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CALIBRATION 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 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, "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

c) 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

d) KDB 865664, "SAR Measurement Requirements for 100 MHz to 6 GHz"

Methods Applied and Interpretation of Parameters:

- *NORMx,y,z:* Assessed for E-field polarization θ=0 (f≤900MHz in TEM-cell; f>1800MHz: waveguide). NORMx,y,z are only intermediate values, i.e., the uncertainties of NORMx,y,z does not effect 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 (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;VRx,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≤800MHz) and inside waveguide using analytical field distributions based on power measurements for f >800MHz. 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 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±50MHz to±100MHz.
- *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).

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Probe EX3DV4

SN: 3962

Calibrated: January 11, 2018

Calibrated for DASY/EASY Systems

(Note: non-compatible with DASY2 system!)

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DASY/EASY – Parameters of Probe: EX3DV4 – SN: 3962

Basic Calibration Parameters

	Sensor X	Sensor Y	Sensor Z	Unc (k=2)
Norm(μV/(V/m)^2)[A]	0.42	0.47	0.44	±10.0%
DCP(mV)[B]	100.3	102.5	94.3	

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	154.3	±2.5%
		Y	0.0	0.0	1.0		162.9	
		Z	0.0	0.0	1.0		153.1	

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 E^2-field uncertainty inside TSL (see Page 5 and Page 6).
[B] Numerical linearization parameter: uncertainty not required.
[E] Uncertainly 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: 3962

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	10.19	10.19	10.19	0.40	0.75	±12.1%
835	41.5	0.90	9.96	9.96	9.96	0.16	1.25	±12.1%
1750	40.1	1.37	8.54	8.54	8.54	0.21	1.15	±12.1%
1900	40.0	1.40	8.26	8.26	8.26	0.26	1.00	±12.1%
2300	39.5	1.67	8.03	8.03	8.03	0.35	0.80	±12.1%
2450	39.2	1.80	7.62	7.62	7.62	0.41	0.88	±12.1%
2600	39.0	1.96	7.52	7.52	7.52	0.42	0.92	±12.1%
5250	35.9	4.71	5.68	5.68	5.68	0.35	1.55	±13.3%
5600	35.5	5.07	4.89	4.89	4.89	0.40	1.50	±13.3%
5750	35.4	5.22	5.05	5.05	5.05	0.40	1.60	±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: 3962

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	10.37	10.37	10.37	0.40	0.85	±12.1%
835	55.2	0.97	9.98	9.98	9.98	0.17	1.43	±12.1%
1750	53.4	1.49	8.49	8.49	8.49	0.22	1.12	±12.1%
1900	53.3	1.52	8.09	8.09	8.09	0.20	1.17	±12.1%
2300	52.9	1.81	7.90	7.90	7.90	0.34	1.17	±12.1%
2450	52.7	1.95	7.78	7.78	7.78	0.34	1.25	±12.1%
2600	52.5	2.16	7.61	7.61	7.61	0.44	0.96	±12.1%
5250	48.9	5.36	5.22	5.22	5.22	0.45	1.45	±13.3%
5600	48.5	5.77	4.45	4.45	4.45	0.50	1.60	±13.3%
5750	48.3	5.94	4.59	4.59	4.59	0.50	1.45	±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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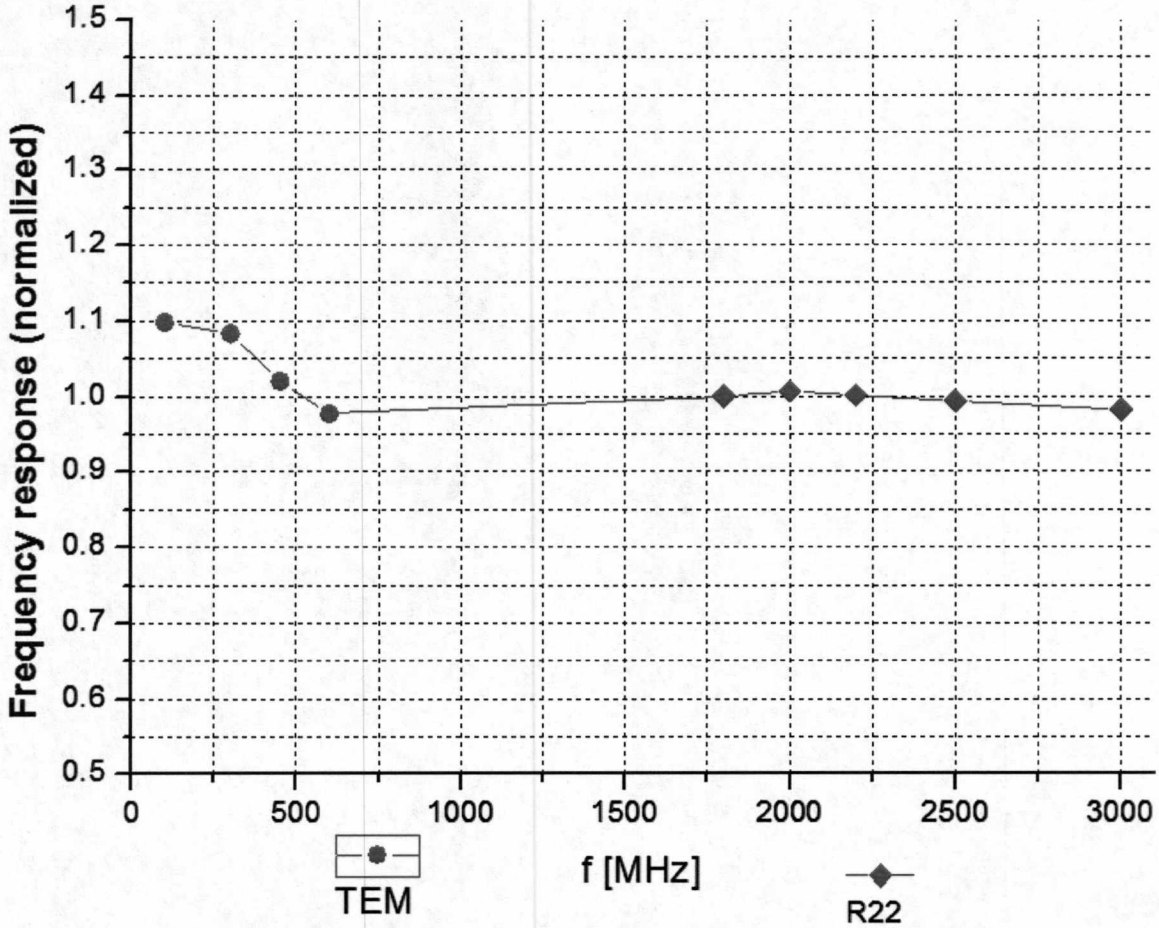
Frequency Response of E-Field
(TEM-Cell: ifi110 EXX, Waveguide: R22)



Uncertainty of Frequency Response of E-field: ±7.4% (k=2)

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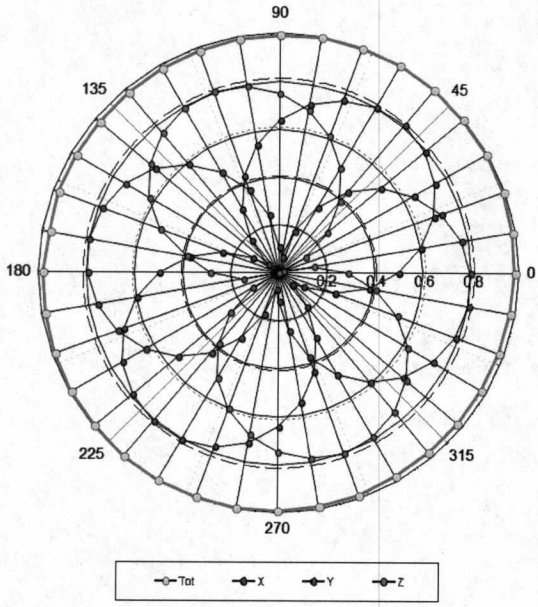
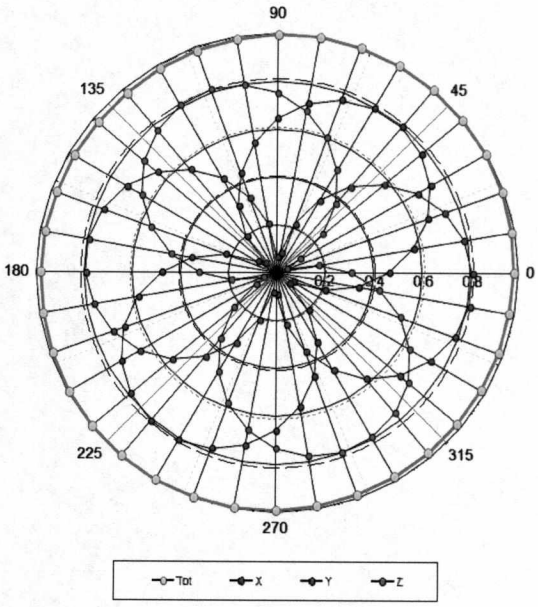
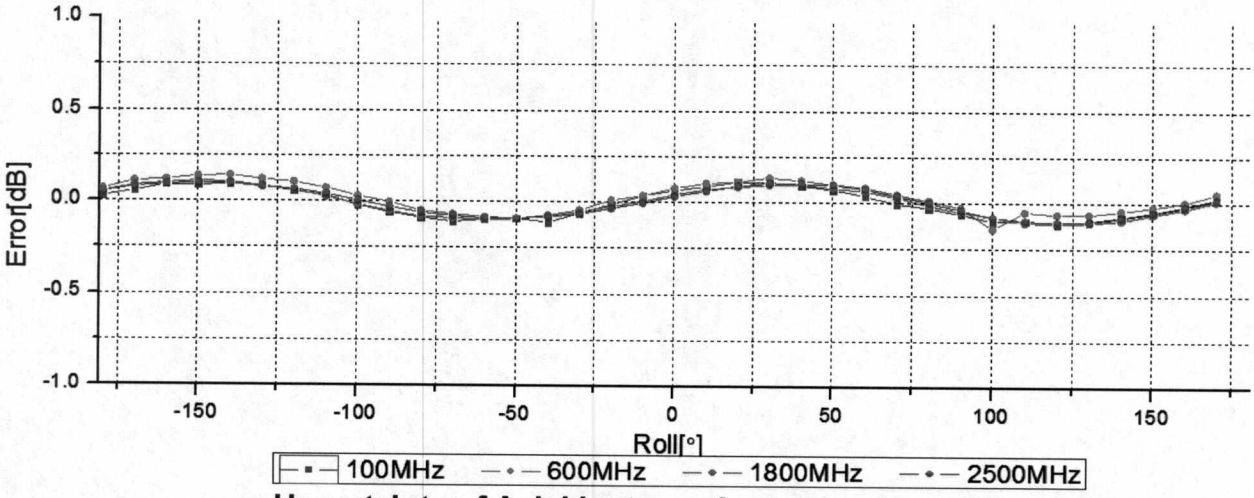
Receiving Pattern (Φ), θ=0°

f=600 MHz, TEM



f=1800 MHz, R22





Uncertainty of Axial Isotropy Assessment: ±1.2% (k=2)

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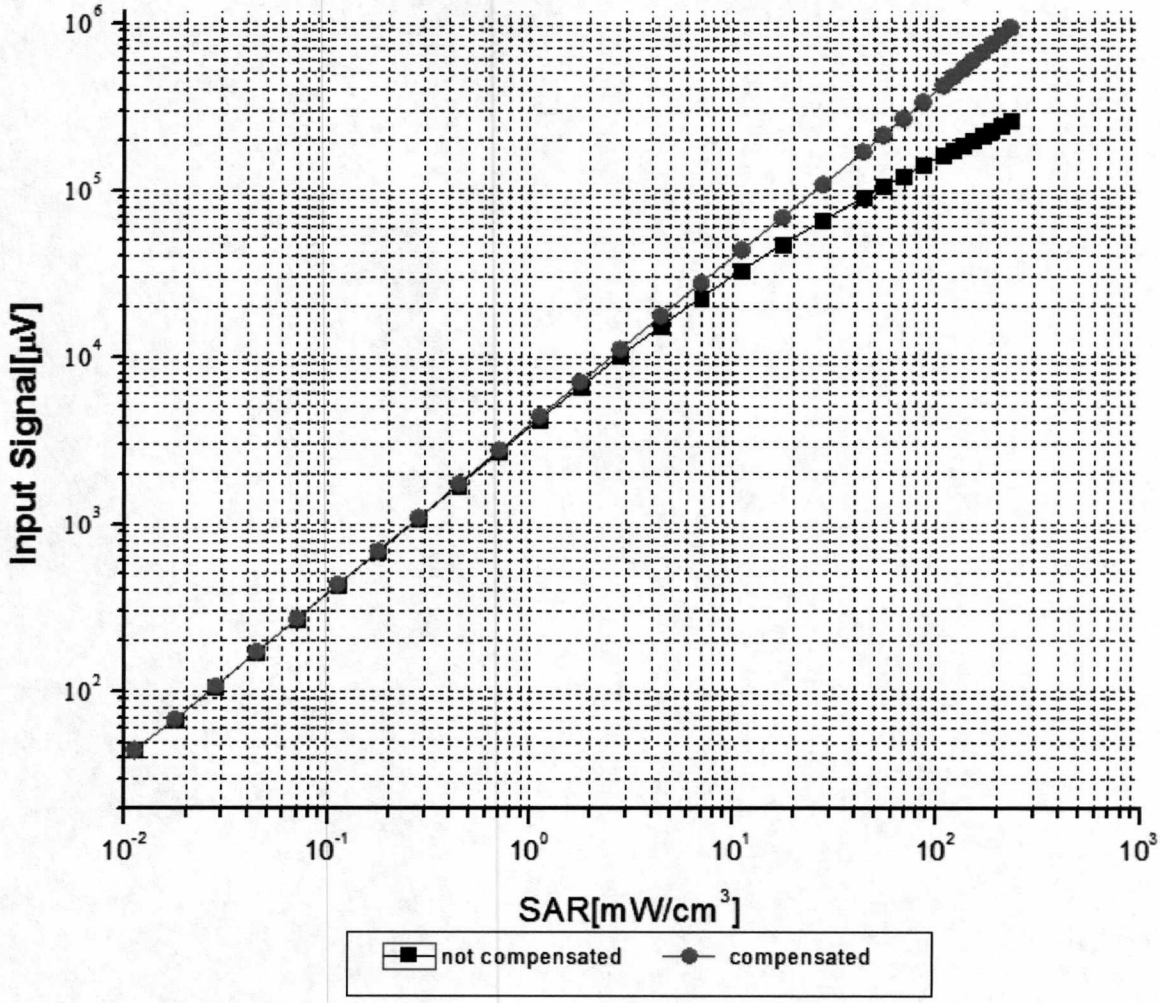
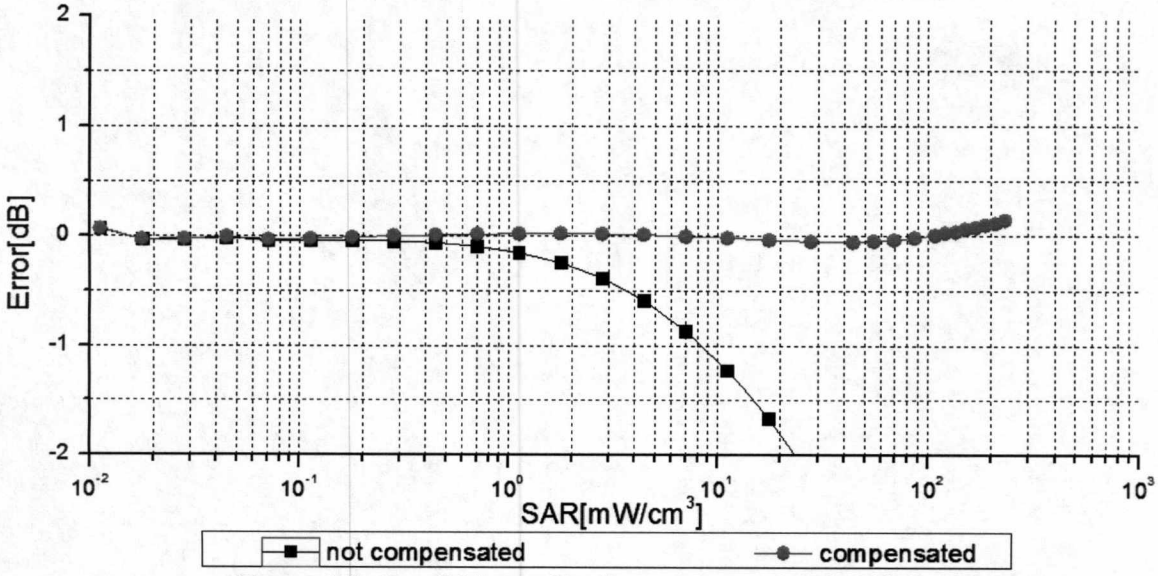
Dynamic Range f(SAR_{head})
(TEM cell, f = 900 MHz)





Uncertainty of Linearity Assessment: ±0.9% (k=2)

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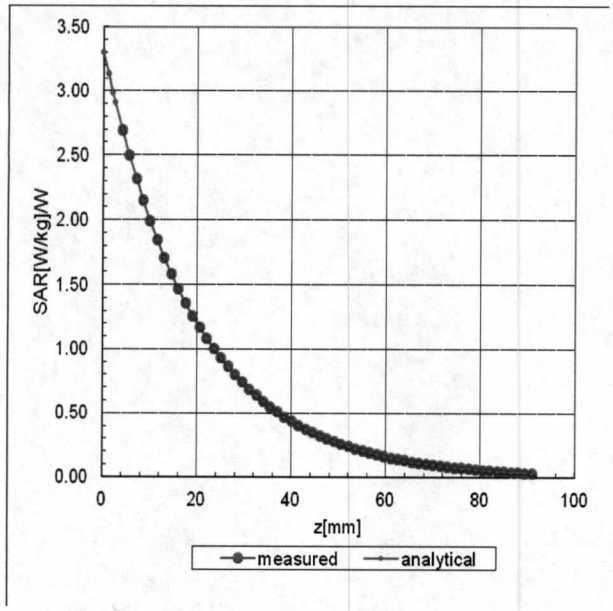
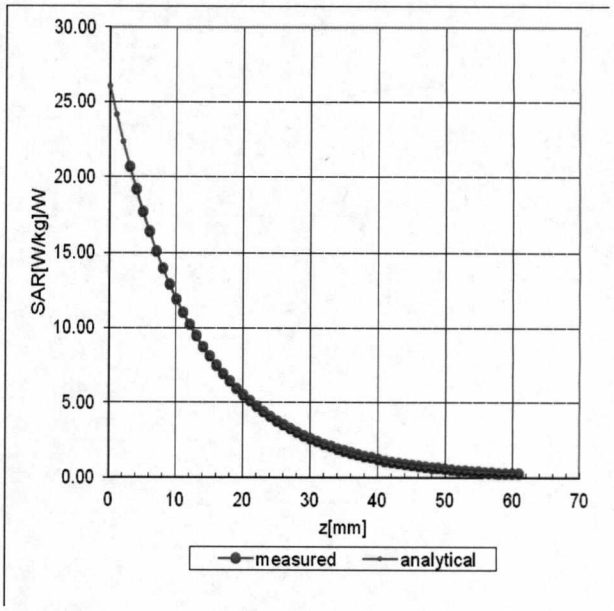
Conversion Factor Assessment

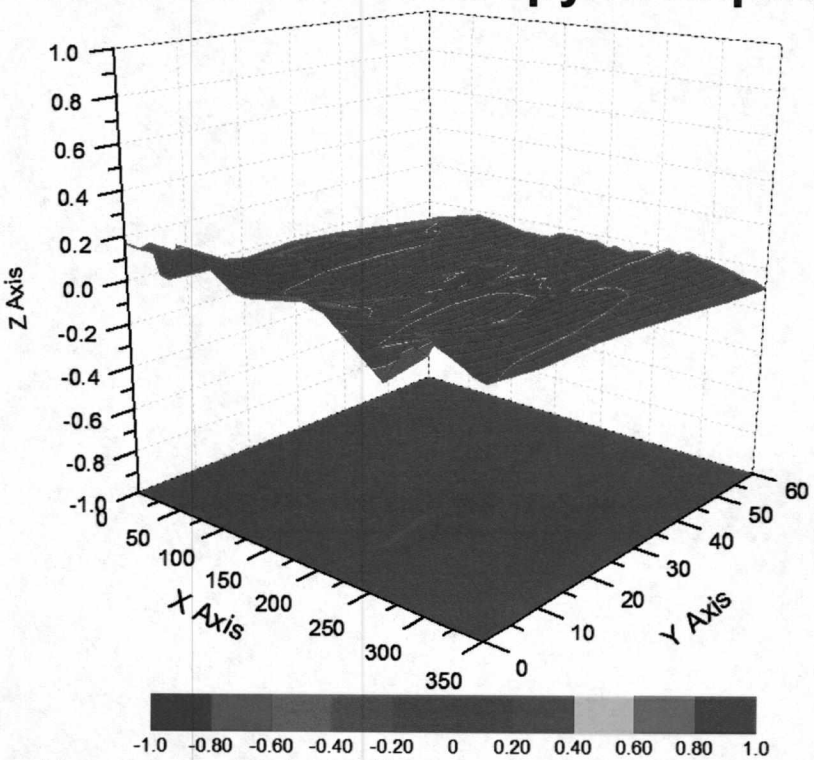
f=835 MHz, WGLS R9(H_convF)



f=1750 MHz, WGLS R22(H_convF)



Deviation from Isotropy in Liquid



Uncertainty of Spherical Isotropy Assessment: ±3.2% (K=2)

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DASY/EASY – Parameters of Probe: EX3DV4 – SN: 3962

Other Probe Parameters

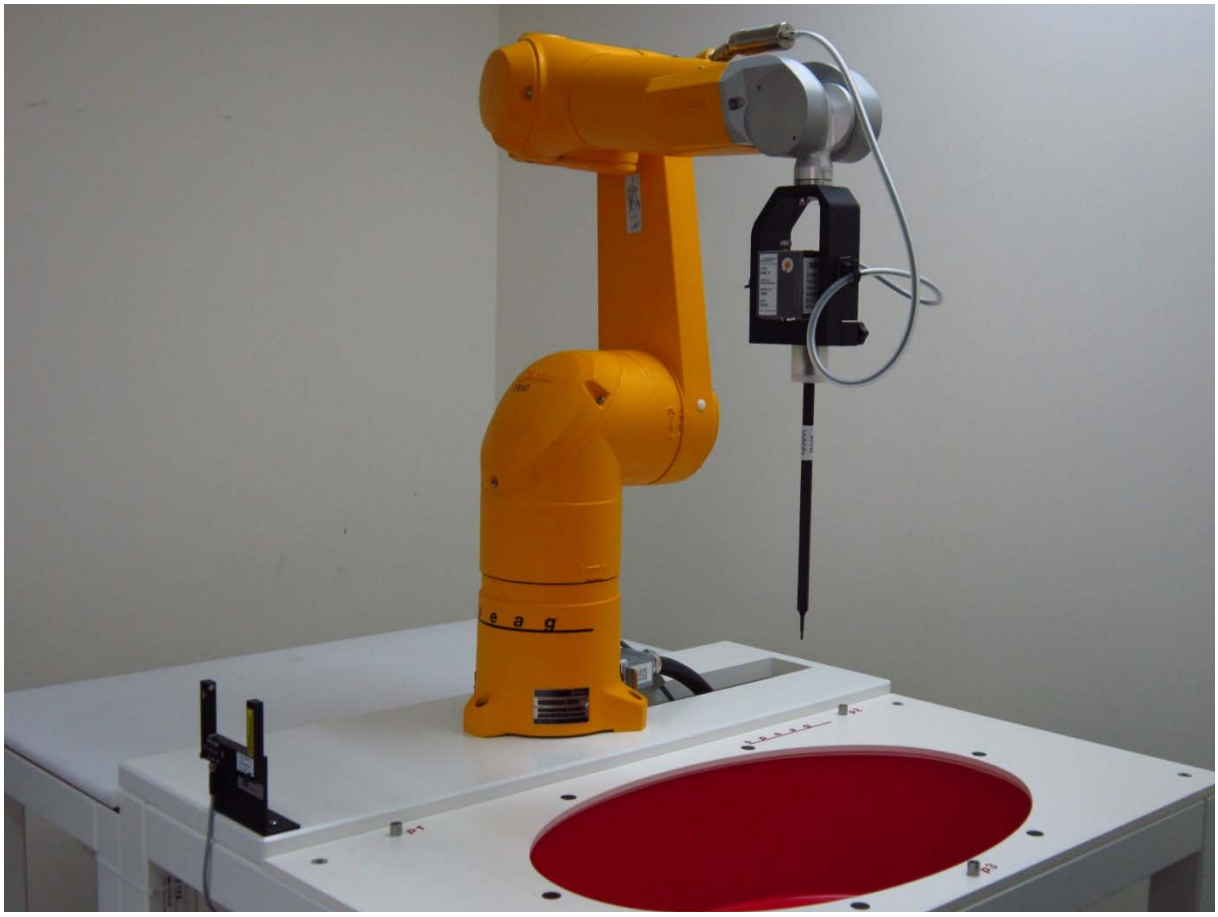
Sensor Arrangement	Triangular
Connector Angle (°)	152.2
Mechanical Surface Detection Mode	enabled
Optical Surface Detection Mode	disable
Probe Overall Length	337mm
Probe Body Diameter	10mm
Tip Length	9mm
Tip Diameter	2.5mm
Probe Tip to Sensor X Calibration Point	1mm
Probe Tip to Sensor Y Calibration Point	1mm
Probe Tip to Sensor Z Calibration Point	1mm
Recommended Measurement Distance from Surface	1.4mm

Appendix D

Photographs

1. SAR measurement System
2. Photographs of Tissue Simulate Liquid
3. Photographs of EUT test position
4. EUT Constructional Details

1. SAR measurement System



2. Photographs of Tissue Simulate Liquid

Photo 1: Tissue Simulant Liquid for Head 835	Photo 2: Tissue Simulant Liquid for Body 835

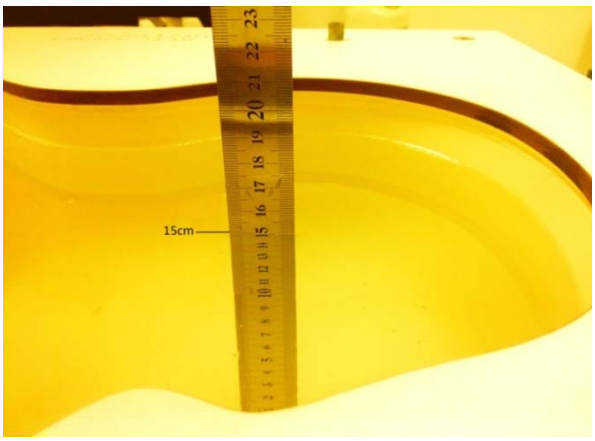
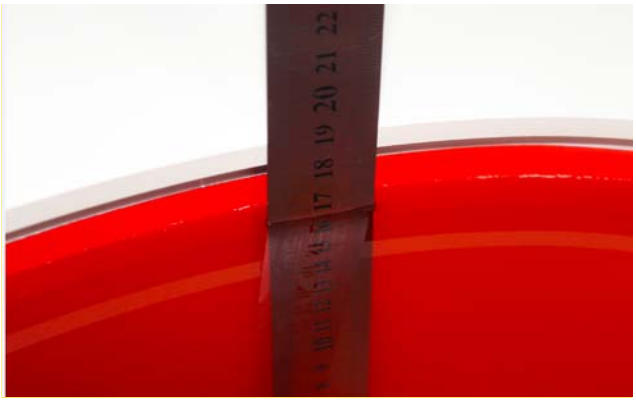

	

Photo 3: Tissue Simulant Liquid for Head 1750	**Photo 4: Tissue Simulant Liquid for Body 1750**

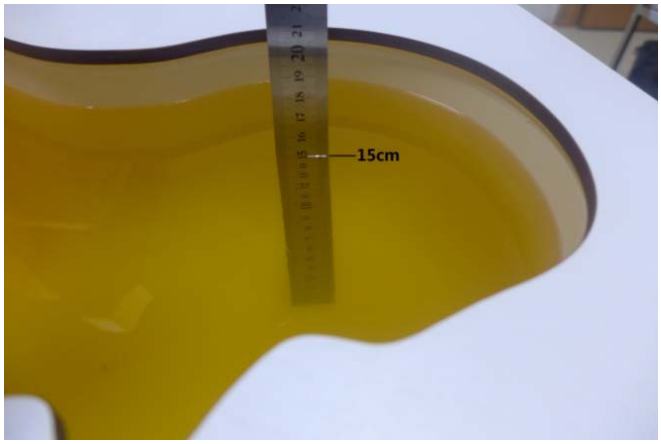
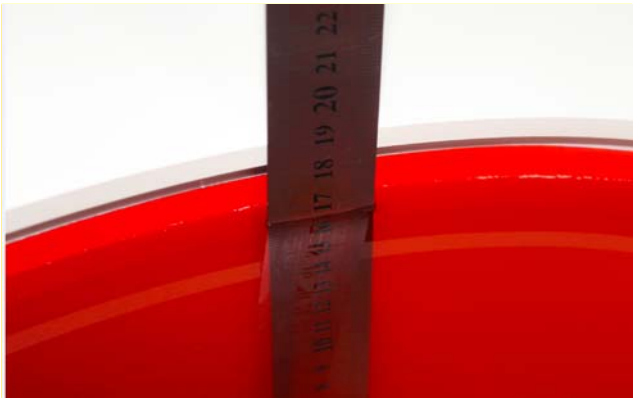

	

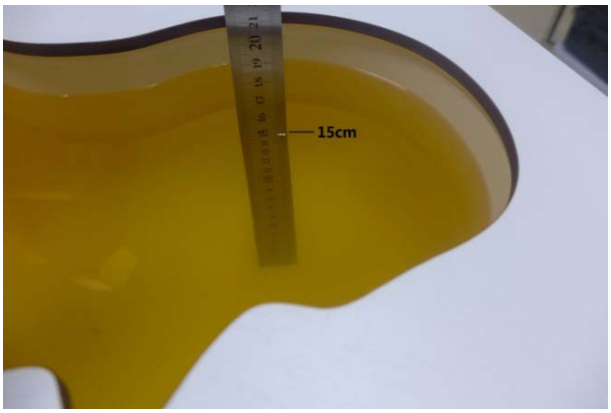
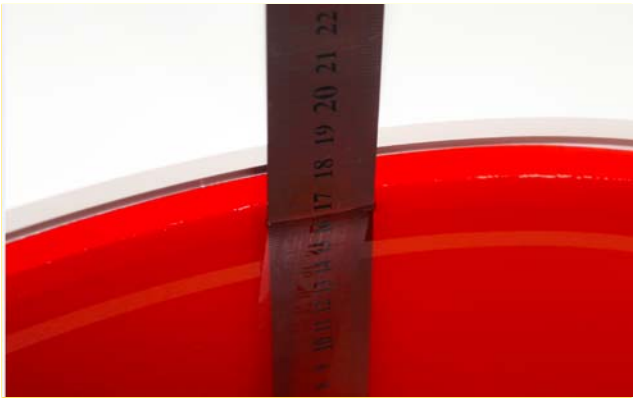
Photo 5: Tissue Simulant Liquid for Head 1900	**Photo 6: Tissue Simulant Liquid for Body 1900**
	

Photo 7: Tissue Simulant Liquid for Head 2300	Photo 8: Tissue Simulant Liquid for Body 2300

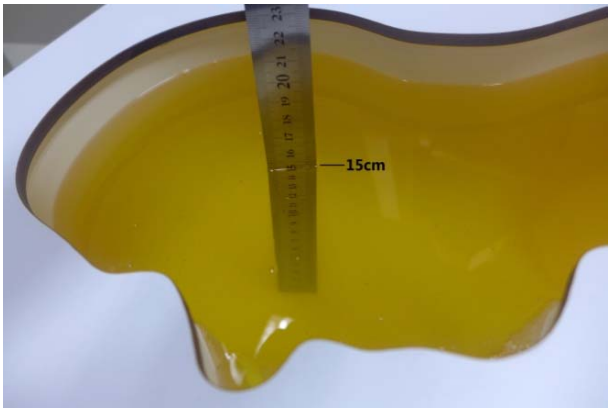
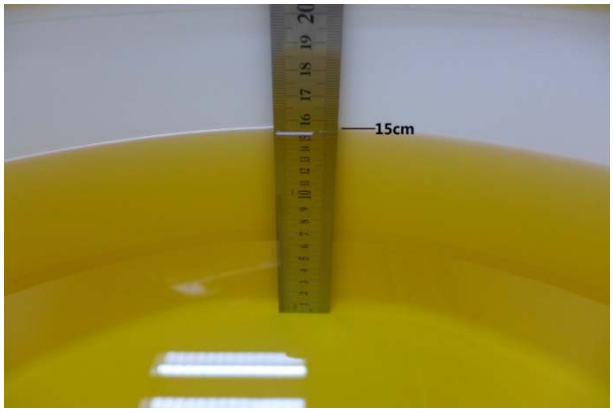

	

Photo 9: Tissue Simulant Liquid for Head 2450	**Photo 10: Tissue Simulant Liquid for Body 2450**

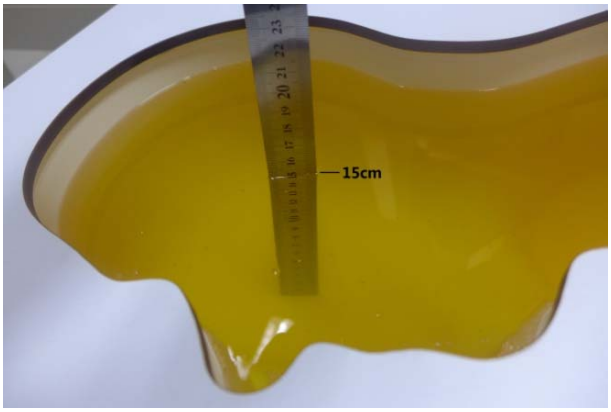
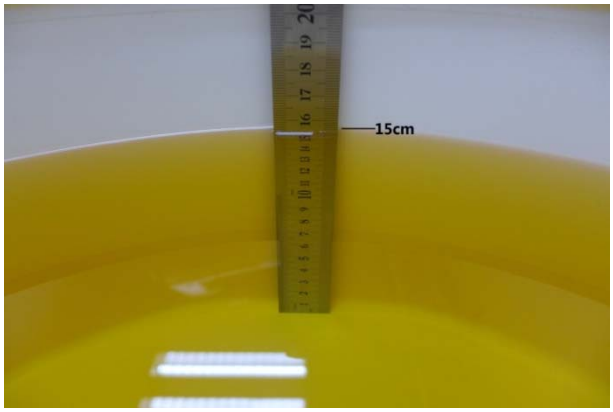
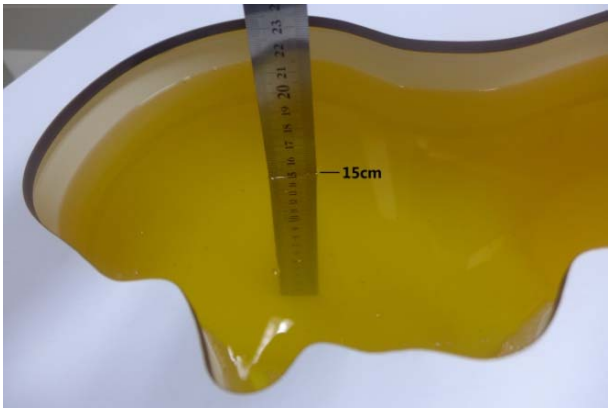
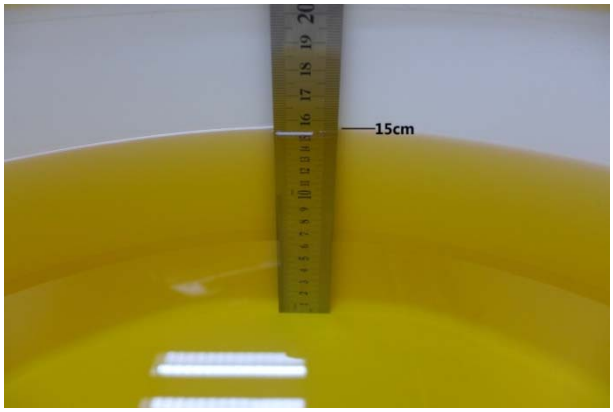

	

Photo 11: Tissue Simulant Liquid for Head 2600	**Photo 12: Tissue Simulant Liquid for Body 2600**
	

3. Photographs of EUT test position

Photo 13: Left touch cheek	Photo 14: Left tilted 15 degree

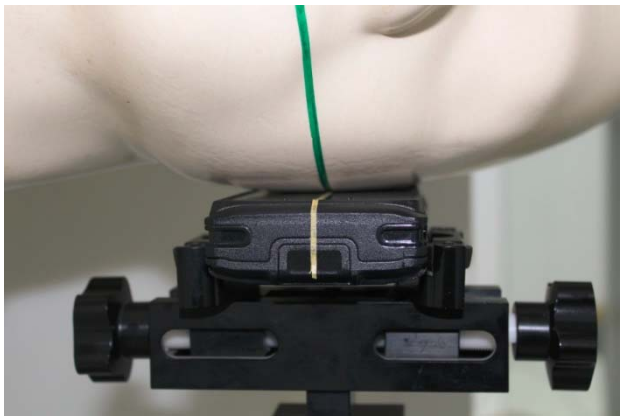
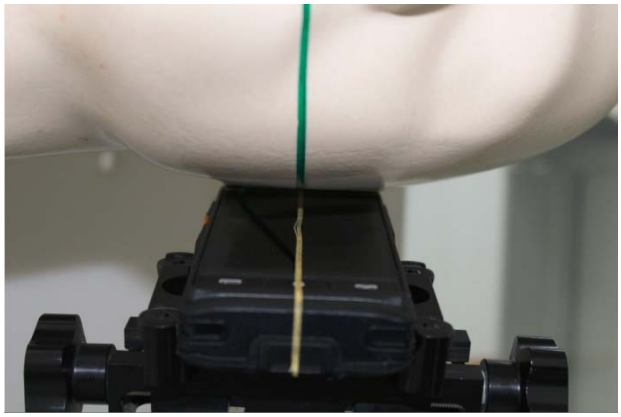

	

Photo 15: Right touch cheek	**Photo 16: Right tilted 15 degree**

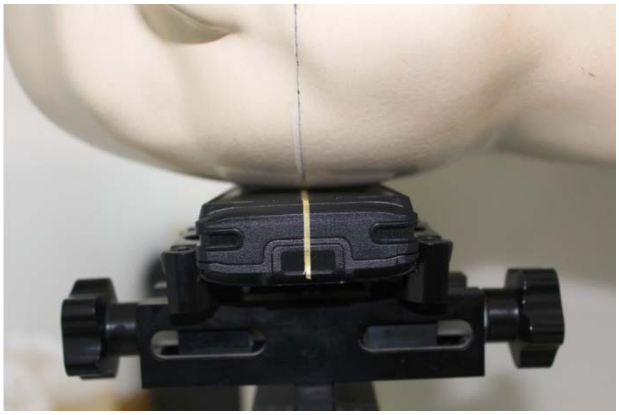
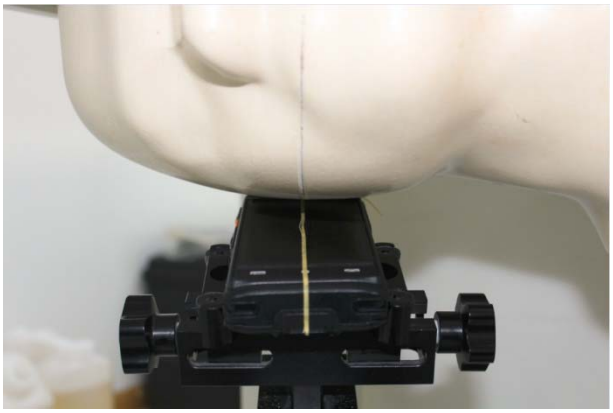

	

Photo 17: Front side 15mm	**Photo 18: Back side 15mm**

Photo 19: Front side 10mm	Photo 20: Back side 10mm
Photo 21: Left side 10mm	**Photo 22: Right side 10mm**
Photo 23: Bottom side 10mm	**Photo 24: Back side 0mm**

4. EUT Constructional Details

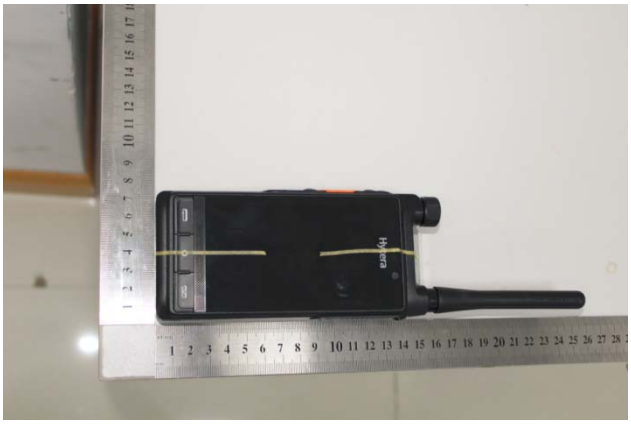



Photo 25: Front View	Photo 26: Back View