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Tissue Parameters Appendix

SAR measurements were made within 24 hours of the measurement of liquid parameters.

Recipe for liquids below 1 GHz:

Water 35-58%

Sugar 40-60%

Salt 0-6%

Hydroxyethyl-cellulose <0.3%

Preventol-D7 0.1-0.7%

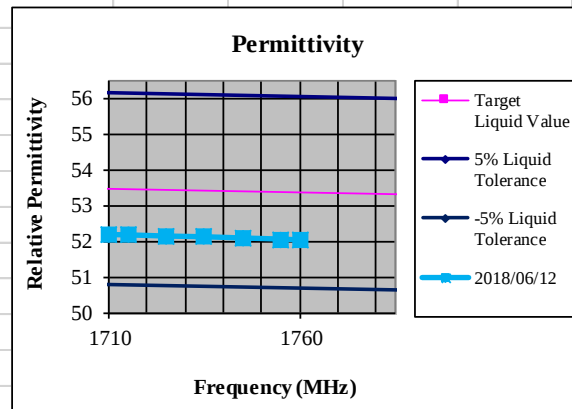
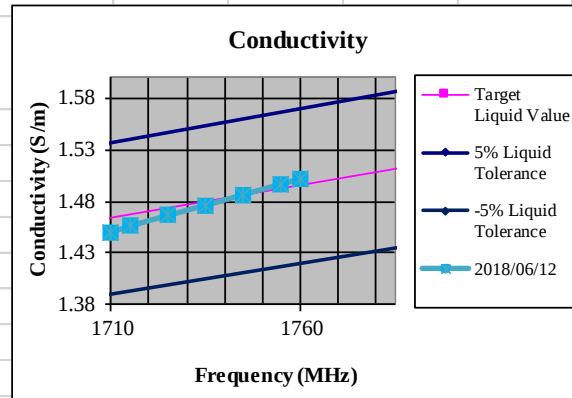
Recipe for liquids above 1-3 GHz:

Water 52-75%

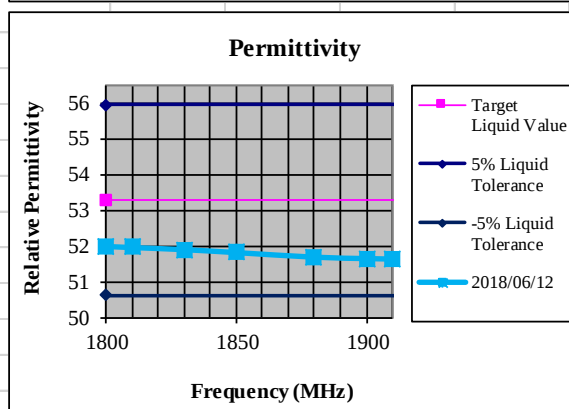
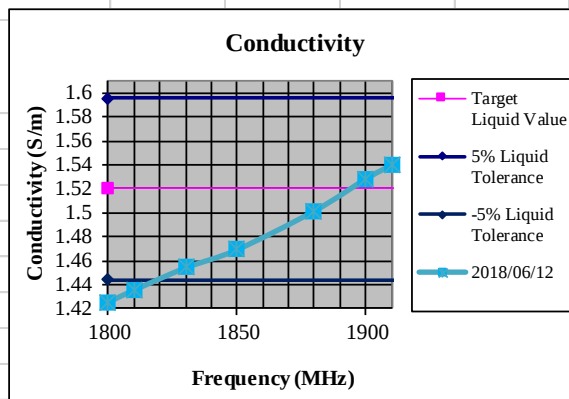
DGBE 25-48%

Salt <1.0%

1750 MHz Body Liquid

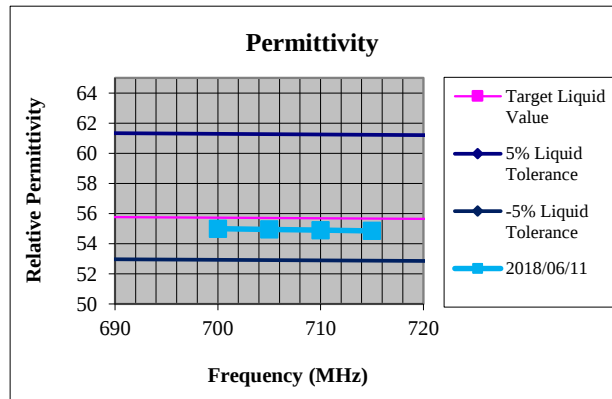
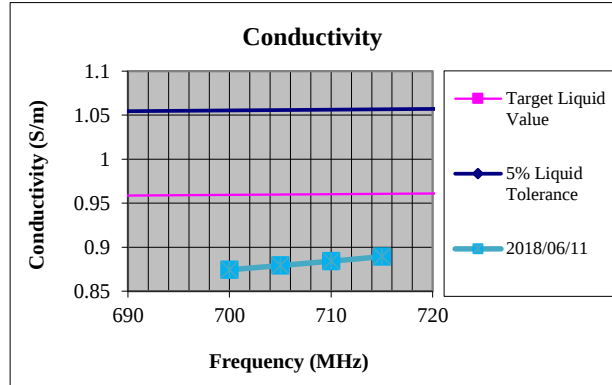
[illegible]

1900 MHz Body Liquid

[illegible]

750 MHz Body Liquid

Date	Temp (°C)	Frequency (MHz)	Relative Permativity	Conductivity (S/m)
2018/06/11	21.9	700	54.9972	0.8743
		705	54.946	0.8792
		710	54.905	0.8841
		715	54.851	0.8893



Test Equipment Appendix

SAR1 Lab

Instrument description	Supplier / Manufacturer	Model	Serial No.	Calibration (date)	Calibration Due (date)
Robot	Staubli	TX90	F10/5D3NA1/A/01	N/A	N/A
Elliptical Phantom	SPEAG	QD OVA 001 BB	1092	N/A	N/A
Software	SPEAG	Dasy52 52.8.8.1222	N/A	N/A	N/A
Device Holder	SPEAG	SD 000H01	N/A	N/A	N/A
Data Acquisition Electronics	SPEAG	DAE4	1266	2017/05/16	2019/05/16
SAR Probe	SPEAG	ES3DV3	3323	2017/05/12	2019/05/12

Shared Equipment

Instrument description	Supplier / Manufacturer	Model	Serial No.	Calibration (date)	Calibration Due (date)
750 MHz Head Tissue Simulant	SPEAG	MSL750	110526-1	2018/06/11	N/A
1750 MHz Head Tissue Simulant	SPEAG	MSL1750	100824-2	2018/06/12	N/A
1900 MHz Head Tissue Simulant	SPEAG	MSL1900	110615-4	2018/05/10	N/A
750 MHz Dipole	SPEAG	D750V3	11032	2016/05/11	N/A
1750 MHz Dipole	SPEAG	D1750V2	1045	2016/05/11	N/A
1900 MHz Dipole	SPEAG	D1900V2	5d135	2016/04/25	N/A
RF Amplifier	Amp. Research	30S1G3	N/A	N/A	N/A
Dielectric Measurement Kit	SPEAG	DAK-3.5	1118	2017/05/10	2019/05/10
Synthesized CW Generator	Agilent	83712B	US37101255	N/A	N/A
Network Analyzer	Agilent	N9923A	MY51491621	2017/08/16	2019/08/16
Power Sensor	Agilent	E9300A	MY41400484	2017/08	2020/08
Power Sensor	Agilent	E9300A	MY41400492	2017/08	2020/08
Power Meter	Agilent	E4419B	MY45101996	2017/08	2020/08
Radio Communications Tester	Rohde & Schwarz	CMW 500	127068	2015/3/12	2018/3/12

Equipment Calibration/Performance Documents

The following pages are calibration reports for:

- SAR Probe ES3DV3
- DAE4 SN1266
- 750MHz Validation Dipole D750V3
- 1750MHz Validation Dipole D1750V2
- 1900MHZ Validation Dipole D1900V2

1.1. ES3DV3-SN3323 May 2017

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



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

Accreditation No.: **SCS 0108**

Client **Cetecom USA**

Certificate No: **ES3-3323_May17**

CALIBRATION CERTIFICATE

Object **ES3DV3 - SN:3323**

Calibration procedure(s) **QA CAL-01.v9, QA CAL-23.v5, QA CAL-25.v6
Calibration procedure for dosimetric E-field probes**

Calibration date: **May 12, 2017**

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-17 (No. 217-02521/02522)	Apr-18
Power sensor NRP-Z91	SN: 103244	04-Apr-17 (No. 217-02521)	Apr-18
Power sensor NRP-Z91	SN: 103245	04-Apr-17 (No. 217-02525)	Apr-18
Reference 20 dB Attenuator	SN: S5277 (20x)	07-Apr-17 (No. 217-02528)	Apr-18
Reference Probe ES3DV2	SN: 3013	31-Dec-16 (No. ES3-3013_Dec16)	Dec-17
DAE4	SN: 660	7-Dec-16 (No. DAE4-660_Dec16)	Dec-17
Secondary Standards	ID	Check Date (in house)	Scheduled Check
Power meter E4419B	SN: GB41293874	06-Apr-16 (in house check Jun-16)	In house check: Jun-18
Power sensor E4412A	SN: MY41498087	06-Apr-16 (in house check Jun-16)	In house check: Jun-18
Power sensor E4412A	SN: 000110210	06-Apr-16 (in house check Jun-16)	In house check: Jun-18
RF generator HP 8648C	SN: US3642U01700	04-Aug-99 (in house check Jun-16)	In house check: Jun-18
Network Analyzer HP 8753E	SN: US37390585	18-Oct-01 (in house check Oct-16)	In house check: Oct-17

Calibrated by:	Name Michael Weber	Function Laboratory Technician	Signature
Approved by:	Katja Pokovic	Technical Manager	

Issued: May 16, 2017

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

Certificate No: ES3-3323_May17

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Zeughausstrasse 43, 8004 Zurich, Switzerland



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Accreditation No.: **SCS 0108**

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., $\vartheta = 0$ 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, "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
- 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 $\vartheta = 0$ ($f \leq 900$ 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 E²-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).

ES3DV3 – SN:3323

May 12, 2017

Probe ES3DV3

SN:3323

Manufactured:	January 10, 2012
Calibrated:	May 12, 2017

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

ES3DV3– SN:3323

May 12, 2017

DASY/EASY - Parameters of Probe: ES3DV3 - SN:3323

Basic Calibration Parameters

	Sensor X	Sensor Y	Sensor Z	Unc (k=2)
Norm ($\mu\text{V}/(\text{V}/\text{m})^2$) ^A	0.94	1.03	0.95	± 10.1 %
DCP (mV) ^B	106.4	106.6	104.4	

Modulation Calibration Parameters

UID	Communication System Name		A dB	B dB/ $\sqrt{\mu\text{V}}$	C	D dB	VR mV	Unc ^E (k=2)
0	CW	X	0.0	0.0	1.0	0.00	178.8	±2.7 %
		Y	0.0	0.0	1.0		195.7	
		Z	0.0	0.0	1.0		187.4	

Note: For details on UID parameters see Appendix.

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.

ES3DV3– SN:3323

May 12, 2017

DASY/EASY - Parameters of Probe: ES3DV3 - SN:3323

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)	Unc (k=2)
750	41.9	0.89	6.49	6.49	6.49	0.80	1.24	± 12.0 %
835	41.5	0.90	6.38	6.38	6.38	0.80	1.18	± 12.0 %
900	41.5	0.97	6.24	6.24	6.24	0.50	1.48	± 12.0 %
1750	40.1	1.37	5.47	5.47	5.47	0.74	1.19	± 12.0 %
1900	40.0	1.40	5.18	5.18	5.18	0.45	1.61	± 12.0 %
1950	40.0	1.40	5.12	5.12	5.12	0.80	1.17	± 12.0 %
2300	39.5	1.67	5.05	5.05	5.05	0.80	1.19	± 12.0 %
2450	39.2	1.80	4.68	4.68	4.68	0.76	1.28	± 12.0 %
2550	39.1	1.91	4.63	4.63	4.63	0.76	1.32	± 12.0 %

^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.

ES3DV3- SN:3323

May 12, 2017

DASY/EASY - Parameters of Probe: ES3DV3 - SN:3323

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)	Unc (k=2)
750	55.5	0.96	6.49	6.49	6.49	0.49	1.55	± 12.0 %
835	55.2	0.97	6.38	6.38	6.38	0.59	1.39	± 12.0 %
900	55.0	1.05	6.31	6.31	6.31	0.63	1.31	± 12.0 %
1750	53.4	1.49	5.15	5.15	5.15	0.55	1.46	± 12.0 %
1900	53.3	1.52	4.97	4.97	4.97	0.70	1.33	± 12.0 %
1950	53.3	1.52	5.09	5.09	5.09	0.62	1.44	± 12.0 %
2300	52.9	1.81	4.71	4.71	4.71	0.80	1.24	± 12.0 %
2450	52.7	1.95	4.60	4.60	4.60	0.80	1.16	± 12.0 %
2550	52.6	2.09	4.45	4.45	4.45	0.80	1.10	± 12.0 %

^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.

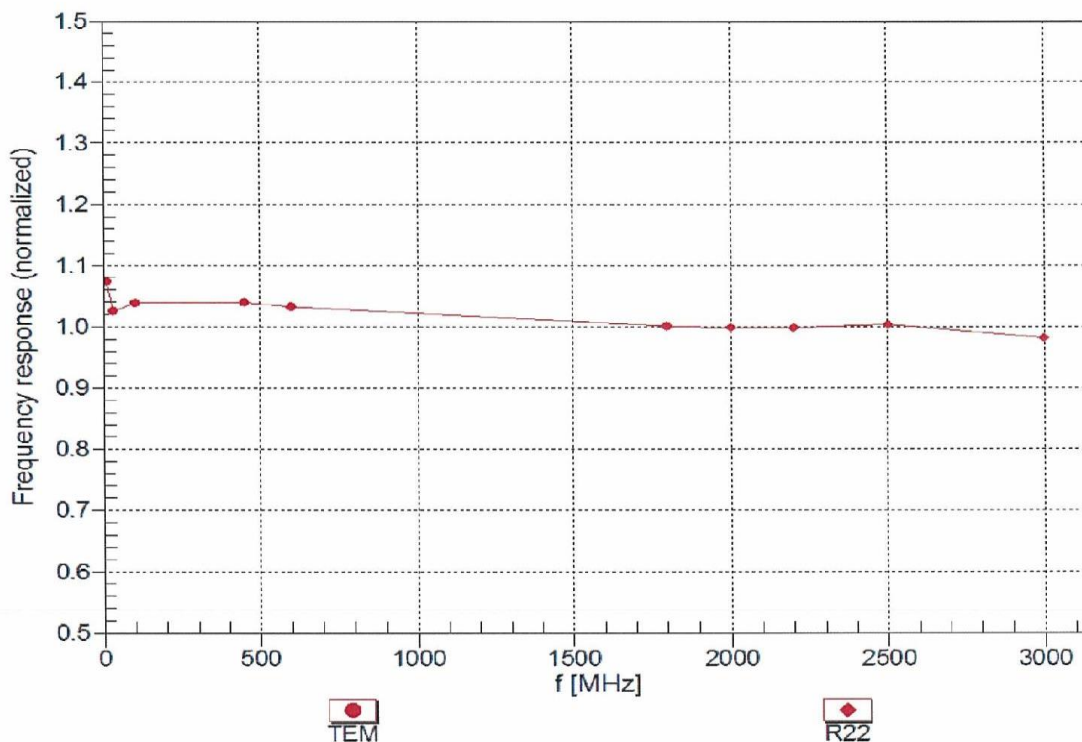
^F At frequencies below 3 GHz, the validity of tissue parameters (ϵ and σ) can be relaxed to ± 10% if liquid compensation formula is applied to measured SAR values. At frequencies above 3 GHz, the validity of tissue parameters (ϵ and σ) is restricted to ± 5%. The uncertainty is the RSS of the ConvF uncertainty 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.

ES3DV3– SN:3323

May 12, 2017

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



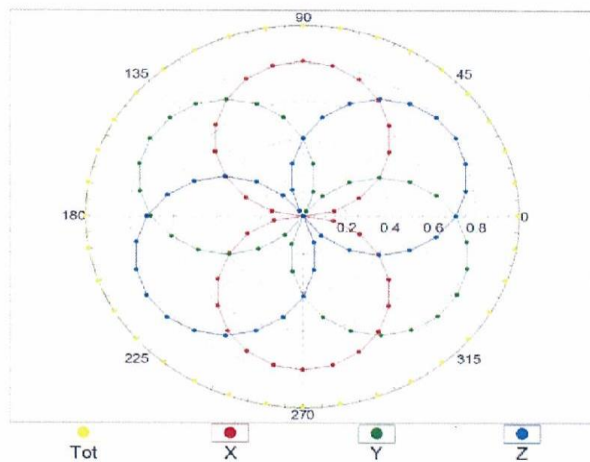
Uncertainty of Frequency Response of E-field: $\pm 6.3\%$ ($k=2$)

ES3DV3- SN:3323

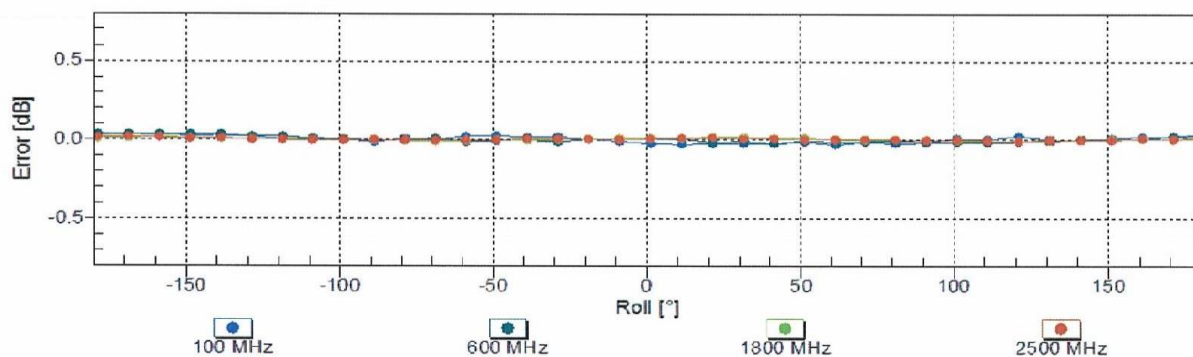
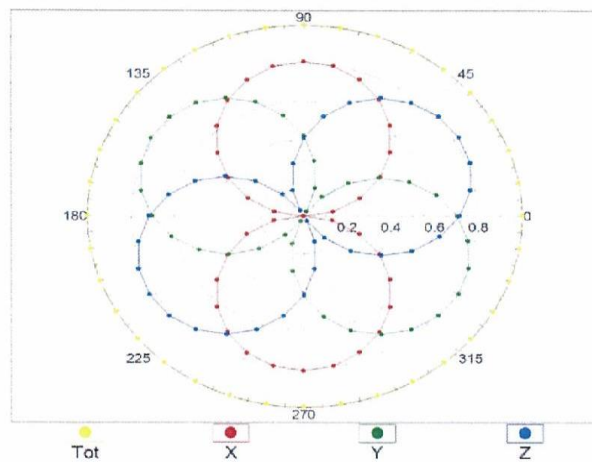
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Receiving Pattern (ϕ), $\theta = 0^\circ$

f=600 MHz,TEM



f=1800 MHz,R22

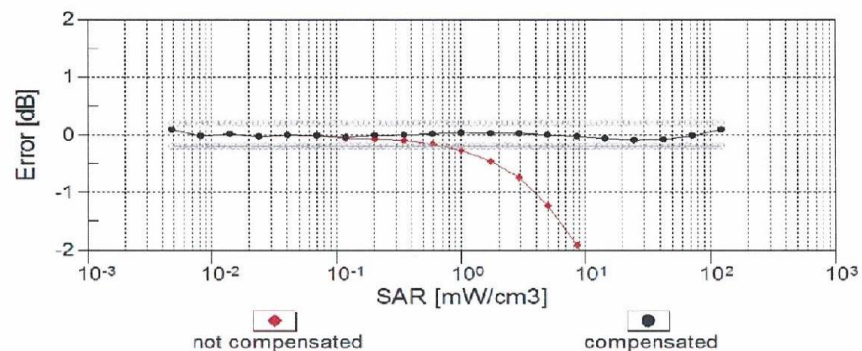
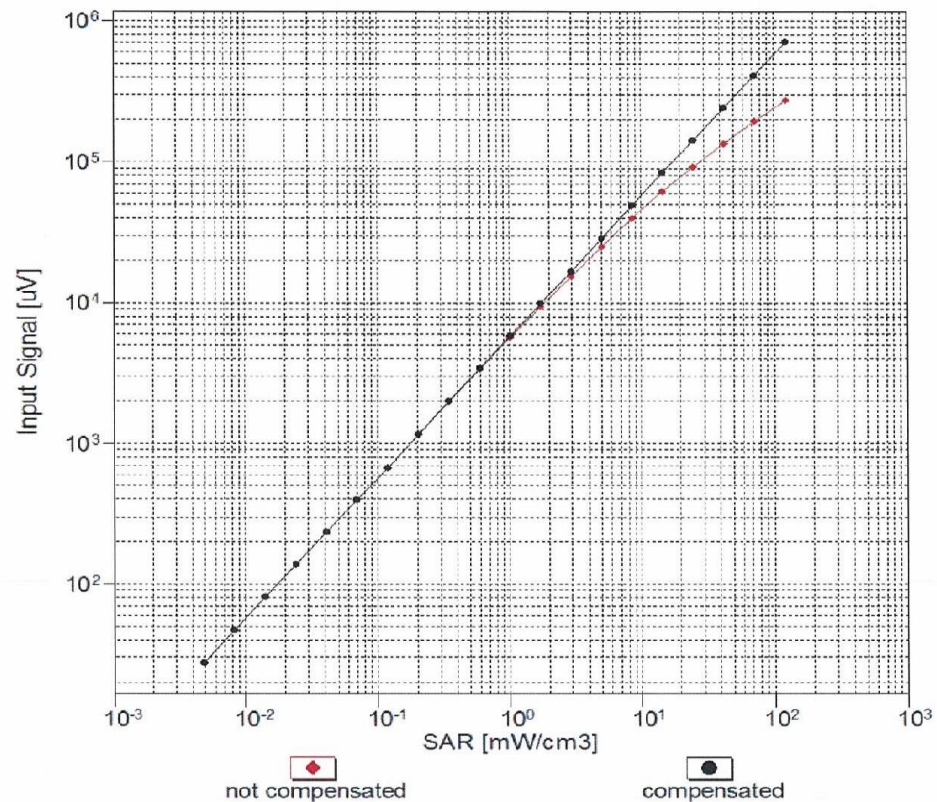


Uncertainty of Axial Isotropy Assessment: $\pm 0.5\%$ ($k=2$)

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Dynamic Range $f(\text{SAR}_{\text{head}})$ (TEM cell , $f_{\text{eval}} = 1900 \text{ MHz}$)

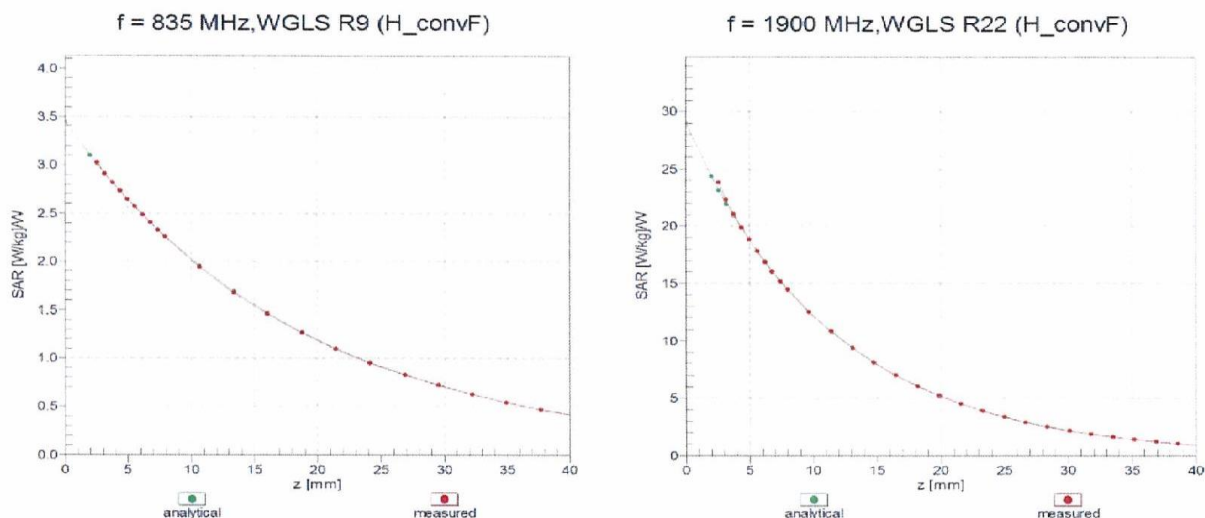


Uncertainty of Linearity Assessment: $\pm 0.6\%$ ($k=2$)

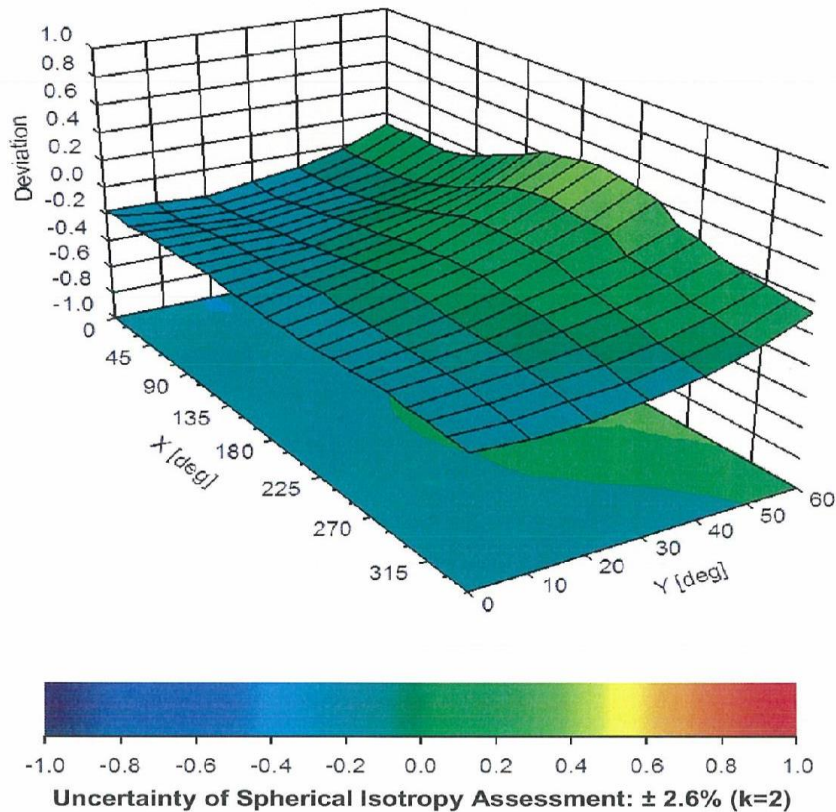
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May 12, 2017

Conversion Factor Assessment



Deviation from Isotropy in Liquid Error (ϕ , θ), f = 900 MHz



ES3DV3– SN:3323

May 12, 2017

DASY/EASY - Parameters of Probe: ES3DV3 - SN:3323

Other Probe Parameters

Sensor Arrangement	Triangular
Connector Angle (°)	21.3
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

ES3DV3- SN:3323

May 12, 2017

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	178.8	±2.7 %
		Y	0.0	0.0	1.0		195.7	
		Z	0.0	0.0	1.0		187.4	
10011-CAB	UMTS-FDD (WCDMA)	X	3.56	68.3	18.9	2.91	145.1	±0.5 %
		Y	3.48	68.5	19.3		114.5	
		Z	3.47	67.8	18.8		108.4	
10021-DAC	GSM-FDD (TDMA, GMSK)	X	18.67	89.6	25.0	9.39	98.4	±0.9 %
		Y	34.44	99.7	29.0		134.0	
		Z	31.99	99.1	29.3		124.4	
10024-DAC	GPRS-FDD (TDMA, GMSK, TN 0-1)	X	20.55	88.1	22.3	6.56	109.6	±1.2 %
		Y	51.06	99.6	26.0		95.2	
		Z	15.88	83.4	21.7		135.6	
10027-DAC	GPRS-FDD (TDMA, GMSK, TN 0-1-2)	X	28.40	90.0	21.2	4.80	120.0	±1.4 %
		Y	61.08	99.9	24.7		101.3	
		Z	25.01	90.0	22.6		137.7	
10028-DAC	GPRS-FDD (TDMA, GMSK, TN 0-1-2-3)	X	7.58	74.1	15.1	3.55	123.4	±1.7 %
		Y	53.57	99.6	24.1		102.2	
		Z	55.82	99.7	24.2		137.0	
10081-CAB	CDMA2000 (1xRTT, RC3)	X	4.14	66.8	18.6	3.97	138.2	±0.7 %
		Y	3.99	66.3	18.6		114.4	
		Z	4.25	67.3	19.0		142.3	
10100-CAC	LTE-FDD (SC-FDMA, 100% RB, 20 MHz, QPSK)	X	6.14	66.4	18.9	5.67	109.4	±1.2 %
		Y	6.46	67.7	19.7		129.2	
		Z	6.37	67.1	19.3		118.1	
10103-CAC	LTE-TDD (SC-FDMA, 100% RB, 20 MHz, QPSK)	X	11.48	75.6	25.1	9.29	113.2	±2.7 %
		Y	14.25	80.5	27.5		149.5	
		Z	13.70	78.8	26.5		138.0	
10108-CAD	LTE-FDD (SC-FDMA, 100% RB, 10 MHz, QPSK)	X	6.15	66.3	19.0	5.80	109.8	±1.2 %
		Y	6.44	67.5	19.8		128.5	
		Z	6.40	67.1	19.4		118.4	
10151-CAC	LTE-TDD (SC-FDMA, 50% RB, 20 MHz, QPSK)	X	11.01	75.2	25.1	9.28	109.5	±2.7 %
		Y	13.57	79.9	27.3		143.3	
		Z	13.17	78.3	26.4		133.0	
10154-CAD	LTE-FDD (SC-FDMA, 50% RB, 10 MHz, QPSK)	X	5.89	65.9	18.8	5.75	108.2	±1.2 %
		Y	6.14	66.9	19.5		126.4	
		Z	6.09	66.5	19.1		116.2	
10169-CAC	LTE-FDD (SC-FDMA, 1 RB, 20 MHz, QPSK)	X	5.20	67.0	19.5	5.73	133.6	±0.9 %
		Y	4.97	66.0	19.1		111.8	
		Z	5.40	67.4	19.9		144.2	

ES3DV3– SN:3323

May 12, 2017

10172-CAC	LTE-TDD (SC-FDMA, 1 RB, 20 MHz, QPSK)	X	10.80	80.1	27.4	9.21	126.2	±2.2 %
		Y	11.04	79.5	27.2		107.6	
		Z	12.99	82.8	28.5		146.6	
10175-CAD	LTE-FDD (SC-FDMA, 1 RB, 10 MHz, QPSK)	X	5.19	67.0	19.5	5.72	132.5	±0.9 %
		Y	5.45	68.2	20.4		149.6	
		Z	5.37	67.3	19.8		137.9	
10297-AAB	LTE-FDD (SC-FDMA, 50% RB, 20 MHz, QPSK)	X	6.18	66.4	19.0	5.81	113.1	±1.2 %
		Y	6.44	67.5	19.8		123.2	
		Z	6.28	66.6	19.2		112.6	
10403-AAB	CDMA2000 (1xEV-DO, Rev. 0)	X	4.75	67.2	18.2	3.76	109.0	±0.5 %
		Y	4.72	67.0	18.3		123.7	
		Z	4.72	66.7	18.0		111.0	

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

