Appendix B: Calibration Certificates

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2 2450 MHZ DIPOLE 13

1 Probe EX3DV4 – SN: 3957

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

S Schweizerischer Kalibrierdienst
C Service suisse d'étalonnage
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S Swiss Calibration Service

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Accreditation No.: SCS 0108

Client DSPR (Auden)

Certificate No: EX3-3957_Mar17

CALIBRATION CERTIFICATE

Object: EX3DV4 - SN:3957

Calibration procedure(s): QA CAL-01.v9, QA CAL-14.v4, QA CAL-23.v5, QA CAL-25.v6
Calibration procedure for dosimetric E-field probes

Calibration date: March 23, 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	06-Apr-16 (No. 217-02288/02289)	Apr-17
Power sensor NRP-Z91	SN: 103244	06-Apr-16 (No. 217-02288)	Apr-17
Power sensor NRP-Z91	SN: 103245	06-Apr-16 (No. 217-02289)	Apr-17
Reference 20 dB Attenuator	SN: S5277 (20x)	05-Apr-16 (No. 217-02293)	Apr-17
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

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

Issued: March 23, 2017

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

Calibration Laboratory of
Schmid & Partner
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Glossary:

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

Calibration is Performed According to the Following Standards:

a) IEEE Std 1528-2013, "IEEE Recommended Practice for Determining the Peak Spatial-Averaged Specific Absorption Rate (SAR) in the Human Head from Wireless Communications Devices: Measurement Techniques", June 2013
b) IEC 62209-1, "Procedure to measure the Specific Absorption Rate (SAR) for hand-held devices used in close proximity to the ear (frequency range of 300 MHz to 3 GHz)", February 2005
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 ≤ 900 MHz in TEM-cell; f > 1800 MHz: R22 waveguide). NORMx,y,z are only intermediate values, i.e., the uncertainties of NORMx,y,z does not affect the E^2-field uncertainty inside TSL (see below *ConvF*).
- *NORM(f)x,y,z = NORMx,y,z * frequency_response* (see Frequency Response Chart). This linearization is implemented in DASY4 software versions later than 4.2. The uncertainty of the frequency response is included in the stated uncertainty of *ConvF*.
- *DCPx,y,z:* DCP are numerical linearization parameters assessed based on the data of power sweep with CW signal (no uncertainty required). DCP does not depend on frequency nor media.
- *PAR:* PAR is the Peak to Average Ratio that is not calibrated but determined based on the signal characteristics
- *Ax,y,z; Bx,y,z; Cx,y,z; Dx,y,z; VRx,y,z*: *A, B, C, D* are numerical linearization parameters assessed based on the data of power sweep for specific modulation signal. The parameters do not depend on frequency nor media. *VR* is the maximum calibration range expressed in RMS voltage across the diode.
- *ConvF and Boundary Effect Parameters:* Assessed in flat phantom using E-field (or Temperature Transfer Standard for f ≤ 800 MHz) and inside waveguide using analytical field distributions based on power measurements for f > 800 MHz. The same setups are used for assessment of the parameters applied for boundary compensation (alpha, depth) of which typical uncertainty values are given. These parameters are used in DASY4 software to improve probe accuracy close to the boundary. The sensitivity in TSL corresponds to *NORMx,y,z * ConvF* whereby the uncertainty corresponds to that given for *ConvF*. A frequency dependent *ConvF* is used in DASY version 4.4 and higher which allows extending the validity from ± 50 MHz to ± 100 MHz.
- *Spherical isotropy (3D deviation from isotropy)*: in a field of low gradients realized using a flat phantom exposed by a patch antenna.
- *Sensor Offset*: The sensor offset corresponds to the offset of virtual measurement center from the probe tip (on probe axis). No tolerance required.
- *Connector Angle*: The angle is assessed using the information gained by determining the *NORMx* (no uncertainty required).

Probe EX3DV4

SN:3957

Manufactured: August 6, 2013
Calibrated: March 23, 2017

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

DASY/EASY - Parameters of Probe: EX3DV4 - SN:3957

Basic Calibration Parameters

	Sensor X	Sensor Y	Sensor Z	Unc (k=2)
Norm ($\mu V/(V/m)^2$)[A]	0.44	0.44	0.46	± 10.1 %
DCP (mV)[B]	103.2	102.4	99.6	

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	140.0	±2.7 %
		Y	0.0	0.0	1.0		158.8	
		Z	0.0	0.0	1.0		140.2	

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 Pages 5 and 6).
[B] Numerical linearization parameter: uncertainty not required.
[E] Uncertainty is determined using the max. deviation from linear response applying rectangular distribution and is expressed for the square of the field value.

DASY/EASY - Parameters of Probe: EX3DV4 - SN:3957

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	11.01	11.01	11.01	0.47	0.95	± 12.0 %
835	41.5	0.90	10.48	10.48	10.48	0.52	0.80	± 12.0 %
900	41.5	0.97	10.28	10.28	10.28	0.55	0.80	± 12.0 %
1450	40.5	1.20	8.92	8.92	8.92	0.35	0.80	± 12.0 %
1640	40.2	1.31	8.84	8.84	8.84	0.23	0.80	± 12.0 %
1750	40.1	1.37	8.76	8.76	8.76	0.37	0.80	± 12.0 %
1900	40.0	1.40	8.58	8.58	8.58	0.35	0.80	± 12.0 %
1950	40.0	1.40	8.40	8.40	8.40	0.31	0.80	± 12.0 %
2300	39.5	1.67	8.18	8.18	8.18	0.31	0.80	± 12.0 %
2450	39.2	1.80	7.82	7.82	7.82	0.32	0.80	± 12.0 %
2600	39.0	1.96	7.55	7.55	7.55	0.35	0.86	± 12.0 %
3500	37.9	2.91	7.46	7.46	7.46	0.30	1.20	± 13.1 %
5200	36.0	4.66	5.54	5.54	5.54	0.35	1.80	± 13.1 %
5300	35.9	4.76	5.24	5.24	5.24	0.35	1.80	± 13.1 %
5500	35.6	4.96	5.02	5.02	5.02	0.40	1.80	± 13.1 %
5600	35.5	5.07	4.81	4.81	4.81	0.40	1.80	± 13.1 %
5800	35.3	5.27	4.86	4.86	4.86	0.40	1.80	± 13.1 %

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

DASY/EASY - Parameters of Probe: EX3DV4 - SN:3957

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	10.71	10.71	10.71	0.44	0.89	± 12.0 %
835	55.2	0.97	10.39	10.39	10.39	0.36	0.96	± 12.0 %
900	55.0	1.05	10.35	10.35	10.35	0.46	0.80	± 12.0 %
1450	54.0	1.30	8.70	8.70	8.70	0.32	0.80	± 12.0 %
1640	53.7	1.42	8.97	8.97	8.97	0.40	0.81	± 12.0 %
1750	53.4	1.49	8.53	8.53	8.53	0.41	0.80	± 12.0 %
1900	53.3	1.52	8.25	8.25	8.25	0.36	0.86	± 12.0 %
1950	53.3	1.52	8.48	8.48	8.48	0.37	0.80	± 12.0 %
2300	52.9	1.81	8.09	8.09	8.09	0.37	0.82	± 12.0 %
2450	52.7	1.95	7.98	7.98	7.98	0.26	0.96	± 12.0 %
2600	52.5	2.16	7.65	7.65	7.65	0.21	0.95	± 12.0 %
3500	51.3	3.31	7.01	7.01	7.01	0.28	1.20	± 13.1 %
5200	49.0	5.30	4.69	4.69	4.69	0.45	1.90	± 13.1 %
5300	48.9	5.42	4.56	4.56	4.56	0.40	1.90	± 13.1 %
5500	48.6	5.65	4.09	4.09	4.09	0.50	1.90	± 13.1 %
5600	48.5	5.77	4.11	4.11	4.11	0.50	1.90	± 13.1 %
5800	48.2	6.00	4.16	4.16	4.16	0.50	1.90	± 13.1 %

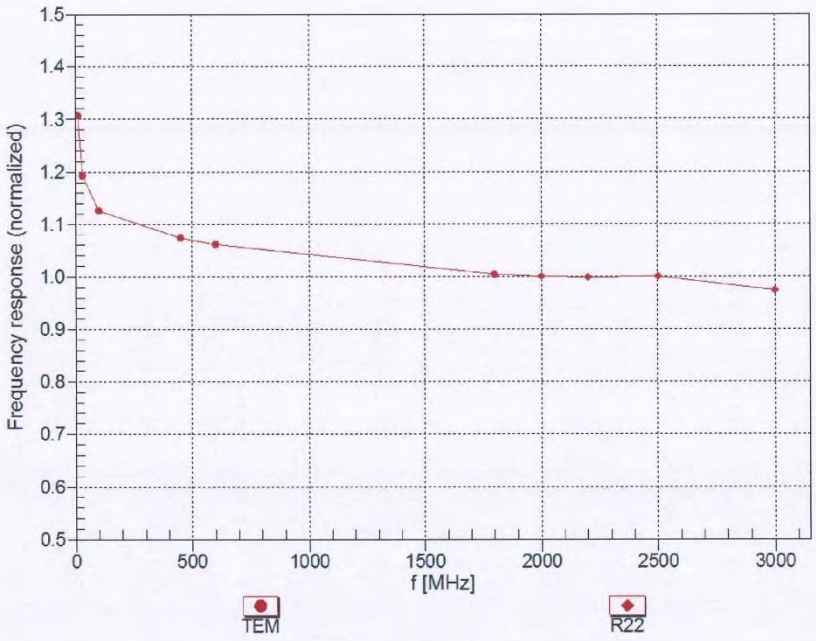
[C] Frequency validity above 300 MHz of ± 100 MHz only applies for DASY v4.4 and higher (see Page 2), else it is restricted to ± 50 MHz. The uncertainty is the RSS of the ConvF uncertainty at calibration frequency and the uncertainty for the indicated frequency band. Frequency validity below 300 MHz is ± 10, 25, 40, 50 and 70 MHz for ConvF assessments at 30, 64, 128, 150 and 220 MHz respectively. Above 5 GHz frequency validity can be extended to ± 110 MHz.

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

[G] Alpha/Depth are determined during calibration. SPEAG warrants that the remaining deviation due to the boundary effect after compensation is always less than ± 1% for frequencies below 3 GHz and below ± 2% for frequencies between 3-6 GHz at any distance larger than half the probe tip diameter from the boundary.

Frequency Response of E-Field

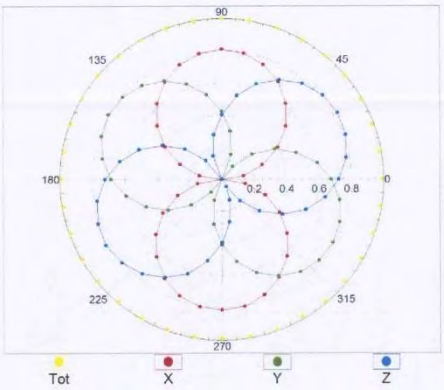
(TEM-Cell:ifi110 EXX, Waveguide: R22)



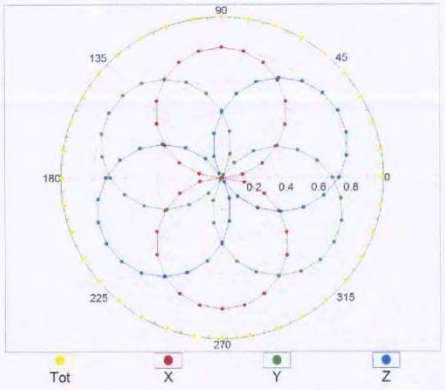
Uncertainty of Frequency Response of E-field: ± 6.3% (k=2)

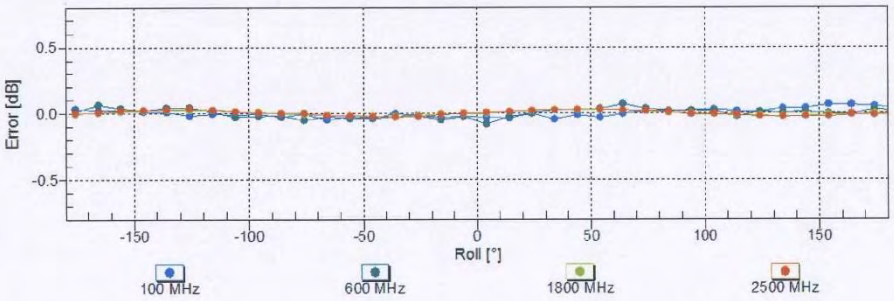
Receiving Pattern (ϕ), ϑ = 0°

f=600 MHz,TEM



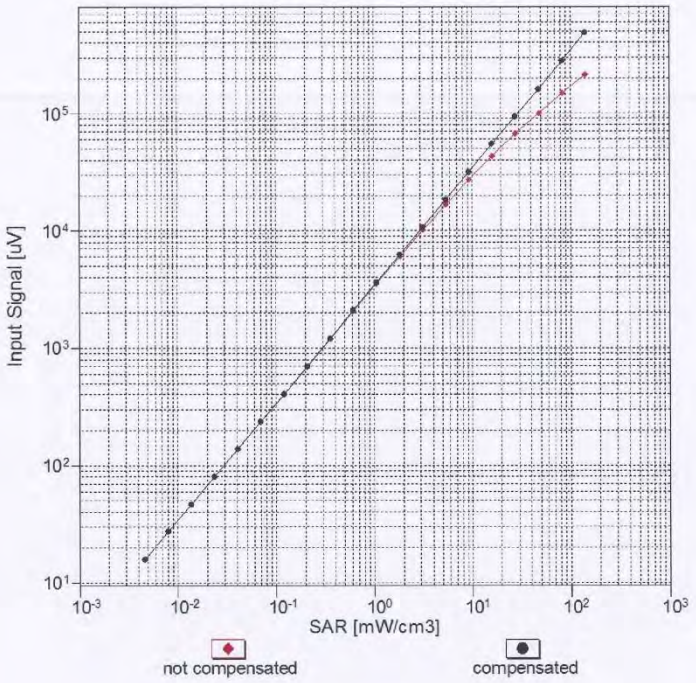
f=1800 MHz,R22

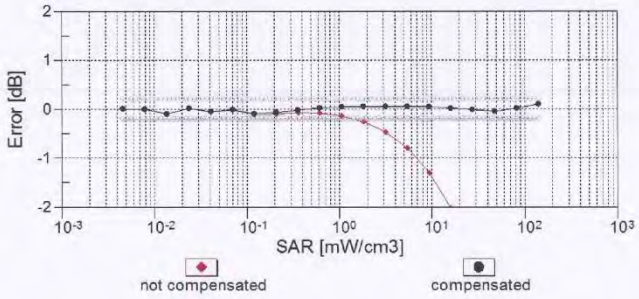




Uncertainty of Axial Isotropy Assessment: ± 0.5% (k=2)

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



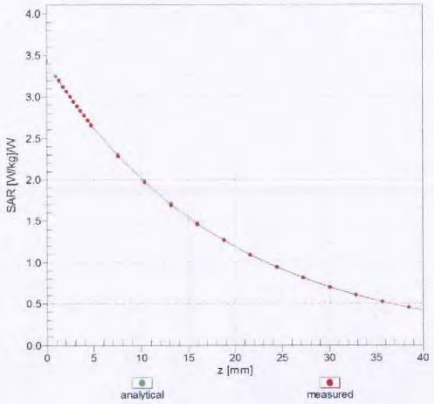


Uncertainty of Linearity Assessment: ± 0.6% (k=2)

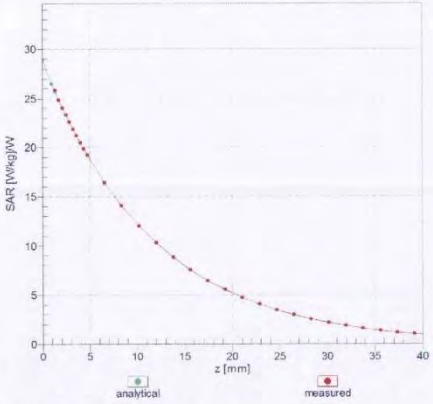
EX3DV4– SN:3957 March 23, 2017

Conversion Factor Assessment

f = 835 MHz,WGLS R9 (H_convF)

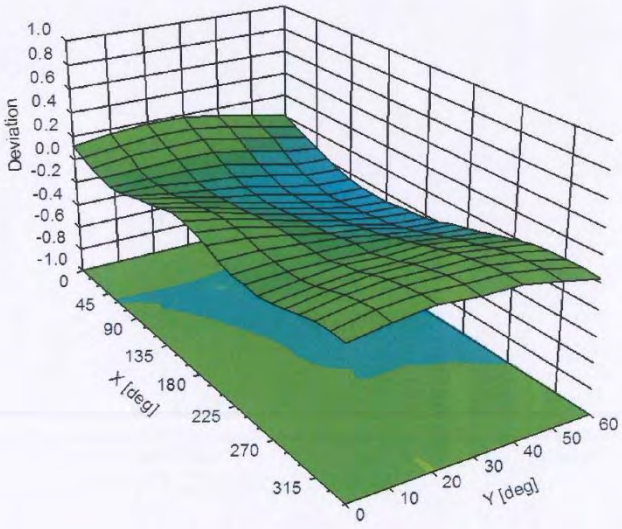


f = 1900 MHz,WGLS R22 (H_convF)



Deviation from Isotropy in Liquid

Error (ϕ, ϑ), f = 900 MHz



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

DASY/EASY - Parameters of Probe: EX3DV4 - SN:3957

Other Probe Parameters

Sensor Arrangement	Triangular
Connector Angle (°)	-15.9
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

2 2450 MHz Dipole

CERTIFICATE OF CALIBRATION

ISSUED BY **UL VS LTD**

DATE OF ISSUE: 20/Mar/2017 CERTIFICATE NUMBER : 11625828JD01G

UKAS CALIBRATION 5248

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Email: calibration.uk@ul.com

APPROVED SIGNATORY

M. Nasser

.....

Naseer Mirza

Customer :
TUV Rheinland of North America Inc
5015 Brandin Court
Fremont, CA 94538, USA

Equipment Details:

Description:	Dipole Validation Kit	Date of Receipt:	20/Dec/2016
Manufacturer:	IMST		
Type/Model Number:	diSARA2450		
Serial Number:	304324-2402103		
Calibration Date:	13/Mar/2017		
Calibrated By:	Chanthu Thevarajah Laboratory Engineer		
Signature:			

.....

All Calibration have been conducted in the closed laboratory facility: Lab Temperature (22±3) °C and humidity < 70%

This certificate is issued in accordance with the laboratory accreditation requirements of the United Kingdom Accreditation Service. It provides traceability of measurement to the SI system of units and/or to units of measurement realised at the National Physical Laboratory or other recognised national metrology institutes. This certificate may not be reproduced other than in full, except with the prior written approval of the issuing laboratory.
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The calibration methods and procedures used were as detailed in:

1. **IEC 62209-1:2005**: Procedure to determine the specific absorption rate (SAR) for hand-held devices used in close proximity to the ear (frequency range of 300 MHz to 3 GHz)
2. **IEC 62209-2:2010:** 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)
3. **IEEE 1528: 2013:** IEEE Recommended Practice for Determining the Peak Spatial-Average Specific Absorption Rate (SAR) in the Human Head from Wireless Communication Devices: Measurement Techniques
4. FCC KDB Publication Number: **"KDB865664 D01 SAR Measurement 100 MHz to 6 GHz"**
5. **SPEAG DASY4/ DASY5 System Handbook**

The measuring equipment used to perform the calibration, documented in this certificate has been calibrated in accordance with the manufacturers' recommendations, and is traceable to recognized national standards.

UL No.	Instrument	Manufacturer	Type No.	Serial No.	Date Last Calibrated	Cal. Interval (Months)
A2110	Data Acquisition Electronics	SPEAG	DAE4	431	18 Nov 2016	12
A2077	Probe	SPEAG	EX3DV4	3814	30 Sep 2016	12
A1322	Dipole	SPEAG	D2450V2	725	29 Sep 2016	12
PRE0151451	Power Monitoring Kit	Art-Fi	ART 100850-01	0001	Cal as part of System	12
PRE0151441	Power Sensor	Rhode & Schwarz	NRP8S	102481	16 Nov 2016	12
M1015	Network Analyser	Agilent Technologies	8753ES	US39172406	26 Sept 2016	12
PRE0151154	Network Analyser	Rhode & Schwarz	ZND8	100151	22 Nov 2016	12
PRE0151877	Calibration Kit	Rhode & Schwarz	Z135	102947-Bt	02 Dec 2016	12
M1768	Signal Generator	Rhode & Schwarz	SME06	837633/001	08 Nov 2016	12

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CERTIFICATE NUMBER : 11625828JD01G

SAR System Specification

Robot System Positioner:	Stäubli Unimation Corp. Robot Model: RX90L
Robot Serial Number:	F00/SD89A1/A/01
DASY Version:	DASY 4 (v4.7.80)
Phantom:	Flat section of SAM Twin Phantom
Distance Dipole Centre:	10 mm (with spacer)
Frequency:	2450 MHz

Dielectric Property Measurements – Head Simulating Liquid (HSL)

Simulant Liquid	Frequency (MHz)	Room Temp		Liquid Temp		Parameters	Target Value	Measured Value	Uncertainty (%)
		Start	End	Start	End				
Head	2450	21.0 °C	21.0 °C	21.0°C	21.0°C	**εr**	39.2	39.359	± 5%
						σ	1.8	1.758	± 5%

SAR Results – Head Simulating Liquid (HSL)

Simulant Liquid	SAR Measured	250 mW input Power	Normalised to 1.00 W	Uncertainty (%)
Head	SAR averaged over 1g	14.1 W/Kg	**56.4 W/Kg**	± 17.57%
	SAR averaged over 10g	6.33 W/Kg	**25.32 W/Kg**	± 17.32%

Antenna Parameters – Head Simulating Liquid (HSL)

Simulant Liquid	Parameter	Measured Level	Uncertainty (%)
Head	Impedance	50.52 Ω -2.35 jΩ	± 0.28 Ω ± 0.044 jΩ
	Return Loss	33.03	± 2.03 dB

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Dielectric Property Measurements – Body Simulating Liquid (MSL)

Simulant Liquid	Frequency (MHz)	Room Temp		Liquid Temp		Parameters	Target Value	Measured Value	Uncertainty (%)
		Start	End	Start	End				
Body	2450	21.0 ℃	21.0 ℃	21.0℃	21.0℃	εr	52.7	52.653	± 5%
						σ	1.95	2.025	± 5%

SAR Results – Body Simulating Liquid (MSL)

Simulant Liquid	**SAR Measured**	250 mW input Power	Normalised to 1.00 W	Uncertainty (%)
Body	SAR averaged over 1g	14 W/Kg	**56 W/Kg**	± 18.06%
	SAR averaged over 10g	6.29 W/Kg	**25.16 W/Kg**	± 17.44%

Antenna Parameters – Body Simulating Liquid (MSL)

Simulant Liquid	Parameter	Measured Level	Uncertainty (%)
Body	Impedance	46.91 Ω -2 jΩ	± 0.28 Ω ± 0.044 jΩ
	Return Loss	28.16	± 2.03 dB

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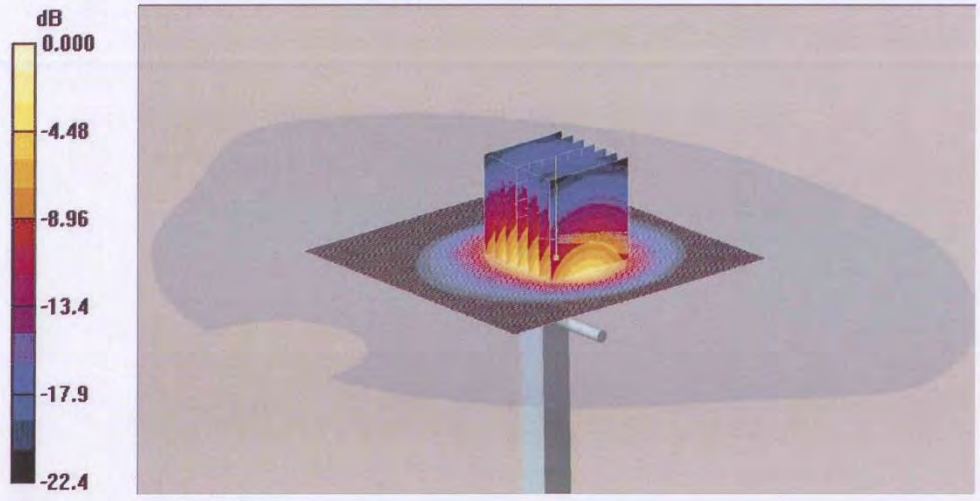
DASY Validation Scan for Head Stimulating Liquid (HSL)

DUT: diSARA2450MHz; Type: 2450; Serial: 304324-2402103



0 dB = 16.3mW/g

Communication System: CW; Frequency: 2450 MHz;Duty Cycle: 1:1
Medium: 835/2300/2450/2600 MHz HSL Medium parameters used: f = 2450 MHz; σ = 1.76 mho/m; ε_r = 39.4; ρ = 1000 kg/m^3
Phantom section: Flat Section

DASY4 Configuration:
- Probe: EX3DV4 - SN3814; ConvF(7.12, 7.12, 7.12);

- Sensor-Surface: 4mm (Mechanical Surface Detection)
- Electronics: DAE4 Sn431; Calibrated: 18/11/2016
- Phantom: SAM 12a (Site 57); Type: SAM 4.0; Serial: TP:1020
- Measurement SW: DASY4, V4.7 Build 80; Postprocessing SW: SEMCAD, V1.8 Build 186

d=10mm, Pin=250mW/Area Scan (81x81x1): Measurement grid: dx=12mm, dy=12mm
Maximum value of SAR (interpolated) = 16.9 mW/g
d=10mm, Pin=250mW/Zoom Scan (7x7x7) (7x7x7)/Cube 0: Measurement grid: dx=5mm, dy=5mm, dz=5mm
Reference Value = 95.0 V/m; Power Drift = -0.009 dB
Peak SAR (extrapolated) = 30.4 W/kg
SAR(1 g) = 14.1 mW/g; SAR(10 g) = 6.33 mW/g
Maximum value of SAR (measured) = 16.3 mW/g

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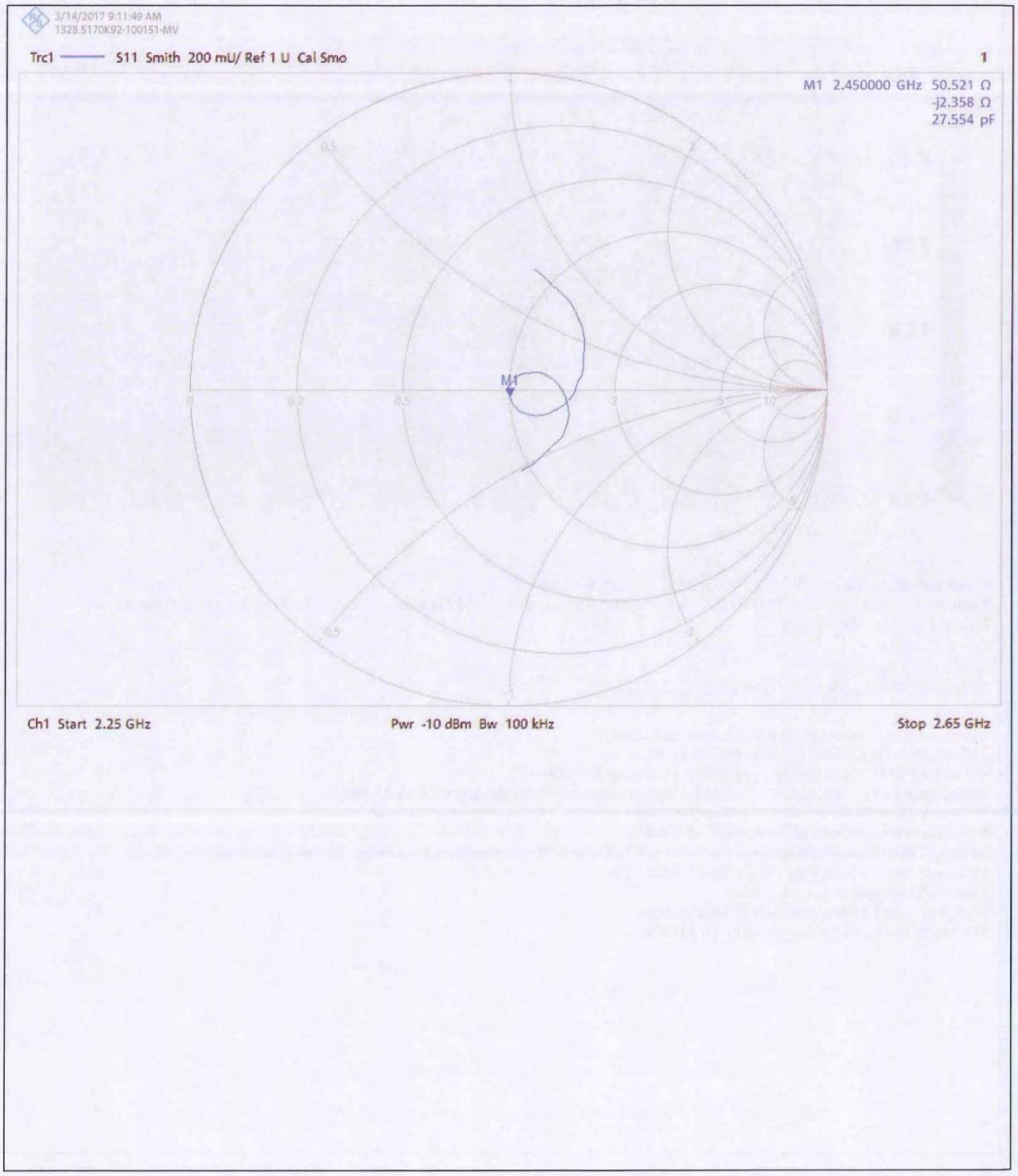
Impedance Measurement Plot for Head Stimulating Liquid (HSL)



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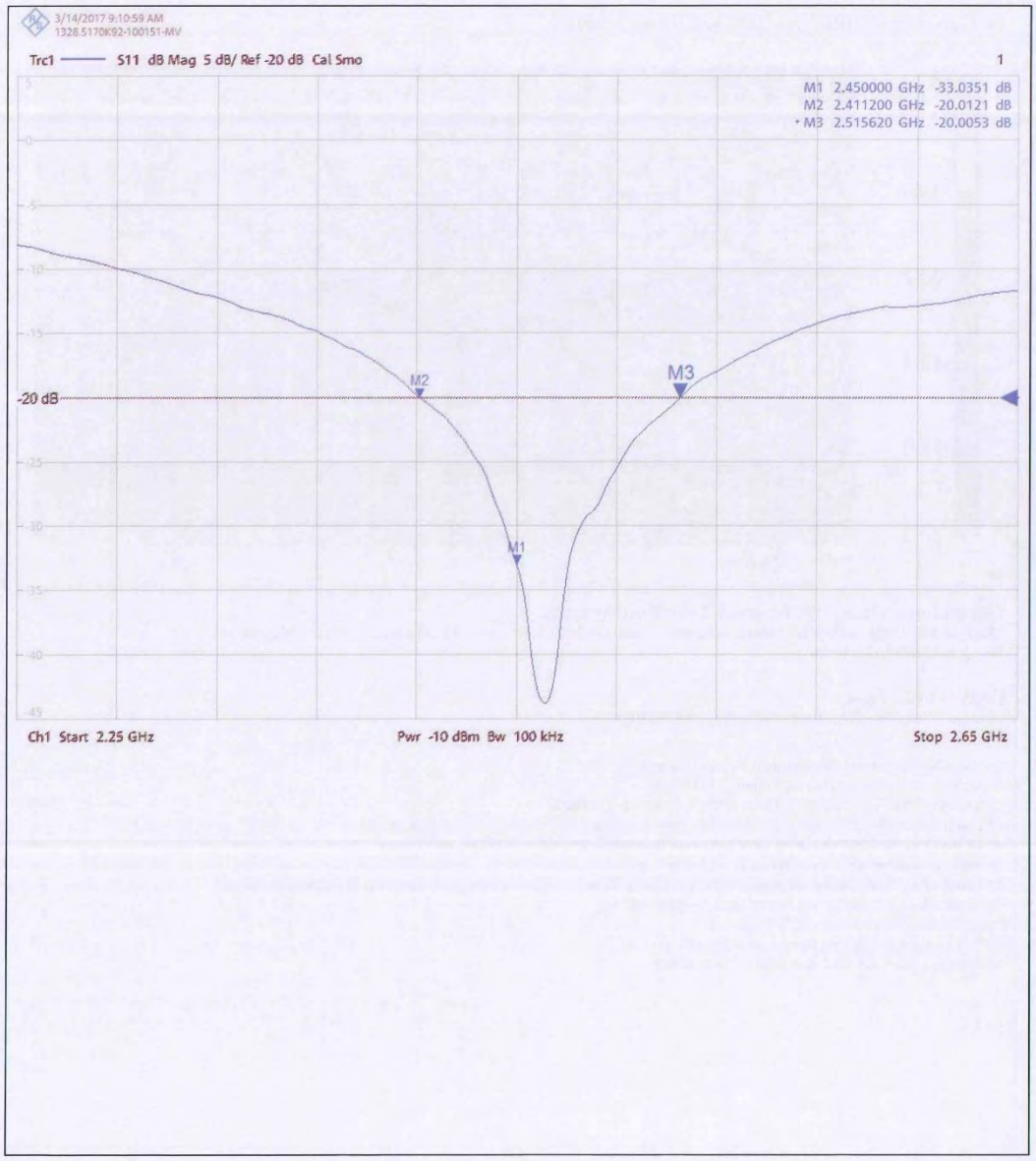
Return Loss Measurement Plot for Head Stimulating Liquid (HSL)



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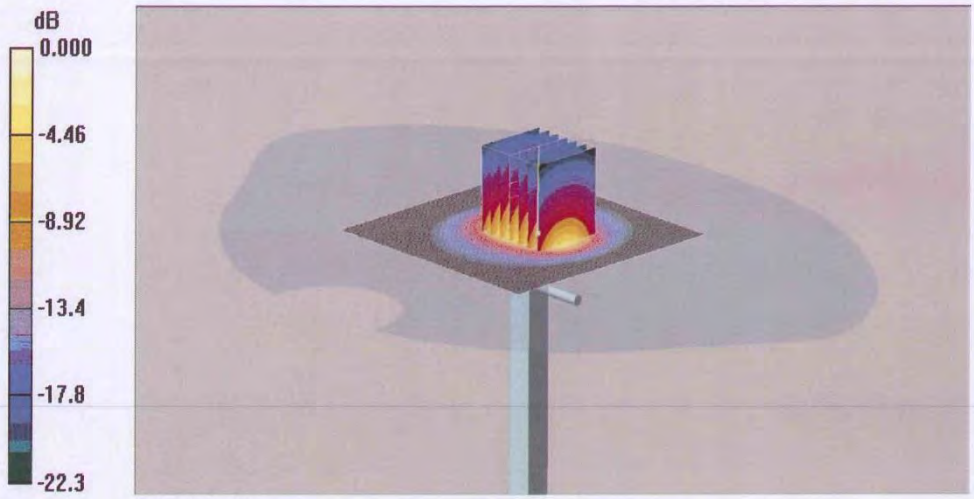
DASY Validation Scan for Body Stimulating Liquid (MSL)

DUT: diSARA2450MHz; Type: 2450; Serial: 304324-2402103



0 dB = 16.2mW/g

Communication System: CW; Frequency: 2450 MHz;Duty Cycle: 1:1
Medium: 2450 MHz BBMSL Medium parameters used: f = 2450 MHz; σ = 2.03 mho/m; ε_r = 52; ρ = 1000 kg/m^3
Phantom section: Flat Section

DASY4 Configuration:
- Probe: EX3DV4 - SN3814; ConvF(7.19, 7.19, 7.19);

- Sensor-Surface: 4mm (Mechanical Surface Detection)
- Electronics: DAE4 Sn431; Calibrated: 18/11/2016
- Phantom: SAM 12a (Site 57); Type: SAM 4.0; Serial: TP:1020
- Measurement SW: DASY4, V4.7 Build 80; Postprocessing SW: SEMCAD, V1.8 Build 186
d=10mm, Pin=250mW/Area Scan (81x81x1): Measurement grid: dx=12mm, dy=12mm
Maximum value of SAR (interpolated) = 16.7 mW/g
d=10mm, Pin=250mW/Zoom Scan (7x7x7) (7x7x7)/Cube 0: Measurement grid: dx=5mm, dy=5mm, dz=5mm
Reference Value = 90.8 V/m; Power Drift = -0.089 dB
Peak SAR (extrapolated) = 28.7 W/kg
SAR(1 g) = 14 mW/g; SAR(10 g) = 6.29 mW/g
Maximum value of SAR (measured) = 16.2 mW/g

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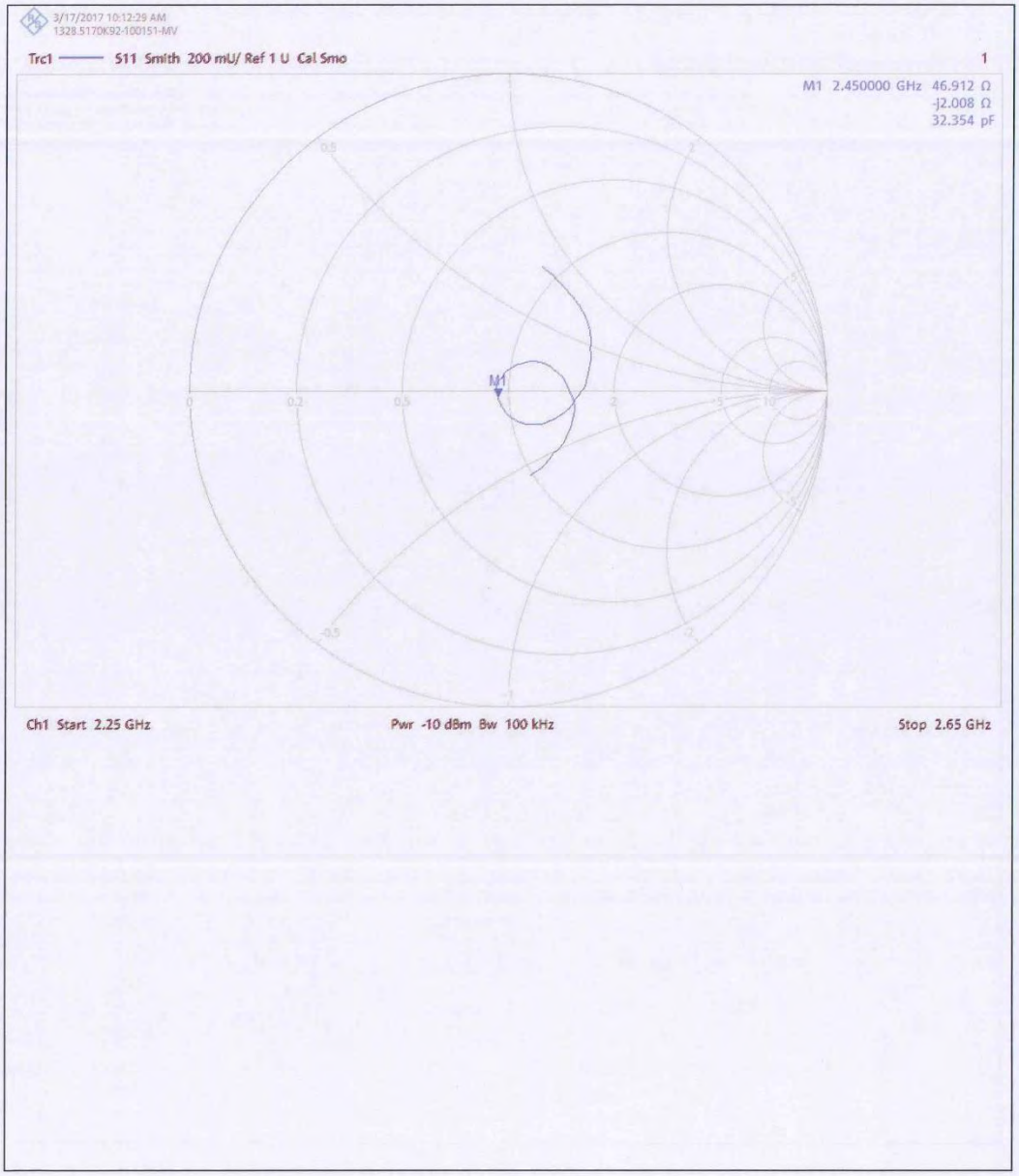
Impedance Measurement Plot for Body Stimulating Liquid (MSL)



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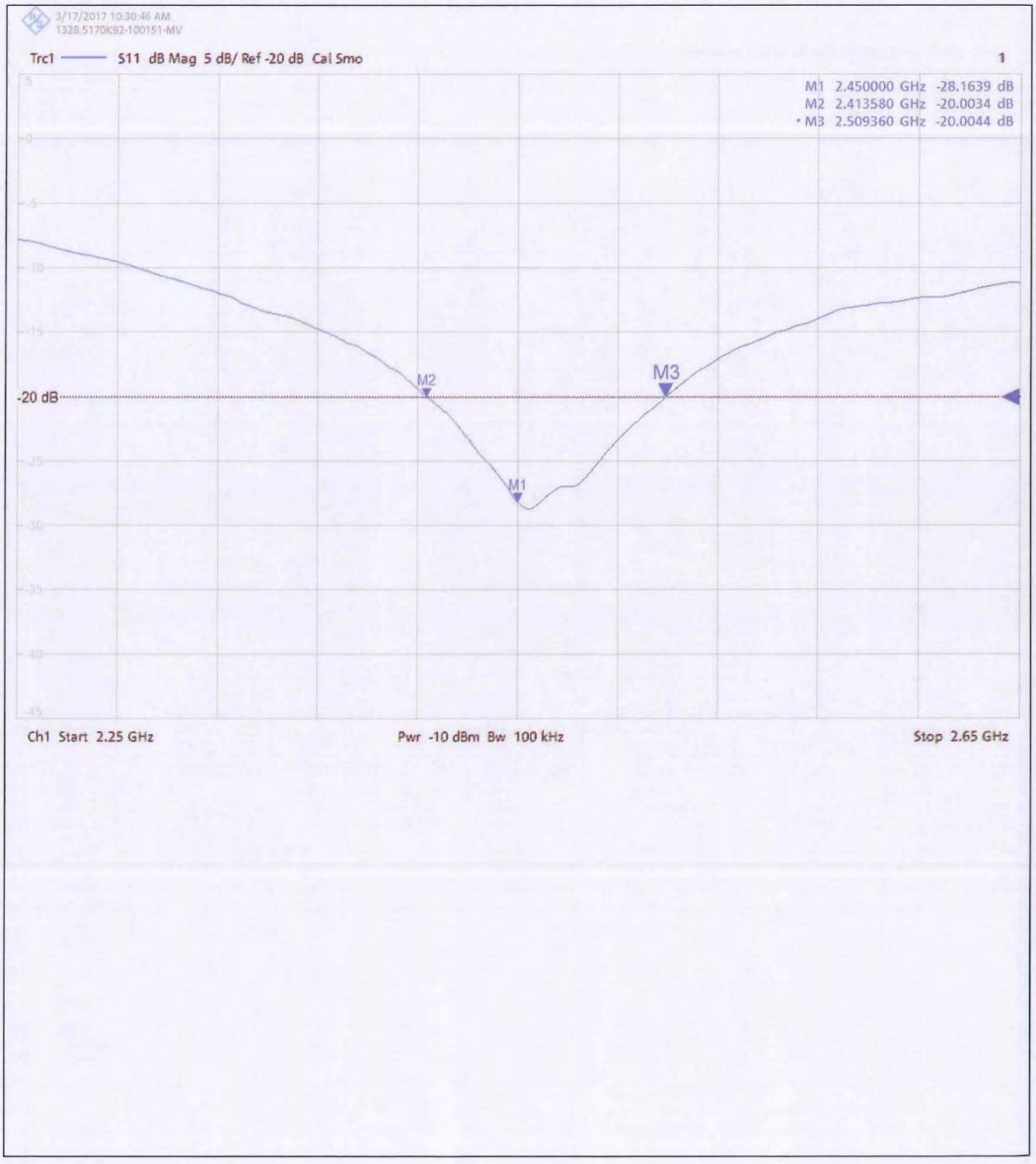
Return Loss Measurement Plot for Body Stimulating Liquid (MSL)



Calibration Certificate Label:

UKAS CALIBRATION 5248	**UL VS LTD - Tel: +44 (0) 1256312000** Certificate Number: 11625828JD01G Instrument ID: 304324-2402103 Calibration Date: 13/Mar/2017 Calibration Due Date:

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