mu\text{V}}$	C	D dB	VR mV	Max dev	Unc ^E (k=2)
0	CW	X	0.0	0.0	1.0	0.00	176.8	$\pm 3.3 \%$	$\pm 4.7 \%$
		Y	0.0	0.0	1.0		186.0		
		Y	0.0	0.0	1.0		183.5		

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 Norm X,Y,Z do not affect the E²-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.

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EX3DV4- SN:7509

March 25, 2019

DASY/EASY - Parameters of Probe: EX3DV4 - SN:7509

Other Probe Parameters

Sensor Arrangement	Triangular
Connector Angle (°)	-47.6
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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EX3DV4- SN:7509

March 25, 2019

DASY/EASY - Parameters of Probe: EX3DV4 - SN:7509**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 ^h (mm)	Unc (k=2)
750	41.9	0.89	10.41	10.41	10.41	0.51	0.80	± 12.0 %
835	41.5	0.90	10.13	10.13	10.13	0.48	0.85	± 12.0 %
900	41.5	0.97	9.89	9.89	9.89	0.44	0.84	± 12.0 %
1750	40.1	1.37	8.84	8.84	8.84	0.28	0.98	± 12.0 %
1900	40.0	1.40	8.50	8.50	8.50	0.30	0.85	± 12.0 %
2000	40.0	1.40	8.39	8.39	8.39	0.35	0.85	± 12.0 %
2300	39.5	1.67	8.13	8.13	8.13	0.29	0.88	± 12.0 %
2450	39.2	1.80	7.79	7.79	7.79	0.30	0.88	± 12.0 %
2600	39.0	1.96	7.70	7.70	7.70	0.36	0.86	± 12.0 %
5200	36.0	4.66	5.46	5.46	5.46	0.40	1.80	± 13.1 %
5300	35.9	4.76	5.20	5.20	5.20	0.40	1.80	± 13.1 %
5600	35.5	5.07	4.77	4.77	4.77	0.40	1.80	± 13.1 %
5800	35.3	5.27	4.94	4.94	4.94	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. Validity of ConvF assessed at 6 MHz is 4-9 MHz, and ConvF assessed at 13 MHz is 9-19 MHz. 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.

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EX3DV4-SN:7509

March 25, 2019

DASY/EASY - Parameters of Probe: EX3DV4 - SN:7509**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 (mm) ^g	Unc (k=2)
750	55.5	0.96	10.91	10.91	10.91	0.45	0.80	± 12.0 %
835	55.2	0.97	10.59	10.59	10.59	0.40	0.88	± 12.0 %
900	55.0	1.05	10.47	10.47	10.47	0.40	0.80	± 12.0 %
1750	53.4	1.49	8.63	8.63	8.63	0.35	0.85	± 12.0 %
1900	53.3	1.52	8.24	8.24	8.24	0.36	0.85	± 12.0 %
2000	53.3	1.52	8.19	8.19	8.19	0.22	1.16	± 12.0 %
2300	52.9	1.81	8.11	8.11	8.11	0.35	0.88	± 12.0 %
2450	52.7	1.95	8.05	8.05	8.05	0.28	0.93	± 12.0 %
2600	52.5	2.16	7.76	7.76	7.76	0.25	0.98	± 12.0 %
5200	49.0	5.30	4.81	4.81	4.81	0.50	1.90	± 13.1 %
5300	48.9	5.42	4.66	4.66	4.66	0.50	1.90	± 13.1 %
5600	48.5	5.77	4.19	4.19	4.19	0.50	1.90	± 13.1 %
5800	48.2	6.00	4.20	4.20	4.20	0.50	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. Validity of ConvF assessed at 6 MHz is 4-9 MHz, and ConvF assessed at 13 MHz is 9-19 MHz. 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.

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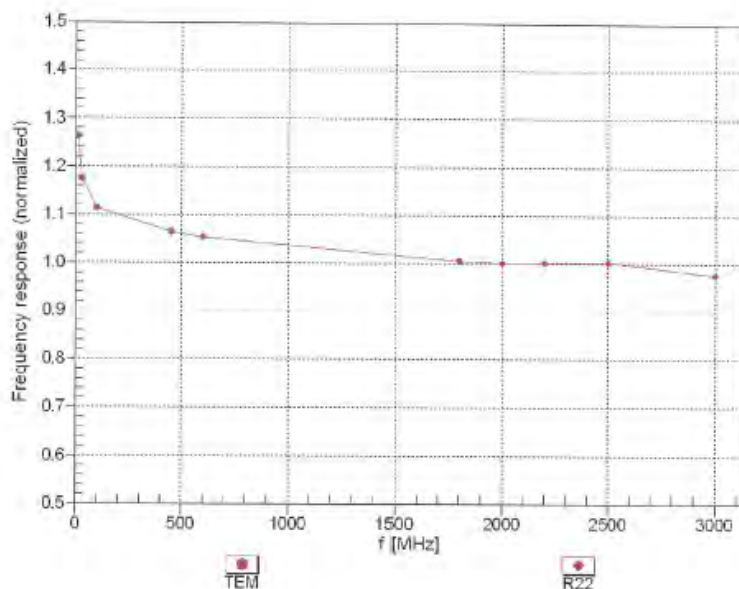
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EX3DV4- SN:7509

March 25, 2019

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



Uncertainty of Frequency Response of E-field: $\pm 6.3\%$ ($k=2$)

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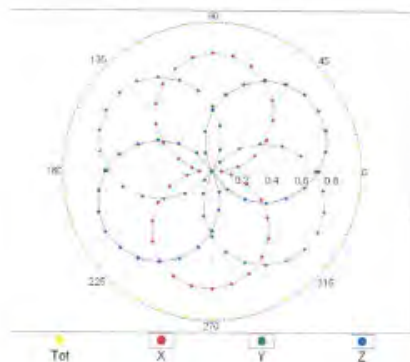
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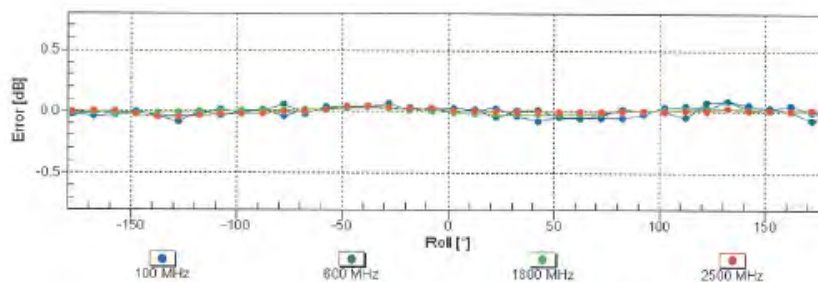
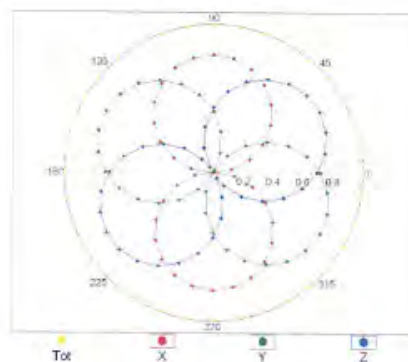
March 25, 2019

Receiving Pattern (ϕ), $\theta = 0^\circ$

f=600 MHz,TEM



f=1800 MHz,R22



Uncertainty of Axial Isotropy Assessment: $\pm 0.5\%$ (k=2)

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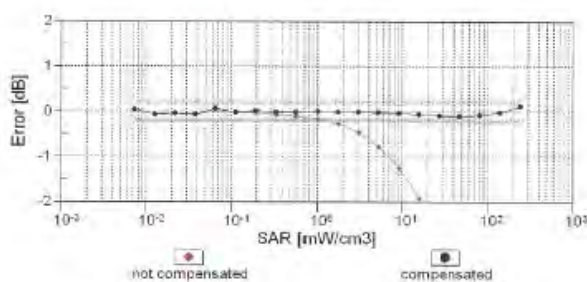
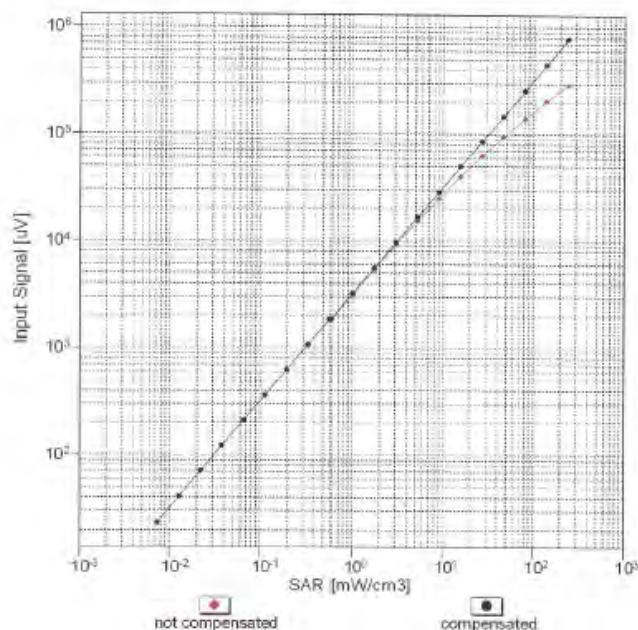
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March 25, 2019

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



Uncertainty of Linearity Assessment: $\pm 0.6\%$ ($k=2$)

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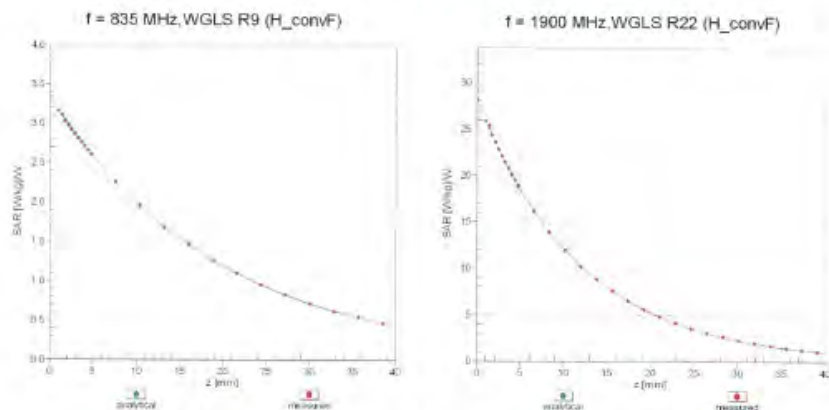
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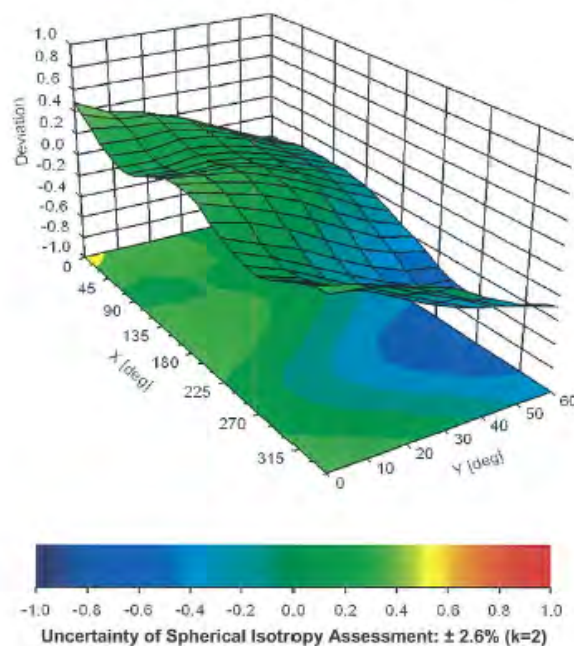
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Conversion Factor Assessment



Deviation from Isotropy in Liquid

Error (ϕ , θ), $f = 900$ MHz



Uncertainty of Spherical Isotropy Assessment: $\pm 2.6\%$ ($k=2$)

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Certificate No: Z18-60229

CALIBRATION CERTIFICATE

Object EX3DV4 - SN:3665

Calibration Procedure(s) FF-Z11-004-01
Calibration Procedures for Dosimetric E-field Probes

Calibration date: August 06, 2018

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(Calibrated by, Certificate No.)	Scheduled Calibration
Power Meter NRP2	101919	20-Jun-18 (CTTL, No.J18X05032)	Jun-19
Power sensor NRP-Z91	101547	20-Jun-18 (CTTL, No.J18X05032)	Jun-19
Power sensor NRP-Z91	101548	20-Jun-18 (CTTL, No.J18X05032)	Jun-19
Reference10dBAttenuator	18N50W-10dB	09-Feb-18(CTTL, No.J18X01133)	Feb-20
Reference20dBAttenuator	18N50W-20dB	09-Feb-18(CTTL, No.J18X01132)	Feb-20
Reference Probe EX3DV4	SN 3846	25-Jan-18(SPEAG,No.EX3-3846_Jan18)	Jan-19
DAE4	SN 777	15-Dec-17(SPEAG, No.DAE4-777_Dec17)	Dec -18
Secondary Standards	ID #	Cal Date(Calibrated by, Certificate No.)	Scheduled Calibration
SignalGeneratorMG3700A	6201052605	21-Jun-18 (CTTL, No.J18X05033)	Jun-19
Network Analyzer E5071C	MY46110673	14-Jan-18 (CTTL, No.J18X00561)	Jan -19

	Name	Function	Signature
Calibrated by:	Yu Zongying	SAR Test Engineer	
Reviewed by:	Lin Hao	SAR Test Engineer	
Approved by:	Qi Dianyuan	SAR Project Leader	

Issued: August 08, 2018

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
NORM _{x,y,z}	sensitivity in free space
ConvF	sensitivity in TSL / NORM _{x,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 $\theta=0$ 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:

- 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
- 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
- IEC 62209-2, "Procedure to determine the Specific Absorption Rate (SAR) for wireless communication devices used in close proximity to the human body (frequency range of 30 MHz to 6 GHz)", March 2010
- KDB 865664, "SAR Measurement Requirements for 100 MHz to 6 GHz"

Methods Applied and Interpretation of Parameters:

- NORM_{x,y,z}**: Assessed for E-field polarization $\theta=0$ ($f \leq 900\text{MHz}$ in TEM-cell; $f > 1800\text{MHz}$: waveguide). NORM_{x,y,z} are only intermediate values, i.e., the uncertainties of NORM_{x,y,z} does not effect the E^2 -field uncertainty inside TSL (see below ConvF).
- NORM(f)_{x,y,z}** = NORM_{x,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.
- DCP_{x,y,z}**: DCP are numerical linearization parameters assessed based on the data of power sweep (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.
- A_{x,y,z}; B_{x,y,z}; C_{x,y,z}; VR_{x,y,z}; A,B,C** 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 $f \leq 800\text{MHz}$) and inside waveguide using analytical field distributions based on power measurements for $f > 800\text{MHz}$. The same setups are used for assessment of the parameters applied for boundary compensation (alpha, depth) of which typical uncertainty valued are given. These parameters are used in DASY4 software to improve probe accuracy close to the boundary. The sensitivity in TSL corresponds to NORM_{x,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 $\pm 50\text{MHz}$ to $\pm 100\text{MHz}$.
- 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 NORM_x (no uncertainty required).

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Probe EX3DV4

SN: 3665

Calibrated: August 06, 2018

Calibrated for DASY/EASY Systems

(Note: non-compatible with DASY2 system!)

Certificate No: Z18-60229

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DASY/EASY – Parameters of Probe: EX3DV4 – SN: 3665

Basic Calibration Parameters

	Sensor X	Sensor Y	Sensor Z	Unc (k=2)
Norm($\mu\text{V}/(\text{V}/\text{m})^2$) ^A	0.51	0.57	0.52	±10.0%
DCP(mV) ^B	100.1	99.7	101.7	

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	171.1	±2.2%
		Y	0.0	0.0	1.0		184.5	
		Z	0.0	0.0	1.0		172.5	

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 Norm X, Y, Z do not affect the E²-field uncertainty inside TSL (see Page 5 and Page 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.

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DASY/EASY – Parameters of Probe: EX3DV4 – SN: 3665

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)
750	41.9	0.89	9.92	9.92	9.92	0.40	0.80	±12.1%
835	41.5	0.90	9.60	9.60	9.60	0.18	1.32	±12.1%
900	41.5	0.97	9.48	9.48	9.48	0.19	1.30	±12.1%
1750	40.1	1.37	8.34	8.34	8.34	0.25	1.02	±12.1%
1900	40.0	1.40	8.06	8.06	8.06	0.26	1.01	±12.1%
2000	40.0	1.40	8.14	8.14	8.14	0.23	1.05	±12.1%
2300	39.5	1.67	7.86	7.86	7.86	0.61	0.71	±12.1%
2450	39.2	1.80	7.48	7.48	7.48	0.47	0.87	±12.1%
2600	39.0	1.96	7.28	7.28	7.28	0.56	0.79	±12.1%
5200	36.0	4.66	5.48	5.48	5.48	0.40	1.30	±13.3%
5300	35.9	4.76	5.24	5.24	5.24	0.40	1.30	±13.3%
5500	35.6	4.96	5.02	5.02	5.02	0.40	1.20	±13.3%

^C Frequency validity above 300 MHz of ±100MHz only applies for DASY v4.4 and higher (Page 2), else it is restricted to ±50MHz. The uncertainty is the RSS of 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 frequency 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 the frequencies between 3-6 GHz at any distance larger than half the probe tip diameter from the boundary.

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DASY/EASY – Parameters of Probe: EX3DV4 – SN: 3665

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)
750	55.5	0.96	10.08	10.08	10.08	0.40	0.80	±12.1%
835	55.2	0.97	9.72	9.72	9.72	0.17	1.46	±12.1%
900	55.0	1.05	9.65	9.65	9.65	0.21	1.26	±12.1%
1750	53.4	1.49	8.11	8.11	8.11	0.22	1.11	±12.1%
1900	53.3	1.52	7.74	7.74	7.74	0.23	1.14	±12.1%
2000	53.3	1.52	8.05	8.05	8.05	0.22	1.11	±12.1%
2300	52.9	1.81	7.70	7.70	7.70	0.64	0.77	±12.1%
2450	52.7	1.95	7.52	7.52	7.52	0.51	0.94	±12.1%
2600	52.5	2.16	7.19	7.19	7.19	0.65	0.76	±12.1%
5200	49.0	5.30	4.78	4.78	4.78	0.50	1.70	±13.3%
5300	48.9	5.42	4.60	4.60	4.60	0.50	1.70	±13.3%
5500	48.6	5.65	4.23	4.23	4.23	0.50	1.80	±13.3%

^C Frequency validity above 300 MHz of ±100MHz only applies for DASY v4.4 and higher (Page 2), else it is restricted to ±50MHz. The uncertainty is the RSS of 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 frequency 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 the frequencies between 3-6 GHz at any distance larger than half the probe tip diameter from the boundary.

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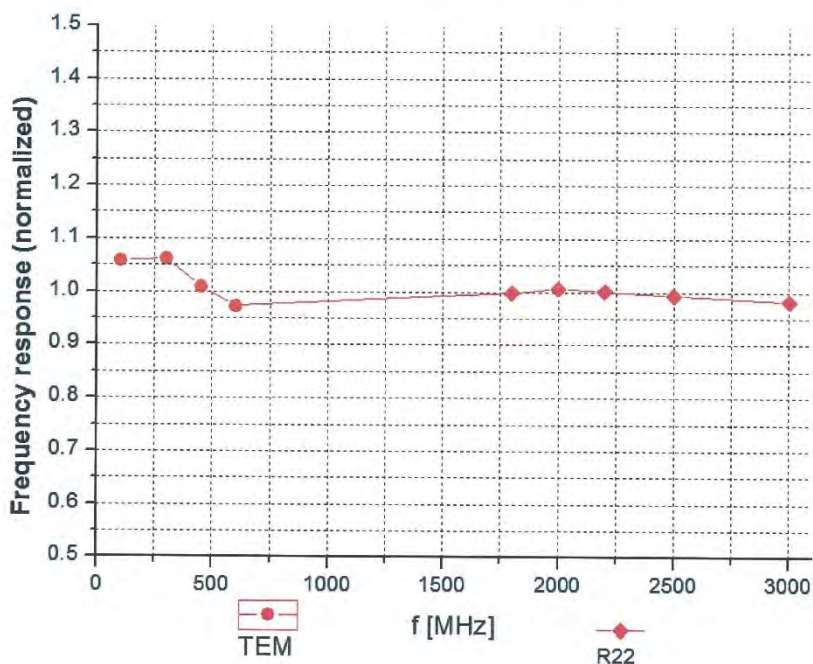
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Frequency Response of E-Field (TEM-Cell: ifi110 EXX, Waveguide: R22)



Uncertainty of Frequency Response of E-field: $\pm 7.4\%$ ($k=2$)

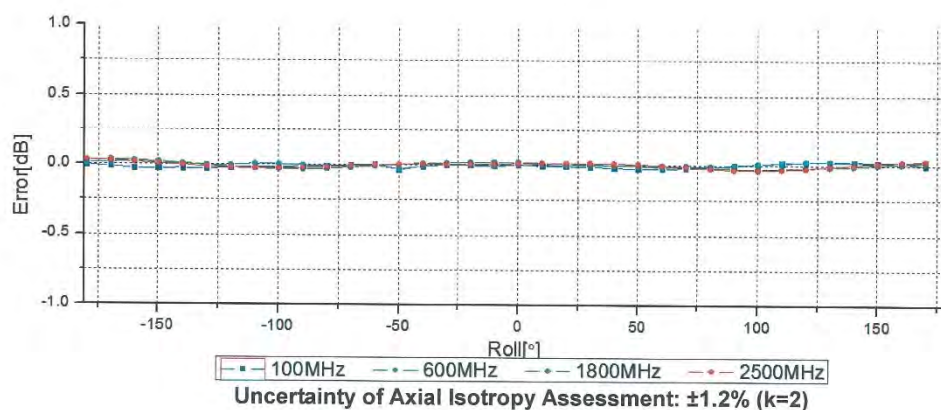
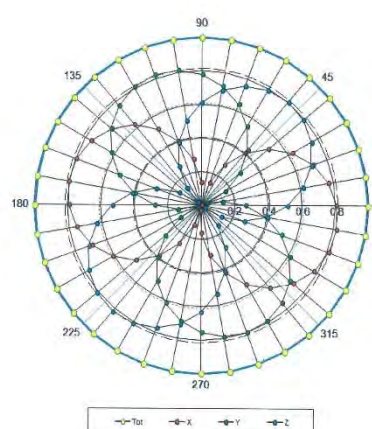
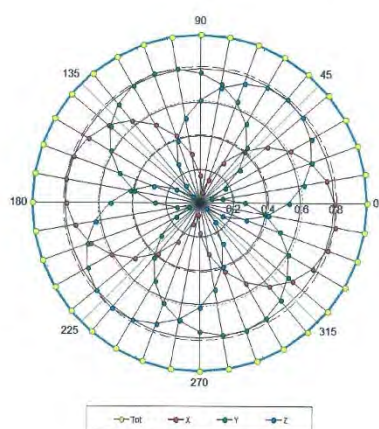


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Receiving Pattern (Φ), $\theta=0^\circ$

f=600 MHz, TEM

f=1800 MHz, R22



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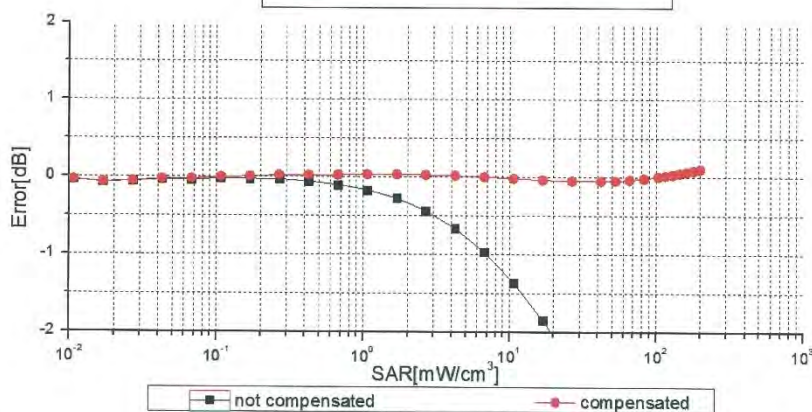
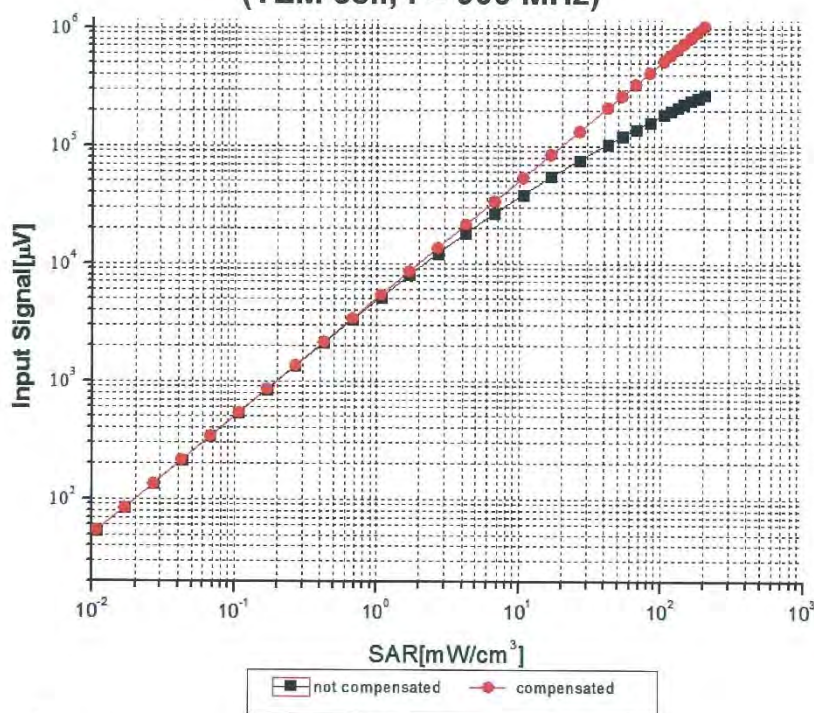
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Tel: +86-10-62304633-2512 Fax: +86-10-62304633-2504
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Dynamic Range f(SAR_{head}) (TEM cell, f = 900 MHz)



Uncertainty of Linearity Assessment: $\pm 0.9\%$ (k=2)

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台灣檢驗科技股份有限公司

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f (886-2) 2298-0488

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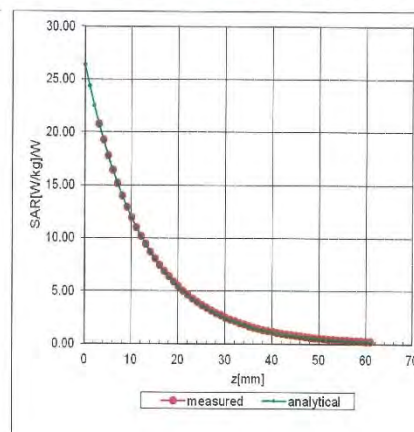
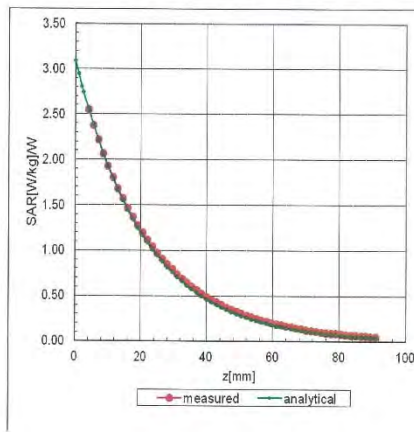


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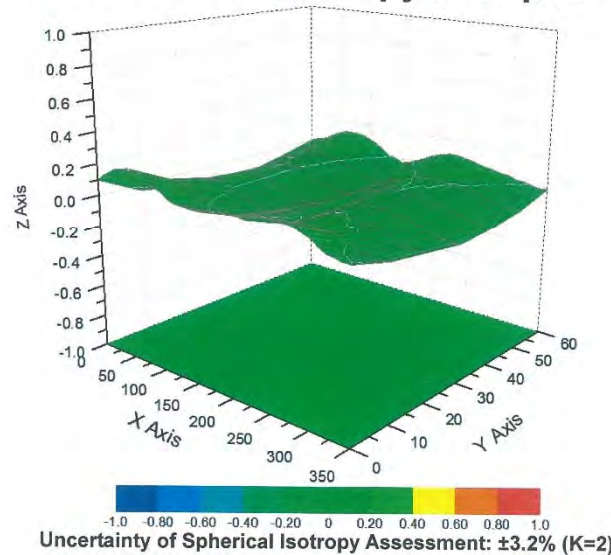
Conversion Factor Assessment

f=750 MHz, WGLS R9(H_convF)

f=1750 MHz, WGLS R22(H_convF)



Deviation from Isotropy in Liquid



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DASY/EASY – Parameters of Probe: EX3DV4 – SN: 3665

Other Probe Parameters

Sensor Arrangement	Triangular
Connector Angle (°)	74.2
Mechanical Surface Detection Mode	enabled
Optical Surface Detection Mode	disable
Probe Overall Length	337mm
Probe Body Diameter	10mm
Tip Length	9mm
Tip Diameter	2.5mm
Probe Tip to Sensor X Calibration Point	1mm
Probe Tip to Sensor Y Calibration Point	1mm
Probe Tip to Sensor Z Calibration Point	1mm
Recommended Measurement Distance from Surface	1.4mm

- End of report -

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