eurofins Product Service

SAR TEST REPORT

FCC 47 CFR Part 2.1093
Industry Canada RSS-102

RF-Exposure evaluation of portable equipment

Report Reference No. .... :	G0M-1712-7088-TFC093SR-V02
Testing Laboratory .... :	Eurofins Product Service GmbH
Address .... :	Storkower Str. 38c 15526 Reichenwalde Germany
Accreditation .... :	ilac-MRA; A2LA ACCREDITED TESTING CERT# 1983.01 FCC Test Firm Designation Number: DE0008 IC Testing Laboratory site: 3470A-2
Applicant's name .... :	FALCOM GmbH
Address .... :	Gewerbering 6 98704 Langewiesen GERMANY
Test specification:	
Standard... :	FCC 47 CFR Part 2 §2.1093 447498 D01 General RF Exposure Guidance v06 IEEE Std. 1528 - 2013 IC RSS-102 Issue 5
Non-standard test method…………..:	None
Test scope………….. .... :	complete Radio compliance test
Equipment under test (EUT):	
Product description	UMTS/GSM-Stick
Model No.	SAMBA3G-G
Additional Model(s)	None
Brand Name(s)	None
Hardware version	F_311_rev01b
Firmware / Software version	None
	FCC-ID: QIXSAMBA3G-G IC: 5383A-SAMBA3GG
Test result	**Passed**

Possible test case verdicts:	
- neither assessed nor tested:	N/N
- required by standard but not appl. to test object:	N/A
- required by standard but not tested:	N/T
- not required by standard for the test object:	N/R
- test object does meet the requirement:	P (Pass)
- test object does not meet the requirement:	F (Fail)

Testing:		
Date of receipt of test item:	2018-01-15	
Date (s) of performance of tests:	2018-01-16 - 2018-01-24	
Compiled by:	Burkhard Pudell	
Tested by (+ signature): (Responsible for Test)	Burkhard Pudell	B. Pudell
Approved by (+ signature): (Head of Lab)	Christian Weber	C. Weber
Date of issue:	2018-04-23	
Total number of pages:	99	

General remarks:

The test results presented in this report relate only to the object tested.

The results contained in this report reflect the results for this particular model and serial number. It is the responsibility of the manufacturer to ensure that all production models meet the intent of the requirements detailed within this report.

Additional comments:

Version History

Version	Issue Date	Remarks	Revised by
01	2018-02-08	Initial Release	
02	2018-04-23	FCC ID corrected.	B. Pudell

REPORT INDEX

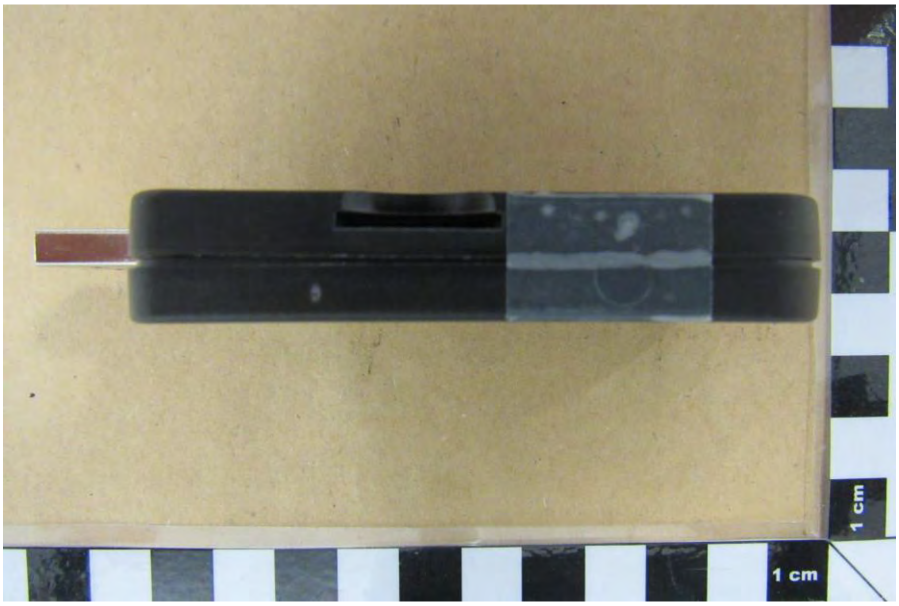
1 Equipment (Test item) Description

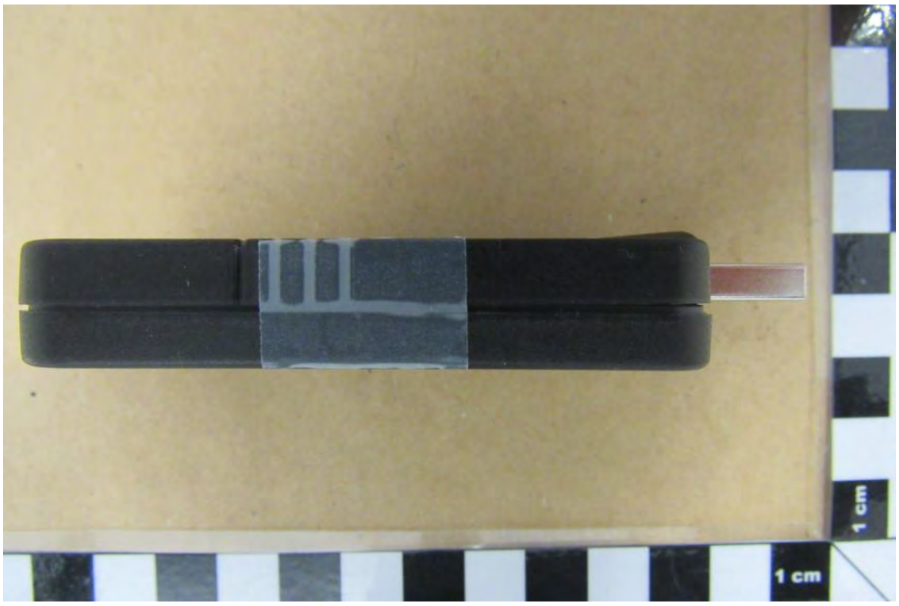
Description	UMTS/GSM-Stick	
Model	SAMBA3G-G	
Additional Model(s)	None	
Brand Name(s)	None	
Serial number	None	
Hardware version	F_311_rev01b	
Software / Firmware version	None	
PMN	UMTS/GSM-Stick	
HVIN	SAMBA3G-G	
FVIN	N/A	
HMN	N/A	
FCC-ID	QIXSAMBA3G-G	
IC	5383A-SAMBA3GG	
Equipment type	End product	
Prototype or production unit	Production Unit	
Device category	Fixed	
Environment	General public	
Radio technologies	GSM + WCDMA (FDD)	
Operating frequency ranges	GSM 850 = UL : 824 - 849 MHz & DL : 869 - 894 MHz PCS 1900 = UL : 1850 - 1910 MHz & DL : 1930 - 1990 MHz WCDMA II = UL : 1850 - 1910 MHz & DL : 1930 - 1990 MHz WCDMA V = UL : 824 - 849 MHz & DL : 869 - 894 MHz	
Number of antennas	1	
Antenna	Type	integrated
	Model	PCB printed
	Manufacturer	FALCOM GmbH
	Gain	0 dBi (declaration)
Power supply	V_{NOM}	5.0VDC (USB powered)
AC/DC-Adaptor	None	
Accessories	None	
Manufacturer	FALCOM GmbH Gewerbering 6 98704 Langewiesen GERMANY	

1.1 Equipment photos

EUT FRONT


EUT BACK


EUT RIGHT


EUT LEFT


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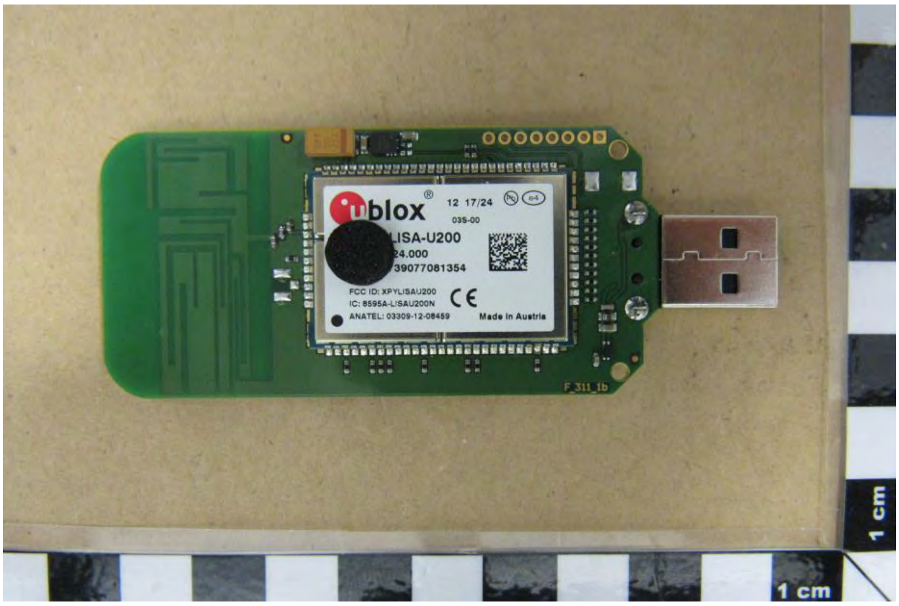

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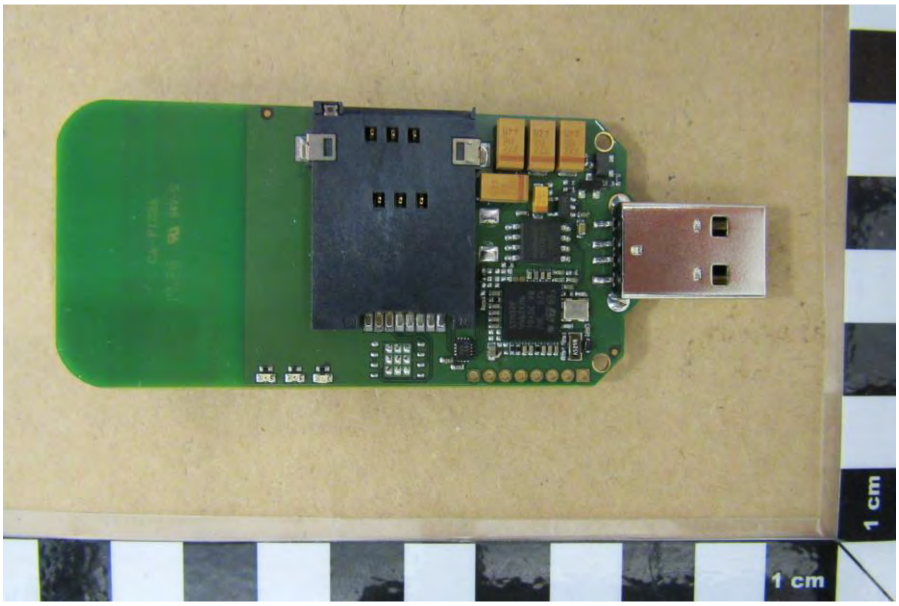
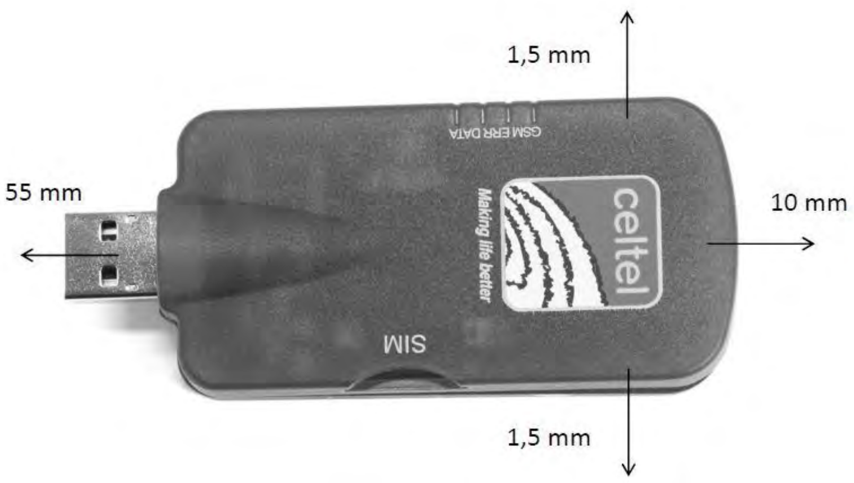


ANTENNA DISTANZ FRONT


ANTENNA DISTANZ SIDE

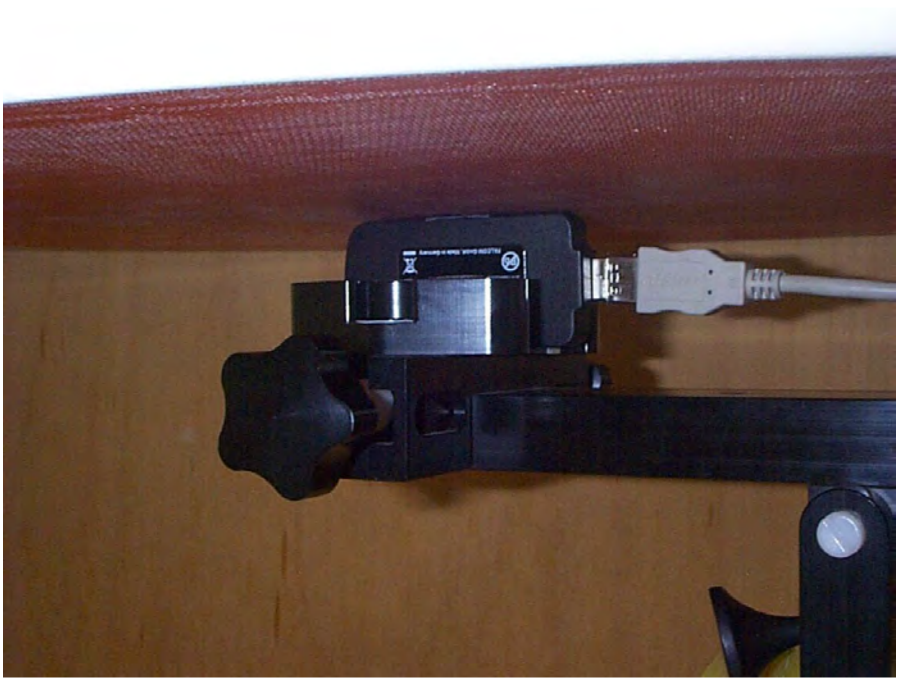

1.2 Equipment setup photos

EUT FRONT


EUT FRONT


EUT BACK


EUT BACK


EUT LEFT


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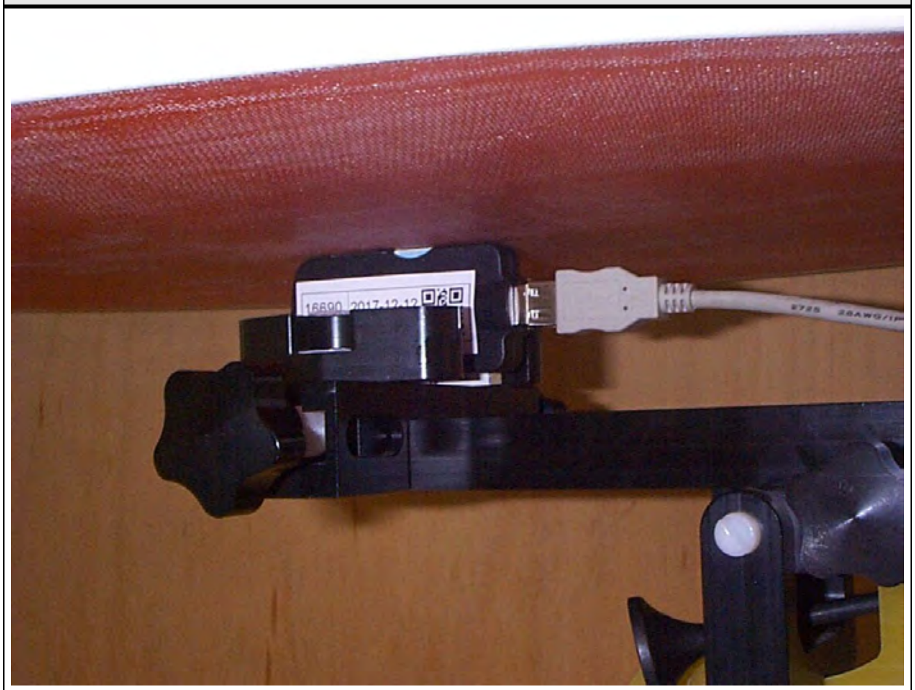

EUT TOP


1.3 Reference Documents

Document
KDB Publication 447498 : Mobile and Portable Device RF Exposure Procedures and Equipment Authorization Polices
KDB Publication 648474 : SAR Evaluation Considerations for Handsets with Multiple Transmitters and Antennas
KDB Publication 648474 : Review and Approval Policies for SAR Evaluation of Handsets with Multiple Transmitters and Antennas
KDB Publication 865664 : SAR measurement procedures for devices operating between 100 MHz to 6 GHz
KDB Publication 941225: SAR Measurement Procedures for 3G Devices
KDB Publication 941225: 3GPP R6 HSPA and R7 HSPA+ SAR Guidance
KDB Publication 941225: Recommended SAR Test Reduction Procedures for GSM/GPRS/EDGE
KDB Publication 941225: SAR Test Consideration for LTE Handsets and Data Modems
KDB Publication 447498 : SAR Measurement Procedures for USB Dongle Transmitters
KDB Publication 248227 : SAR Measurement Procedures for 802.11 a/b/g Transmitters
KDB Publication 450824 : SAR Probe Calibration and System Verification considerations for measurements from 150 MHz to 3 GHz

1.4 Supporting Equipment Used During Testing

Product Type*	Device	Manufacturer	Model No.	Comments
SIM	Communication Tester	R&S	CMU200	GSM-WCDMA-tester

***Note:** Use the following abbreviations:

AE : Auxiliary/Associated Equipment, or

SIM : Simulator (Not Subjected to Test)

CABL : Connecting cables

1.5 Supported standalone operating modes

Band	Mode	Frequency range	Duty cycle
GSM 850	GPRS	824 MHz - 849 MHz	25.0%
PCS1900	GPRS	1850 MHz - 1910 MHz	25.0%
WCDMA II	RMC	1850 MHz - 1910 MHz	100%
WCDMA V	RMC	824 MHz - 849 MHz	100%

Comment: Maximum power (worst case) was searched for all RMC and HSDPA/HSUPA subtest configurations. Configuration with maximum output power was selected for compliance testing.

1.6 Conducted Power Values FCC

GSM850 – Average Output Power includes Tune Up tolerance +2dB										
Band	Mode	Coding	Active Timeslots	Ch.	Frequency [MHz]	TS1 [dBm]	TS2 [dBm]	TS3 [dBm]	TS4 [dBm]	Source-based average power [dBm]
850	GRPS	CS1	2	128	824.1	32,70	32,70			28.68
				188	836.6	32,60	32,60			28.58
				251	848.0	32,60	32,60			28.58

PCS 1900 – Average Output Power includes Tune Up tolerance +2dB										
Band	Mode	Coding	Active Timeslots	Ch.	Frequency [MHz]	TS1 [dBm]	TS2 [dBm]	TS3 [dBm]	TS4 [dBm]	Source-based average power [dBm]
1900	GRPS	CS1	2	512	1850.2	30,00	30,00			25.98
				661	1880.0	29,80	29,80			25.78
				810	1909.8	29,80	29,80			25.78

UMTS FDDII RMC – Average Output Power Includes Tune up Tolerance +2dB						
Band	Ch.	Frequency [MHz]	Source-based average power [dBm]			
			RMC 12.2	RMC 64	RMC 144	RMC 3848
FDDII	9263	1852.6	**25,40**	25,40	25,40	25,40
	9400	1880.0	25,30	25,20	25,20	25,20
	9537	1907.4	25,20	25,30	25,30	25,30

UMTS FDDV RMC – Average Output Power Includes Tune up Tolerance +2dB						
Band	Ch.	Frequency [MHz]	Source-based average power [dBm]			
			RMC 12.2	RMC 64	RMC 144	RMC 384
FDDV	4133	826.6	**26,10**	26,10	26,10	26,00
	4182	836.6	25,70	25,80	25,80	25,80
	4232	846.4	25,70	25,70	25,70	25,70

1.7 Radiated Power Values ISED

GSM850 – Average Output Power includes Tune Up tolerance +2dB										
Band	Mode	Coding	Active Timeslots	Ch.	Frequency [MHz]	TS1 [dBm]	TS2 [dBm]	TS3 [dBm]	TS4 [dBm]	Source-based average power [dBm]
850	GRPS	CS1	2	128	824.1	32,70	32,70			**28.68**
				188	836.6	32,60	32,60			28.58
				251	848.0	32,60	32,60			28.58

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Band	Mode	Coding	Active Timeslots	Ch.	Frequency [MHz]	TS1 [dBm]	TS2 [dBm]	TS3 [dBm]	TS4 [dBm]	Source-based average power [dBm]
1900	GRPS	CS1	2	512	1850.2	30,00	30,00			**25.98**
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Band	Ch.	Frequency [MHz]	Source-based average power [dBm]			
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FDDII	9263	1852.6	**25,40**	25,40	25,40	25,40
	9400	1880.0	25,30	25,20	25,20	25,20
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FDDV	4133	826.6	**26,10**	26,10	26,10	26,00
	4182	836.6	25,70	25,80	25,80	25,80
	4232	846.4	25,70	25,70	25,70	25,70

1.8 Standalone Operational Mode Test Exclusion for FCC

According to KDB 447498 D01 v05r02 for standalone SAR evaluation the test exclusion power condition is given by

$$\frac{\max Power, mW}{test\ distance, mm} \cdot \sqrt{f_{GHz}} \leq 3.0$$

for test separation distance ≤ 50mm. For test separation distances > 50mm, the SAR test exclusion threshold is:

$$P_{TH}[mW] = Power\ allowed\ at\ numeric\ threshold\ for\ 50mm + (test\ distance, mm - 50mm) \cdot \frac{f[MHz]}{150} \quad , \quad 100\ MHz < f < 1500\ MHz$$

$$P_{TH}[mW] = Power\ allowed\ at\ numeric\ threshold\ for\ 50mm + (test\ distance, mm - 50mm) \cdot 10 \quad , \quad 1500\ MHz < f < 6\ GHz$$

SAR Test Exclusion															
Mode	P [mW]	Ant.	Reg	EUT Edge											
				Top		Left		Right		Bottom		Back		Front	
				Antenna distance to user [mm]	SAR Test Exclusion Threshold [mW]	Antenna distance to user [mm]	SAR Test Exclusion Threshold [mW]	Antenna distance to user [mm]	SAR Test Exclusion Threshold [mW]	Antenna distance to user [mm]	SAR Test Exclusion Threshold [mW]	Antenna distance to user [mm]	SAR Test Exclusion Threshold [mW]	Antenna distance to user [mm]	SAR Test Exclusion Threshold [mW]
GPRS	740	Int	FCC	**10**	**34**	**1.5**	**5**	**1.5**	**5**	**-**	**-**	**7**	**24**	**5**	**17**
			IC	**10**	**31**	**1.5**	**18**	**1.5**	**18**	**-**	**-**	**7**	**23**	**5**	**18**
Comments: All bold Threshold values are above the limit and have to be measured															

1.9 Standalone Operational Mode Exemption limits for IC

Frequency (MHz)	Exemption Limits (mW)				
	At separation distance of ≤5 mm	At separation distance of 10 mm	At separation distance of 15 mm	At separation distance of 20 mm	At separation distance of 25 mm
≤300	71 mW	101 mW	132 mW	162 mW	193 mW
450	52 mW	70 mW	88 mW	106 mW	123 mW
835	17 mW	30 mW	42 mW	55 mW	67 mW
1900	7 mW	10 mW	18 mW	34 mW	60 mW
2450	4 mW	7 mW	15 mW	30 mW	52 mW
3500	2 mW	6 mW	16 mW	32 mW	55 mW
5800	1 mW	6 mW	15 mW	27 mW	41 mW
Frequency (MHz)	Exemption Limits (mW)				
	At separation distance of 30 mm	At separation distance of 35 mm	At separation distance of 40 mm	At separation distance of 45 mm	At separation distance of ≥50 mm
≤300	223 mW	254 mW	284 mW	315 mW	345 mW
450	141 mW	159 mW	177 mW	195 mW	213 mW
835	80 mW	92 mW	105 mW	117 mW	130 mW
1900	99 mW	153 mW	225 mW	316 mW	431 mW
2450	83 mW	123 mW	173 mW	235 mW	309 mW
3500	86 mW	124 mW	170 mW	225 mW	290 mW
5800	56 mW	71 mW	85 mW	97 mW	106 mW

1.10 SAR value estimation for multi-transmitter evaluation

According to KDB 447498 D01 v05r02 for standalone SAR evaluation the estimated SAR is given by

$$\frac{\max Power\ (including\ tune\ up\ tolerance), mW}{min.\, test\ separation\ distance, mm} \cdot \sqrt{\frac{f_{GHz}}{x}} \leq 0.4 \frac{W}{kg}$$

x=7.5 for 1-g SAR, and x=18.75 for 10-g SAR, for test separation ≤ 50mm.

For test separation distance > 50mm, the estimated SAR value is 0.4 W/kg

1.11 Supported concurrent (multi-transmitter) operating modes

N/A, no multi-transmitter evaluation

1.12 Supported use cases

Use case	Distance to human body	corresponding test configuration
People hold the device in hand or carry on human body	0 mm (worst case)	body-worn device

1.13 Radio Test Modes

Mode	Settings
GPRS	Band = GSM 900 & 1800 Modulation = GMSK Duty cycle = 25% Power level = maximum (Gamma=3) Antenna = integrated
RMC	Band = WCDMA FDD I & VIII Modulation = QPSK (12.2kbps) Duty cycle = 100% Power level = maximum (TPC=All1) Antenna = integrated

1.14 Test Positions

Position	Description
Flat-Front_0mm	EUT front side directly touching the phantom.
Flat-Back_0mm	EUT back side directly touching the phantom.
Flat-Left_0mm	EUT left side directly touching the phantom.
Flat-Right_0mm	EUT right side directly touching the phantom.
Flat-Top_0mm	EUT top side directly touching the phantom.

1.15 Test Equipment Used During Testing

SAR Measurement					
Description	Manufacturer	Model	Identifier	Cal. Date	Cal. Due
Stäubli Robot	Stäubli	RX90B L	EF00271	functional test	functional test
Stäubli Robot Controller	Stäubli	CS7MB	EF00272	functional test	functional test
DASY 5 Measurement Server	Schmid & Partner		EF00273	functional test	functional test
Control Pendant	Stäubli		EF00274	functional test	functional test
Dell Computer	Schmid & Partner	Intel	EF00275	functional test	functional test
Data Acquisition Electronics	Schmid & Partner	DAE3V1	EF00276	2017-09	2018-09
Dosimetric E-Field Probe	Schmid & Partner	EX3DV4	EF00826	2017-09	2018-09
System Validation Kit	Schmid & Partner	D900V2	EF00281	2015-09	2018-09
System Validation Kit	Schmid & Partner	D1900V2	EF00283	2015-09	2018-09
Oval flat phantom	Schmid & Partner	ELI 4	EF00289	functional test	functional test
Mounting Device	Schmid & Partner	V 3.1	EF00287	functional test	functional test
Millivoltmeter	Rohde & Schwarz	URV 5	EF00126	2016-08	2019-08
Power sensor	Rohde & Schwarz	NRV-Z2	EF00125	2017-07	2019-07
RF signal generator	Rohde & Schwarz	SMP 02	EF00165	2017-07	2019-07
Insertion unit	Rohde & Schwarz	URV5-Z4	EF00322	2017-08	2019-08
Directional Coupler	HP	HP 87300B	EF00288	functional test	functional test
Universal Radio Communication Tester	Rohde & Schwarz	CMU 200	EF00304	2017-07	2018-07
Network Analyzer 300 kHz to 3 GHz	Agilent	8752C	EF00140	2017-07	2018-07
Dielectric Probe Kit	Agilent	85070C	EF00291	functional test	functional test
Dielectric Probe Kit	SPEAG	DAK-3.5	EF00945	2017-09	2018-09
DAK Measurement Software	SPEAG	DAKS	EF00965	-	-
Thermometer	LKM electronic GmbH	DTM3000	EF00967	2017-11	2018-11

2 Result Summary

447498 D01 General RF Exposure Guidance, RSS-102					
Product Specific Standard Section	**Requirement – Test**	**Reference Method**	**Maximum SAR [W/kg]**	**Result**	**Remarks**
447498 D01 General RF Exposure Guidance RSS-102 Section 3	Single-band conformity	KDB Publication 447498 KDB Publication 248227 KDB Publication 865664	**1.46**	**PASS**	
447498 D01 General RF Exposure Guidance RSS-102 Section 3	Multi-band conformity	KDB Publication 447498 KDB Publication 648474 KDB Publication 865664	N/A	N/R	No concurrent transmission modes
Remarks:					

3 Definitions

The specific absorption rate (SAR) is defined as the time derivative of the incremental energy (*dW*) absorbed by (dissipated in) an incremental mass (*dm*) contained in a volume element *(dV*) of a given density (ρ_t), expressed in watts per kilogram (W/kg)

$$SAR = d/dt\ (dW/dm) = d/dt\ (dW/\rho_t dV) = \sigma/\rho_t\ |E_t|^2$$

where

$$dW/dt = \int_V E\ J\ dV = \int_V \sigma E^2\ dV$$

3.1 Controlled Exposure

The general population/uncontrolled exposure limits are applicable to situations in which the general public may be exposed or in which persons who are exposed as a consequence of their employment may not be made fully aware of the potential for exposure or cannot exercise control over their exposure. Members of the general public would come under this category when exposure is not employment-related; for example, in the case of a wireless transmitter that exposes persons in its vicinity. Warning labels placed on low-power consumer devices such as cellular telephones are not considered sufficient to allow the device to be considered under the occupational/controlled category and the general population/uncontrolled exposure limits apply to these devices.

3.2 Uncontrolled Exposure

In general, occupational/controlled exposure limits are applicable to situations in which persons are exposed as a consequence of their employment, who have been made fully aware of the potential for exposure and can exercise control over their exposure. This exposure category is also applicable when the exposure is of a transient nature due to incidental passage through a location where the exposure levels may be higher than the general population/uncontrolled limits, but the exposed person is fully aware of the potential for exposure and can exercise control over his or her exposure by leaving the area or by some other appropriate means. Awareness of the potential for RF exposure in a workplace or similar environment can be provided through specific training as part of a RF safety program. If appropriate, warning signs and labels can also be used to establish such awareness by providing prominent information on the risk of potential exposure and instructions on the risk of potential exposure and instructions on methods to minimize such exposure risks.

3.3 Localized SAR

Compliance with the localized SAR limits is demonstrated using the head and trunk limit because this SAR limit is only half the limbs limit value. The values are obtained by SAR measurements according to EN 62209-2.

4 Localized SAR Measurement Equipment

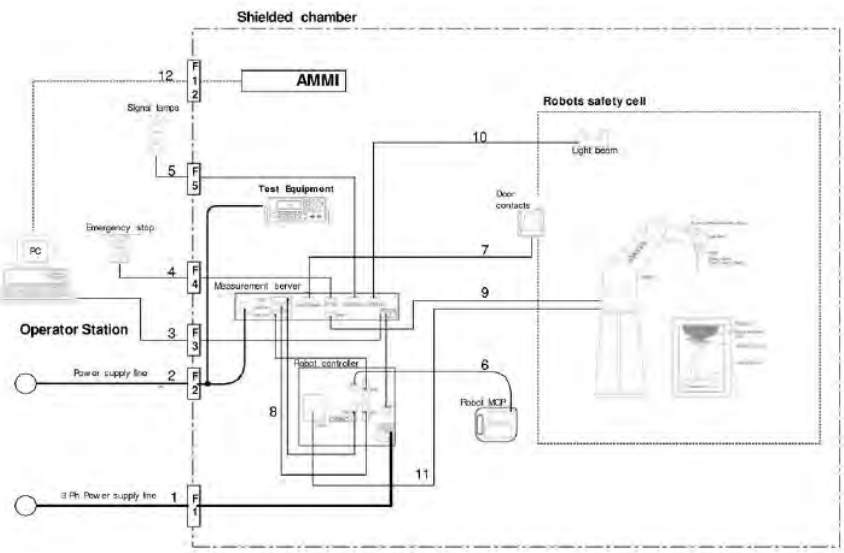
The measurements were performed with Dasy5 automated near-field scanning system comprised of high precision robot, robot controller, computer, e-field probe, probe alignment unit, phantoms, non-conductive phone positioned and software extension.

4.1 Complete SAR DASY5 Measurement System

Measurements are performed using the DASY5 automated assessment system made by Schmid & Partner Engineering AG (SPEAG) in Zurich, Switzerland.

DASY 5 SAR Measurement Setup


The following Diagram show the elements involved in the measurement setup.

DASY 5 SAR Measurement Diagram


The DASY5 system for performing compliance tests consists of the following items:

DASY5 SAR Measurement System	
Device	Description:
RX90BL	A standard high precision 6-axis robot (Stäubli RX family) with controller, teach pendant and software.
Probe Alignment Unit	A probe alignment unit which improves the (absolute) accuracy of the probe positioning.
Teach Pendant	The Manual Control Pendant (MCP), also called the manual teach pendant, is the user interface to the robot. In DASY, it is used for certain installation and teach procedures
Signal Lamps	External warning lamp which indicates when the robot arm is powered-on and if the robot is under software control or in manual mode (controlled with the teach pendant).
DAE	The data acquisition electronics (DAE) which performs the signal amplification, signal multiplexing, AD-conversion, offset measurements, mechanical surface detection, collision detection, etc. The unit is battery powered with standard or rechargeable batteries. The signal is optically transmitted to the EOC.
E-Field Probes	Isotropic E-Field probe optimized and calibrated for E-field measurements in free space.
EOC	The electro-optical converter (EOC) performs the conversion between optical and electrical signals
Measurement Server	The functions of the measurement server is to perform the time critical task such as signal filtering, surveillance of the robot operation, fast movement interrupts.
Control Computer	A computer operating Windows 2000 or Windows NT with DASY 4 Software.
Control Software	DASY4 and SEMCAD post processing Software
SAM Twin Phantom	The SAM twin phantom enabling testing left-hand and right-hand usage.
Flat Phantom	Flat Phantom (only for body-mounted transceivers operating below 800 MHz).
Tissue simulating liquid	Tissue simulating liquid mixed according to the given recipes.
Device Holder	The device holder for handheld mobile phones.
System Validation Dipoles	System validation dipoles allowing to validate the proper functioning of the system.

4.2 Robot Arm

The DASY5 system uses the high precision robots RX90BL type out of the newer series from Stäubli SA (France).

The RX robot series have many features that are important for our application:

- High precision (repeatability 0.02 mm)
- High reliability (industrial design)
- Jerk-free straight movements
- Low ELF interference (the closed metallic construction shields against motor control fields)
- 6-axis controller

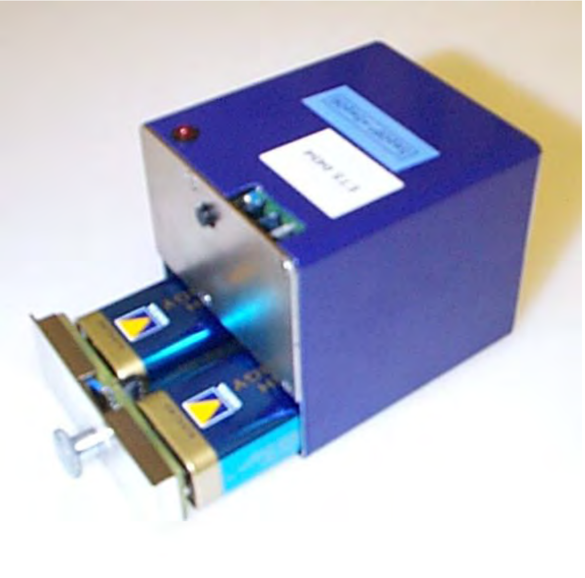
Robot arm

4.3 Data Acquisition Electronics

The data acquisition electronics (DAE3) consists of a highly sensitive electrometer-grade preamplifier with auto-zeroing, a channel and gain-switching multiplexer, a fast 16 bit AD-converter and a command decoder and control logic unit. Transmission to the measurement server is accomplished through an optical downlink for data and status information as well as an optical uplink for commands and the clock.

The mechanical probe mounting device includes two different sensor systems for frontal and sideways probe contacts. They are used for mechanical surface detection and probe collision detection. The input impedance of the DAE3 is 200M Ohm; the inputs are symmetrical and floating. Common mode rejection is above 80dB.

Data Acquisition Electronics



4.4 Isotropic E-Field Probe ≤ 6 GHz

Probe Specifications

Isotropic E-Field Probe EX3DV4

Construction:

One dipole parallel, two dipoles normal to probe axis built-in shielding against static charges.

Calibration:

In air from 10 MHz to 6 GHz,
In brain and muscle simulating tissue at Frequencies of 835MHz, 900MHz, 1800MHz, 1900MHz, 2450MHz, 5200MHz, 5500MHz and 5800MHz

Frequency:

10MHz to 6GHz,
Linearity ±0.2dB (30MHz to 6GHz)

Directivity:

±0.3dB in HSL (rotation around probe axis)
±0.5dB in tissue material (rotation normal to probe axis)

Dynamic Range:

10µW/g to > 100mW/g

Linearity:

±0.2dB

Dimensions:

Overall Length: 337mm (Tip: 20mm),
Tip Diameter: 2.5mm (Body: 12mm),
Distance from probe tip to dipole centers: 1mm

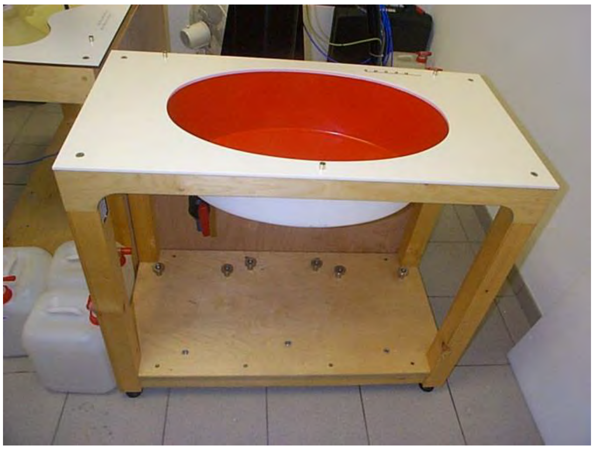
Application:

General dosimetry up to 6 GHz
Compliance tests of mobile phones
Fast automatic scanning in arbitrary phantoms

4.5 Test phantom and positioner

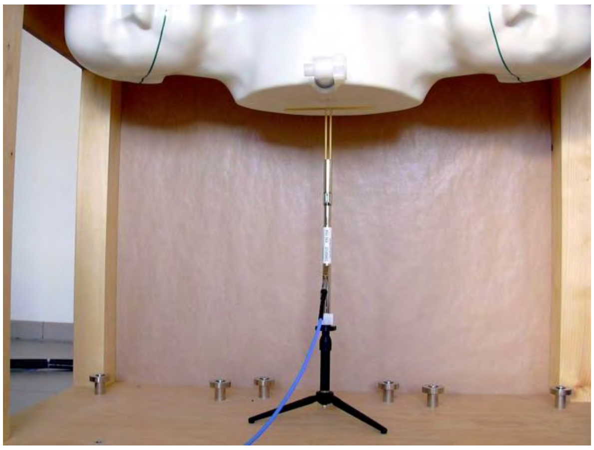
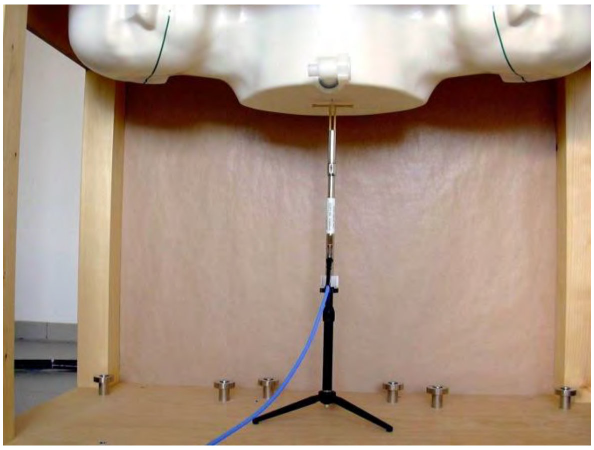
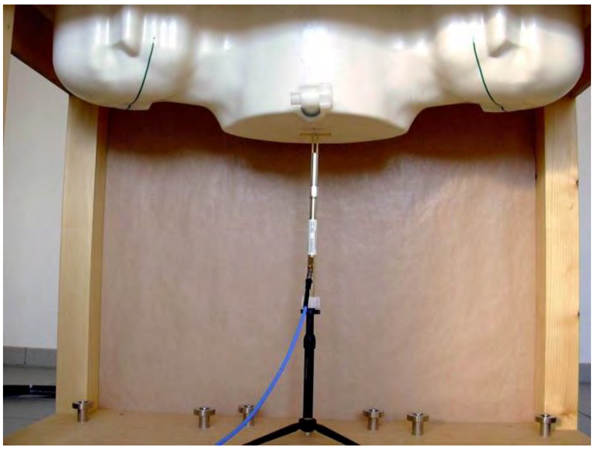
The positioner and test phantoms are manufactured by SPEAG. The test phantoms are used for all tests i.e. for both validation testing and device testing. The positioner and test phantom conforms to the requirements of EN 62209 and IEEE 1528.

The SPEAG device holder was used to position the test device in all tests whilst a tripod was used to position the validation dipoles in the test arch.

<table>
<tr><th>Probe Positioner</th><th>SAM Twin Phantom</th></tr>
<tr><td></td><td></td></tr>
<tr><th>ELI4 phantom</th><th>Flat phantom</th></tr>
<tr><td></td><td></td></tr>
</table>

4.6 System Validation Dipoles

A set of calibration dipoles (D900V2, D1900V2, D2450V2, D5GHzV2) is included as a part of the SAR measurement setup. These are used for the validation of the test setup after its installation and prior to the EUT measurements. The calibration dipole is placed in the position normally occupied by the EUT. All calibration dipoles have the same height which allows an exact fitting below the center point of the test phantom. The dipole center is 10mm below the surface of the test phantom.

900MHz Dipole	1900MHz Dipole
	
2450MHz Dipole	**5000MHz Dipole**
	

5 Single-band SAR Measurement

After successful completion of the tissue and system verification the SAR values of the EUT are measured according to the following description.

5.1 General measurement description

The measurement is performed for each frequency band of the device. If the width of the transmit frequency band exceeds 1% of its center frequency, than the channels at the lowest and highest frequencies should also be tested. Furthermore, if the width of the transmit band exceeds 10% of its center frequency the following formula is used to determine the number of channels:

$$N_C=2 \cdot \text{roundup}[10\cdot(f_{high} - f_{low})/f_c] + 1$$

First the device is tested on the center channel of each frequency band used by the device. An operation mode and configuration with maximum transmit power is established. If battery operated equipment is used, the batteries are fully charged.

SAR measurements are performed using the steps outlined in the next section for all relevant operational modes, EUT configurations and measurement positions.

For the condition (position, configuration, operational mode) that provides the highest spatial-average SAR value on the center channel, the other channels are also tested.

Additionally all other conditions where the spatial-average SAR value is within 3dB of the SAR limit are also tested on all determined test frequencies.

5.2 SAR measurement description

First the local SAR value at a test point within 10mm or less in normal direction from the inner surface of the phantom is measured. This SAR value is used to determine the measurement drift during SAR measurement.

Next an area scan is performed over an area larger than the projection of the EUT with antenna on the surface of the phantom with a spatial grid step of 10mm.

From the scanned SAR distribution the position of maximum SAR value is identified as well as any local SAR maxima within 2dB of the maximum value that are not within the zoom scan volume. (The additional peaks are only measured when the primary peak is within 2dB of the SAR limit.)

The zoom-scan volume constructed on the peak SAR position is scanned with a grid step of 5mm. The measured data are extracted and the local SAR value for each measurement point is calculated. The measured values are interpolated over a fine-mesh within the scan volume and the average SAR value over 10g mass is calculated.

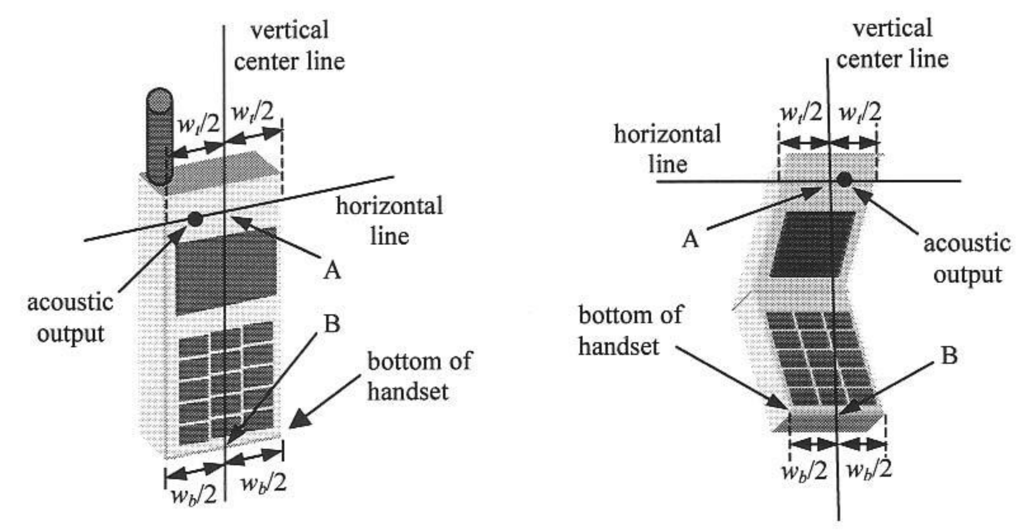
At the end of the measurement the reference point measured at the beginning of the measurement is measured again and from the difference the drift is calculated.

5.3 Reference lines and points for Handsets

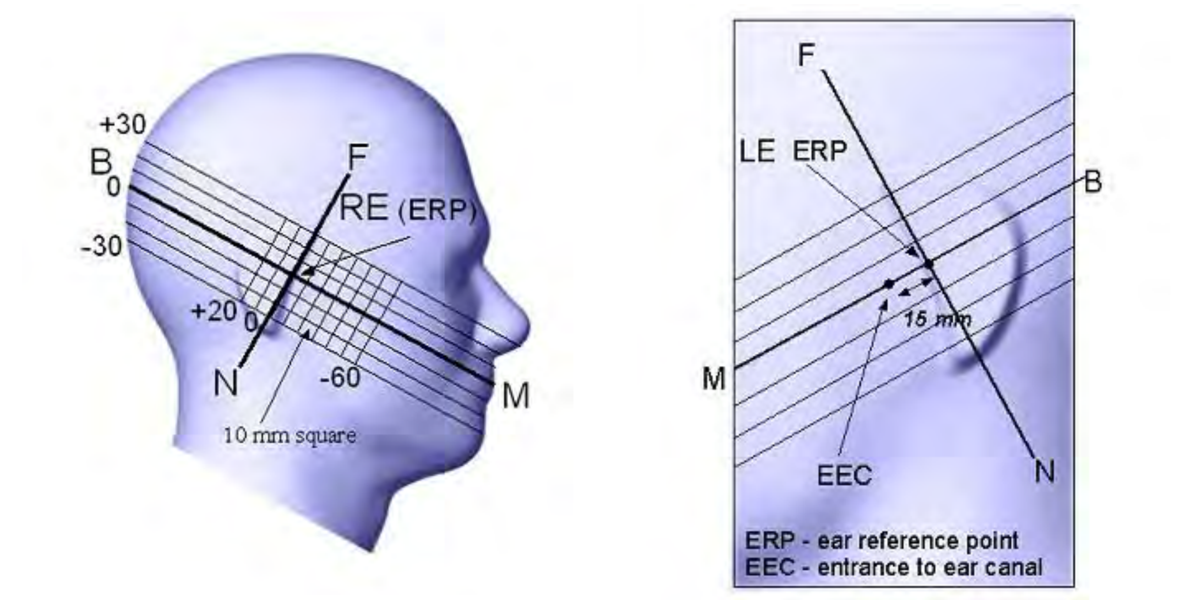
For all measurement positions of the EUT, the EUT has to be place in a specific orientation with respect to the phantom. The orientation of the EUT relative to the phantom is defined by reference lines and points.

According to IEEE 1528, the reference lines and points shall be positioned at the EUT as shown in the following figure.

Reference lines and points on EUT acc. to IEEE 1528



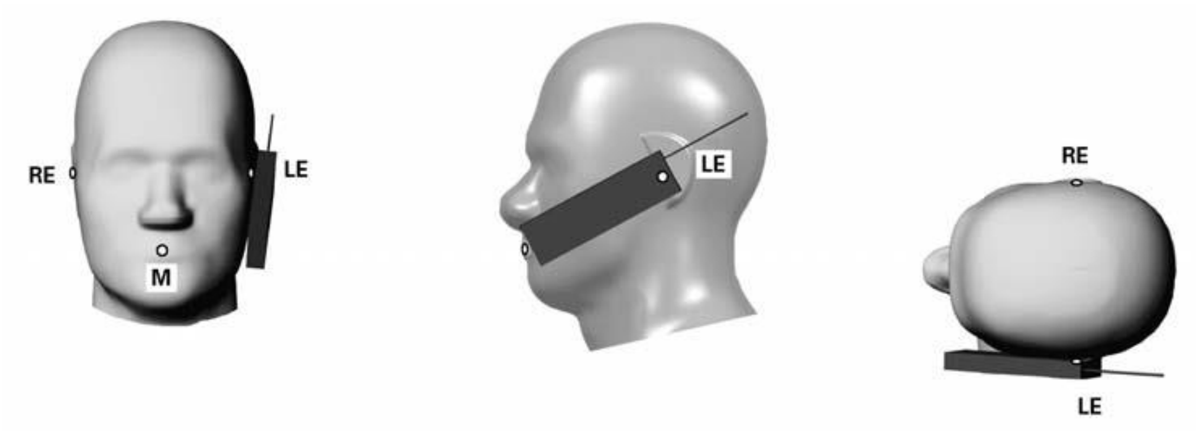
Reference lines and points on human head acc. to IEEE 1528



5.4 Test positions relative to the Head

Cheek position

Cheek positions according to IEEE 1528

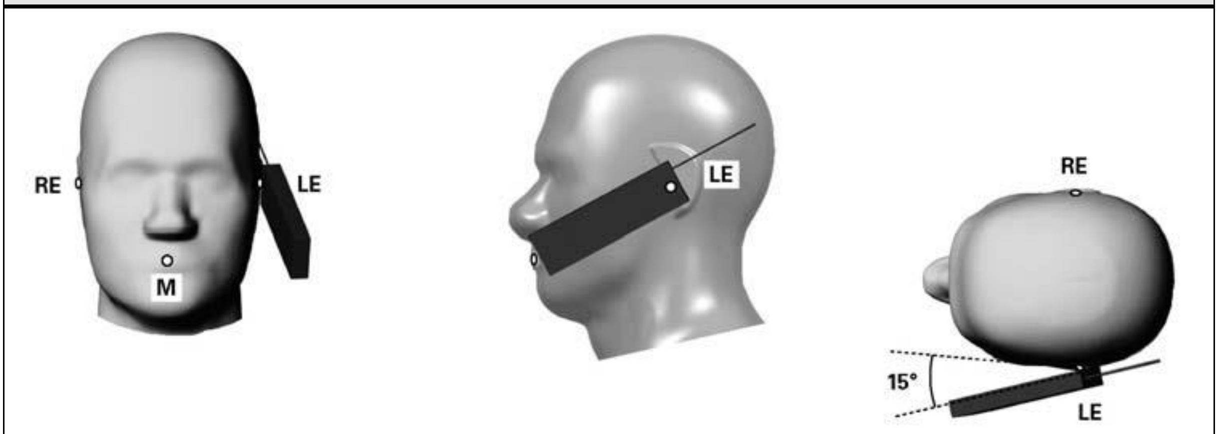


The handset is positioned close to the surface of the phantom such that point A is on the (virtual) extension of the line passing through points RE and LE on the phantom (see Figure), such that the plane defined by the vertical centerline and the horizontal line of the handset is approximately parallel to the sagittal plane of the phantom. Next the handset is translated towards the phantom along the line passing through RE and LE until handset point A touches the pinna at the ERP.

While the handset is maintained in this plane, it is rotated around the LE-RE line until the vertical centerline is in the plane normal to the plane containing B-M and N-F lines, i.e., the Reference Plane. Then it is rotated around the vertical centerline until the handset (horizontal line) is parallel to the N-F line. While the vertical centerline is maintained in the Reference Plane, point A is kept on the line passing through RE and LE, and the handset is maintained in contact with the pinna, the handset is rotated about the N-F line until any point on the handset is in contact with a phantom point below the pinna on the cheek.

Tilt position

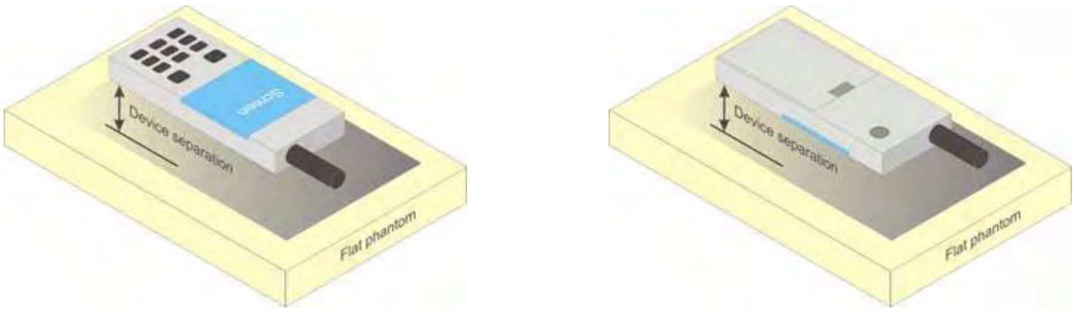
Tilt positions according to IEEE 1528



First the EUT is placed in the cheek position. Next the handset is moved away from the pinna along the line passing through RE and LE far enough to allow a rotation of the handset away from the cheek by 15°. Then the handset is rotated around the horizontal line by 15°.

The handset is moved towards the phantom on the line passing through RE and LE until any part of the handset touches the ear. The tilt position is obtained when the contact point is on the pinna. See Figure. If contact occurs at any location other than the pinna, e.g., the antenna at the back of the phantom head, the angle of the handset should be reduced. In this case, the tilt position is obtained if any point on the handset is in contact with the pinna and a second point on the handset is in contact with the phantom, e.g., the antenna with the back of the head

5.5 Test positions relative to the human body

Body positions according to IEEE 1528


In body worn configuration the device is positioned parallel to the phantom surface with either top or bottom side of the EUT facing against the phantom.

The separation distance of the EUT is selected according to the use case of the EUT (e.g. with belt clip or holster).

5.6 Measurement Uncertainty

Measurement Uncertainty according to IEEE 1528							
Error Description	**Uncertainty Value**	**Probability Distribution**	**Div.**	**c_i (1g)**	**c_i (10g)**	**Std. Unc. 1g**	**Std. Unc. 10g**
Measurement System							
Probe Calibration	±6.55%	N	1	1	1	±6.55%	±6.55%
Axial Isotropy	±4.7%	R	$\sqrt{3}$	0.7	0.7	±1.9%	±1.9%
Hemispherical Isotropy	±9.6%	R	$\sqrt{3}$	0.7	0.7	±3.9%	±3.9%
Linearity	±4.7%	R	$\sqrt{3}$	1	1	±2.7%	±2.7%
Modulation Response	±2.4%	R	$\sqrt{3}$	1	1	±1.4%	±1.4%
System Detection Limits	±1.0%	R	$\sqrt{3}$	1	1	±0.6%	±0.6%
Boundary effects	±2.0%	R	$\sqrt{3}$	1	1	±1.2%	±1.2%
Readout Electronics	±0.3%	N	1	1	1	±0.3%	±0.3%
Response Time	±0.8%	R	$\sqrt{3}$	1	1	±0.5%	±0.5%
Integration Time	±2.6%	R	$\sqrt{3}$	1	1	±1.5%	±1.5%
RF Ambient Noise	±3.0%	R	$\sqrt{3}$	1	1	±1.7%	±1.7%
RF Ambient Reflections	±3.0%	R	$\sqrt{3}$	1	1	±1.7%	±1.7%
Probe Positioner	±0.8%	R	$\sqrt{3}$	1	1	±0.5%	±0.5%
Probe Positioning	±6.7%	R	$\sqrt{3}$	1	1	±3.9%	±3.9%
Post processing	±4.0%	R	$\sqrt{3}$	1	1	±2.3%	±2.3%
Test Sample Related							
Device Holder	±3.6%	N	1	1	1	±3.6%	±3.6%
Test Sample Positioning	±2.9%	N	1	1	1	±2.9%	±2.9%
Power Scaling	±0%	R	$\sqrt{3}$	1	1	±0%	±0%
Power Drift	±5.0%	R	$\sqrt{3}$	1	1	±2.9%	±2.9%
Phantom and Setup Related							
Phantom Uncertainty	±7.9%	R	$\sqrt{3}$	1	1	±4.6%	±4.6%
SAR correction	±1.9%	R	$\sqrt{3}$	1	0.84	±1.1%	±0.9%
Liquid conductivity (measured)	±2.5%	N	1	0.78	0.71	±2.0%	±1.8%
Liquid permittivity (measured)	±2.5%	N	1	0.26	0.26	±0.1%	±0.1%
Temperature uncertainty - Conductivity	±5.2%	R	$\sqrt{3}$	0.78	0.71	±2.3%	±2.1%
Temperature uncertainty - Permittivity	±0.8%	R	$\sqrt{3}$	0.23	0.26	±0.1%	±0.1%
Combined Standard Uncertainty						±12.8%	±12.7%
Expanded Standard Uncertainty						**±25.6%**	**±25.4%**

Measurement Uncertainty according to EN 62209-1							
Error Description	**Uncertainty Value**	**Probability Distribution**	**Div.**	**c_i (1g)**	**c_i (10g)**	**Std. Unc. 1g**	**Std. Unc. 10g**
Measurement System							
Probe Calibration	±6.0%	N	1	1	1	±6.0%	±6.0%
Axial Isotropy	±4.7%	R	$\sqrt{3}$	0.7	0.7	±1.9%	±1.9%
Hemispherical Isotropy	±9.6%	R	$\sqrt{3}$	0.7	0.7	±3.9%	±3.9%
Boundary effects	±1.0%	R	$\sqrt{3}$	1	1	±0.6%	±0.6%
Linearity	±4.7%	R	$\sqrt{3}$	1	1	±2.7%	±2.7%
System Detection Limits	±1.0%	R	$\sqrt{3}$	1	1	±0.6%	±0.6%
Readout Electronics	±0.3%	N	1	1	1	±0.3%	±0.3%
Response Time	±0.8%	R	$\sqrt{3}$	1	1	±0.5%	±0.5%
Integration Time	±2.6%	R	$\sqrt{3}$	1	1	±1.5%	±1.5%
RF Ambient Noise	±3.0%	R	$\sqrt{3}$	1	1	±1.7%	±1.7%
RF Ambient Reflections	±3.0%	R	$\sqrt{3}$	1	1	±1.7%	±1.7%
Probe Positioner	±0.4%	R	$\sqrt{3}$	1	1	±0.2%	±0.2%
Probe Positioning	±2.9%	R	$\sqrt{3}$	1	1	±1.7%	±1.7%
Max. SAR Evaluation	±2.0%	R	$\sqrt{3}$	1	1	±1.2%	±1.2%
Test Sample Related							
Device Positioning	±2.9%	N	1	1	1	±2.9%	±2.9%
Device Holder	±3.6%	N	1	1	1	±3.6%	±3.6%
Power Drift	±5.0%	R	$\sqrt{3}$	1	1	±2.9%	±2.9%
Power Scaling	±0%	R	$\sqrt{3}$	1	1	±0.0%	±0.0%
Phantom and Setup Related							
Phantom Uncertainty	±6.1%	R	$\sqrt{3}$	1	1	±3.5%	±3.5%
SAR correction	±1.9%	R	$\sqrt{3}$	1	0.84	±1.1%	±0.9%
Liquid conductivity (measured)	±2.5%	N	1	0.78	0.71	±2.0%	±1.8%
Liquid permittivity (measured)	±2.5%	N	1	0.26	0.26	±0.6%	±0.7%
Temperature uncertainty - Conductivity	±5.2%	R	$\sqrt{3}$	0.78	0.71	±2.3%	±2.1%
Temperature uncertainty - Permittivity	±0.8%	R	$\sqrt{3}$	0.23	0.26	±0.1%	±0.1%
Combined Standard Uncertainty						±11.4%	±11.3%
Expanded Standard Uncertainty						**±22.9%**	**±22.7%**

Measurement Uncertainty according to EN 62209-2							
Error Description	**Uncertainty Value**	**Probability Distribution**	**Div.**	**c_i (1g)**	**c_i (10g)**	**Std. Unc. 1g**	**Std. Unc. 10g**
Measurement System							
Probe Calibration	±6.55%	N	1	1	1	±6.55%	±6.55%
Axial Isotropy	±4.7%	R	$\sqrt{3}$	0.7	0.7	±1.9%	±1.9%
Hemispherical Isotropy	±9.6%	R	$\sqrt{3}$	0.7	0.7	±3.9%	±3.9%
Linearity	±4.7%	R	$\sqrt{3}$	1	1	±2.7%	±2.7%
Modulation Response	±2.4%	R	$\sqrt{3}$	1	1	±1.4%	±1.4%
System Detection Limits	±1.0%	R	$\sqrt{3}$	1	1	±0.6%	±0.6%
Boundary effects	±2.0%	R	$\sqrt{3}$	1	1	±1.2%	±1.2%
Readout Electronics	±0.3%	N	1	1	1	±0.3%	±0.3%
Response Time	±0.8%	R	$\sqrt{3}$	1	1	±0.5%	±0.5%
Integration Time	±2.6%	R	$\sqrt{3}$	1	1	±1.5%	±1.5%
RF Ambient Noise	±3.0%	R	$\sqrt{3}$	1	1	±1.7%	±1.7%
RF Ambient Reflections	±3.0%	R	$\sqrt{3}$	1	1	±1.7%	±1.7%
Probe Positioner	±0.8%	R	$\sqrt{3}$	1	1	±0.5%	±0.5%
Probe Positioning	±6.7%	R	$\sqrt{3}$	1	1	±3.9%	±3.9%
Post processing	±4.0%	R	$\sqrt{3}$	1	1	±2.3%	±2.3%
Test Sample Related							
Device Holder	±3.6%	N	1	1	1	±3.6%	±3.6%
Test Sample Positioning	±2.9%	N	1	1	1	±2.9%	±2.9%
Power Scaling	±0%	R	$\sqrt{3}$	1	1	±0%	±0%
Power Drift	±5.0%	R	$\sqrt{3}$	1	1	±2.9%	±2.9%
Phantom and Setup Related							
Phantom Uncertainty	±7.9%	R	$\sqrt{3}$	1	1	±4.6%	±4.6%
SAR correction	±1.9%	R	$\sqrt{3}$	1	0.84	±1.1%	±0.9%
Liquid conductivity (measured)	±2.5%	N	1	0.78	0.71	±2.0%	±1.8%
Liquid permittivity (measured)	±2.5%	N	1	0.26	0.26	±0.1%	±0.1%
Temperature uncertainty - Conductivity	±5.2%	R	$\sqrt{3}$	0.78	0.71	±2.3%	±2.1%
Temperature uncertainty - Permittivity	±0.8%	R	$\sqrt{3}$	0.23	0.26	±0.1%	±0.1%
Combined Standard Uncertainty						±12.8%	±12.7%
Expanded Standard Uncertainty						**±25.6%**	**±25.4%**

6 Test Conditions and Results

6.1 Recipes for Tissue Simulating Liquids

Body Tissue Simulating Liquids					
Ingredient	M 450-B weight (%)	M 900-B weight (%)	M 1800-B weight (%)	M 1950-A weight (%)	M 2450-B weight (%)
Water	46.21	50.75	70.17	69.79	68.64
Sugar	51.17	48.21			
Cellulose	0.18				
Salt	2.34		0.39	0.2	
Preventol	0.08	0.1			
DGBE			29.44	30	31.37
Head Tissue Simulating Liquids					
Ingredient	HSL 450-A weight (%)	HSL 900-B weight (%)	HSL 1800-F weight (%)	HSL 1950-B weight (%)	HSL 2450-B weight (%)
Water	38.91	40.29	55.24	55.41	55
Sugar	56.93	57.9			
Cellulose	0.25	0.24			
Salt	3.79	1.38	0.31	0.08	
Preventol	0.12	0.18			
DGBE			44.45	44.51	45

Water: deionized water, resistivity ≥ 16 MΩ
Sugar: refined white sugar
Salt: pure NaCl
Cellulose: Hydroxyethyl-cellulose
Preservative: Preventol D-7
DGBE: Diethylenglycol-monobuthyl ether

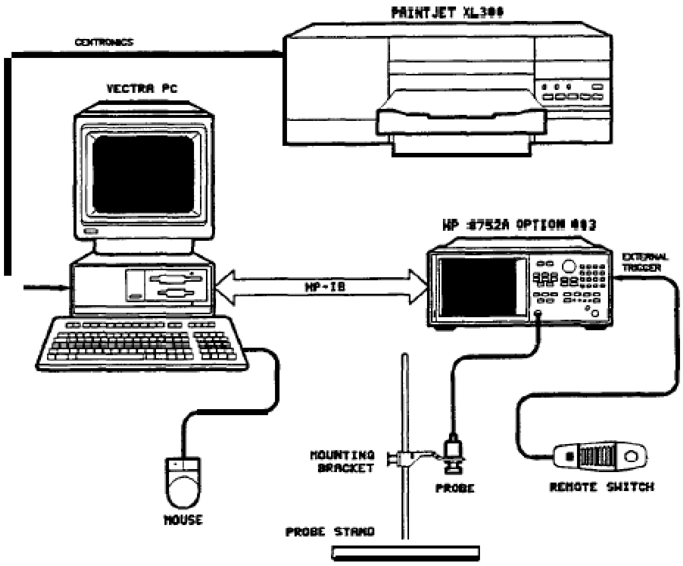
The parameters for the different frequencies are defined in the corresponding compliance standards (e.g., IEEE 1528-2003, IEC 62209-1)

The HBBL3-6GHz and MBBL 3-6 GHz liquids are direct from Speag.

6.2 Test Conditions and Results – Tissue Validation

Tissue Validation acc. to 865664 D01 SAR Measurement 100 MHz to 6 GHz / IC RSS-102					Verdict: PASS
Test according to measurement reference		Reference Method			
		865664 D01 SAR Measurement 100 MHz to 6 GHz			
Target Values					
Frequency [MHz]	Head		Body		Permitted tolerance [%]
	Relative dielectric constant ε_r	Conductivity σ [S/m]	Relative dielectric constant ε_r	Conductivity σ [S/m]	
150	52.3	0.76	61.9	0.80	≤ ±5
300	45.3	0.87	58.2	0.92	≤ ±5
450	43.5	0.87	56.7	0.94	≤ ±5
835	41.5	0.90	55.2	0.97	≤ ±5
900	41.5	0.97	55.0	1.05	≤ ±5
915	41.5	0.98	55.0	1.06	≤ ±5
1450	40.5	1.20	54.0	1.30	≤ ±5
1610	40.3	1.29	53.8	1.40	≤ ±5
1800 – 2000	40.0	1.40	53.3	1.52	≤ ±5
2450	39.2	1.80	52.7	1.95	≤ ±5
3000	38.5	2.40	52.0	2.73	≤ ±5
5200	36.0	4.66	49.0	5.30	≤ ±5
5500	35.6	4.96	48.6	5.65	≤ ±5
5800	35.3	5.27	48.2	6.00	≤ ±5

Test setup



Test procedure

1. The dielectric probe kit is calibrated using the standards air, short circuit and deionized water
2. The tissue simulating liquid is measured using the dielectric probe
3. Target values are compared to the measurement values and deviations are determined

Test results

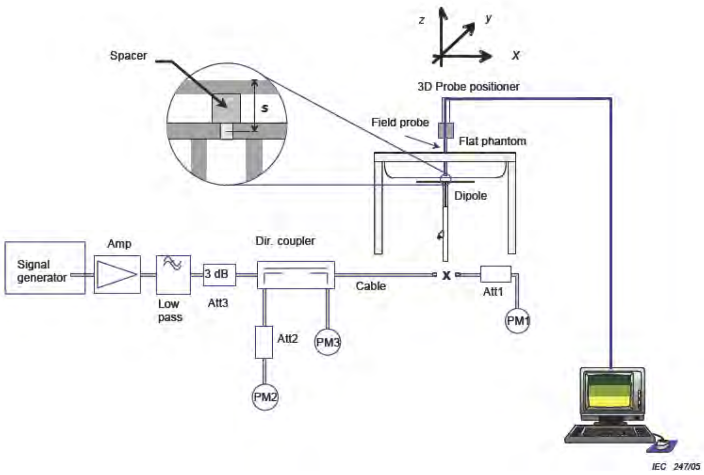
Frequency [MHz]	Tissue	Measured ε_r	Target ε_r	Delta ε_r [%]	Measured σ [S/m]	Target σ [S/m]	Delta σ [%]
824.2	Body	54.873	55.2	-0,59	0.998	0.97	2,89
826.4	Body	54.848	55.2	-0,64	1.000	0.97	3,09
836.2	Body	54.667	55.2	-0,97	1.011	0.97	4,23
846.6	Body	54.525	55.2	-1,22	1.023	0.98	4,39
848.8	Body	54.492	55.2	-0,92	1.026	0.99	3,64
900.0	Body	53.700	55.0	-2.36	1.088	1.05	3.62
1850.2	Body	53.687	53.3	0,73	1.454	1.52	-4.34
1852.4	Body	53.684	53.3	0,65	1.452	1.52	-4.47
1880.0	Body	53.676	53.3	0.71	1.492	1.52	1.84
1900.0	Body	53.687	53.3	0.73	1.521	1.52	0.07
1907.6	Body	53.683	53.3	0,72	1.532	1.52	0.79
1909.8	Body	53.689	53.3	0,73	1.535	1.52	0.99

Comments: * Measured radio frequencies

6.3 Test Conditions and Results – System Validation

System Validation acc. to 865664 D01 SAR Measurement 100 MHz to 6 GHz / IC RSS-102		Verdict: PASS
Test according to measurement reference	Reference Method	
	865664 D01 SAR Measurement 100 MHz to 6 GHz / IEEE 1528	
Test frequency range	Tested frequencies	
	900 MHz , 1900 MHz	
Test mode	unmodulated CW	
Target Values		
Frequency [MHz]	Target SAR value [W/kg (1g)]	Permitted tolerance [%]
900	2.8 @ 250mW	≤ ±10
1900	10.2 @ 100mW	≤ ±10
The target reference values are taken from the calibration sheets (see annex)		

Test setup



Test procedure

1. The dipole antenna input power is set to 250mW
2. The reference dipole is positioned under the phantom
3. With the dipole antenna powered the SAR value is measured
4. The measured SAR values are compared to the target SAR values

Test results				
Frequency [MHz]	Input power [mW]	Measured SAR value [W/kg (1g)]	Target SAR value [W/kg (1g)]	Delta [%]
900	250	2.89	2.8	3.21
900	250	2.71	2.8	-3.21
1900	250	10.4	10.2	1.96
1900	250	10.2	10.2	0.00
Comments:				

6.4 Test Conditions and Results – Standalone SAR Measurement

Standalone SAR acc. to 865664 D01 SAR Measurement 100 MHz to 6 GHz / IC RSS-102	**Verdict: PASS**
Test according to measurement reference	Reference Method
	865664 D01 SAR Measurement 100 MHz to 6 GHz / IC RSS-102 Issue 5
Room temperature	22.0 – 22.6 °C
Liquid depth	15.5 cm
Environment	general public

Limits		
Region	Occupational SAR values [W/kg]	General public SAR values [W/kg]
Whole body average SAR	0.4	0.08
Localized SAR (Head and trunk) SAR averaging mass = 1g	8	1.6
Localized SAR (Limbs) SAR averaging mass = 10g	20	4

Test results								
Mode	Position	Channel	Frequency [MHz]	Drift [dB]	Scaling Factor*	Measured SAR [W/kg (1g)]	Reported SAR [W/kg (1g)] **	SAR Limit [W/kg (1g)]
GPRS	Front	128	824.2	-0.17	1,075	1.340	1.441	1.6
GPRS	Back	128	824.2	-0.09	1,075	1.230	1.322	1.6
GPRS	Left	128	824.2	-0.05	1,075	0.599	0.644	1.6
GPRS	Right	128	824.2	-0.15	1,075	1.040	1.118	1.6
GPRS	Front	188	836.2	-0.15	1.079	1.350	**1.460**	1.6
GPRS	Back	188	836.2	-0.17	1.079	1.180	1.273	1.6
GPRS	Left	188	836.2	-0.16	1.079	0.523	0.564	1.6
GPRS	Right	188	836.2	-0.15	1.079	1.040	1.122	1.6

GPRS	Top	188	836.2	-0.15	1.079	0.117	0.126	1.6
GPRS	Front	251	848.8	-0.16	1.079	1.310	1.413	1.6
GPRS	Back	251	848.8	-0.06	1.079	1.160	1.252	1.6
GPRS	Left	251	848.8	-0.03	1.079	0.521	0.562	1.6
GPRS	Right	251	848.8	-0.01	1.079	0.992	1.070	1.6
GPRS	Front	188	836.2	-0.18	1.079	1.300	**1.400**	1.6
RMC	Front	4132	826.4	0.06	1.083	0.822	**0.890**	1.6
RMC	Back	4132	826.4	0.02	1.083	0.783	0.848	1.6
RMC	Left	4132	826.4	0.07	1.083	0.368	0.399	1.6
RMC	Right	4132	826.4	0.01	1.083	0.637	0.690	1.6
RMC	Front	4183	836.6	-0.14	1.101	0.724	0.797	1.6
RMC	Back	4183	836.6	-0.13	1.101	0.688	0.757	1.6
RMC	Left	4183	836.6	-0.17	1.101	0.310	0.341	1.6
RMC	Right	4183	836.6	-0.06	1.101	0.557	0.613	1.6
RMC	Top	4183	836.6	-0.06	1.101	0.065	0.072	1.6
RMC	Front	4233	846.6	0.01	1.101	0.683	0.752	1.6
RMC	Back	4233	846.6	0.01	1.101	0.633	0.697	1.6
RMC	Left	4233	846.6	0.04	1.101	0.275	0.303	1.6
RMC	Right	4233	846.6	-0.06	1.101	0.525	0.578	1.6
GPRS	Front	661	1880.0	-0.10	1.092	0.040	0.044	1.6
GPRS	Back	661	1880.0	0.04	1.092	0.044	**0.048**	1.6
GPRS	Left	661	1880.0	0.16	1.092	0.020	0.022	1.6
GPRS	Right	661	1880.0	-0.13	1.092	0.005	0.005	1.6
GPRS	Top	661	1880.0	0.11	1.092	0.004	0.004	1.6
RMC	Front	9400	1880.0	-0.16	1.090	0.036	0.039	1.6
RMC	Back	9400	1880.0	-0.15	1.090	0.038	**0.041**	1.6
RMC	Left	9400	1880.0	-0.12	1.090	0.017	0.019	1.6
RMC	Right	9400	1880.0	-0.17	1.090	0.004	0.004	1.6
RMC	Top	9400	1880.0	-0.19	1.090	0.004	0.004	1.6
Overall maximum SAR value [W/kg (1g)]							**1.46**	**1.6**
Comments:*tune up limit power (mW) / measured conducted power (mW) = scaling factor ** attached measurement plot: highest SAR value for the communication system								

According to KDB 865664 D02 v01r02 only the SAR plots for the highest SAR results for each EUT configuration and operating condition are given in the “SAR Results” part of the report.

6.5 Test Conditions and Results – Multi-transmitter SAR Result

None

ANNEX A Calibration Documents

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

S **Schweizerischer Kalibrierdienst**
C **Service suisse d'étalonnage**
S **Servizio svizzero di taratura**
Swiss Calibration Service

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 **Eurofins**

Certificate No: DAE3-522_Sep17

CALIBRATION CERTIFICATE

Object	DAE3 - SD 000 D03 AA - SN: 522
Calibration procedure(s)	QA CAL-06.v29 Calibration procedure for the data acquisition electronics (DAE)
Calibration date:	September 18, 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
Keithley Multimeter Type 2001	SN: 0810278	31-Aug-17 (No:21092)	Aug-18
Secondary Standards	**ID #**	**Check Date (in house)**	**Scheduled Check**
Auto DAE Calibration Unit	SE UWS 053 AA 1001	05-Jan-17 (in house check)	In house check: Jan-18
Calibrator Box V2.1	SE UMS 006 AA 1002	05-Jan-17 (in house check)	In house check: Jan-18

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

Issued: September 18, 2017

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.

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	404.509 ± 0.02% (k=2)	404.695 ± 0.02% (k=2)	404.120 ± 0.02% (k=2)
Low Range	3.92852 ± 1.50% (k=2)	3.91800 ± 1.50% (k=2)	3.91819 ± 1.50% (k=2)

Connector Angle

Connector Angle to be used in DASY system	57.5 ° ± 1 °

Appendix (Additional assessments outside the scope of SCS0108)

1. DC Voltage Linearity

High Range		Reading (μV)	Difference (μV)	Error (%)
Channel X	+ Input	199994.82	-0.56	-0.00
Channel X	+ Input	20003.33	1.87	0.01
Channel X	- Input	-20000.12	1.10	-0.01
Channel Y	+ Input	199991.86	-3.71	-0.00
Channel Y	+ Input	20004.92	3.31	0.02
Channel Y	- Input	-19993.60	7.50	-0.04
Channel Z	+ Input	199990.86	-4.57	-0.00
Channel Z	+ Input	20000.33	-1.19	-0.01
Channel Z	- Input	-20002.88	-1.70	0.01

Low Range		Reading (μV)	Difference (μV)	Error (%)
Channel X	+ Input	2001.30	0.28	0.01
Channel X	+ Input	201.10	-0.28	-0.14
Channel X	- Input	-198.17	0.25	-0.13
Channel Y	+ Input	2000.80	-0.32	-0.02
Channel Y	+ Input	200.72	-0.83	-0.41
Channel Y	- Input	-198.48	-0.12	0.06
Channel Z	+ Input	2001.19	0.18	0.01
Channel Z	+ Input	200.52	-0.87	-0.43
Channel Z	- Input	-199.09	-0.55	0.28

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	3.13	1.90
	- 200	-0.92	-2.67
Channel Y	200	3.67	3.47
	- 200	-4.61	-4.74
Channel Z	200	-6.36	-6.38
	- 200	4.03	4.15

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	-	-0.13	-3.67
Channel Y	200	7.29	-	-0.19
Channel Z	200	7.08	5.65	-

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	16113	16236
Channel Y	16216	16793
Channel Z	16308	16730

5. Input Offset Measurement

DASY measurement parameters: Auto Zero Time: 3 sec; Measuring time: 3 sec
Input 10MΩ

	Average (μV)	min. Offset (μV)	max. Offset (μV)	Std. Deviation (μV)
Channel X	1.18	-0.73	3.40	0.58
Channel Y	0.14	-1.02	1.30	0.46
Channel Z	0.24	-0.72	1.24	0.45

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

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

S **Schweizerischer Kalibrierdienst**
C **Service suisse d'étalonnage**
S **Servizio svizzero di taratura**
Swiss Calibration Service

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 **Eurofins**

Certificate No: EX3-3893_Sep17

CALIBRATION CERTIFICATE

Object	EX3DV4 - SN:3893
Calibration procedure(s)	QA CAL-01.v9, QA CAL-12.v9, QA CAL-14.v4, QA CAL-23.v5, QA CAL-25.v6 Calibration procedure for dosimetric E-field probes
Calibration date:	September 25, 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

	Name	Function	Signature
Calibrated by:	Jeton Kastrati	Laboratory Technician	
Approved by:	Katja Pokovic	Technical Manager	

Issued: September 25, 2017

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, ", "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 ≤ 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:3893

Manufactured: October 9, 2012
Calibrated: September 25, 2017

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

DASY/EASY - Parameters of Probe: EX3DV4 - SN:3893

Basic Calibration Parameters

	Sensor X	Sensor Y	Sensor Z	Unc (k=2)
Norm ($\mu V/(V/m)^2$)[A]	0.54	0.41	0.32	± 10.1 %
DCP (mV)[B]	101.5	103.5	100.2	

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	145.1	±2.5 %
		Y	0.0	0.0	1.0		132.0	
		Z	0.0	0.0	1.0		136.0	

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:3893

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)
300	45.3	0.87	12.50	12.50	12.50	0.08	1.20	± 13.3 %
450	43.5	0.87	11.59	11.59	11.59	0.14	1.20	± 13.3 %
750	41.9	0.89	11.04	11.04	11.04	0.48	0.81	± 12.0 %
900	41.5	0.97	10.32	10.32	10.32	0.48	0.82	± 12.0 %
1750	40.1	1.37	9.11	9.11	9.11	0.39	0.80	± 12.0 %
1810	40.0	1.40	8.79	8.79	8.79	0.41	0.81	± 12.0 %
1950	40.0	1.40	8.41	8.41	8.41	0.32	0.86	± 12.0 %
2150	39.7	1.53	8.35	8.35	8.35	0.39	0.84	± 12.0 %
2450	39.2	1.80	7.73	7.73	7.73	0.35	0.87	± 12.0 %
2600	39.0	1.96	7.55	7.55	7.55	0.44	0.84	± 12.0 %
5200	36.0	4.66	5.25	5.25	5.25	0.35	1.80	± 13.1 %
5500	35.6	4.96	5.14	5.14	5.14	0.40	1.80	± 13.1 %
5800	35.3	5.27	4.98	4.98	4.98	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:3893

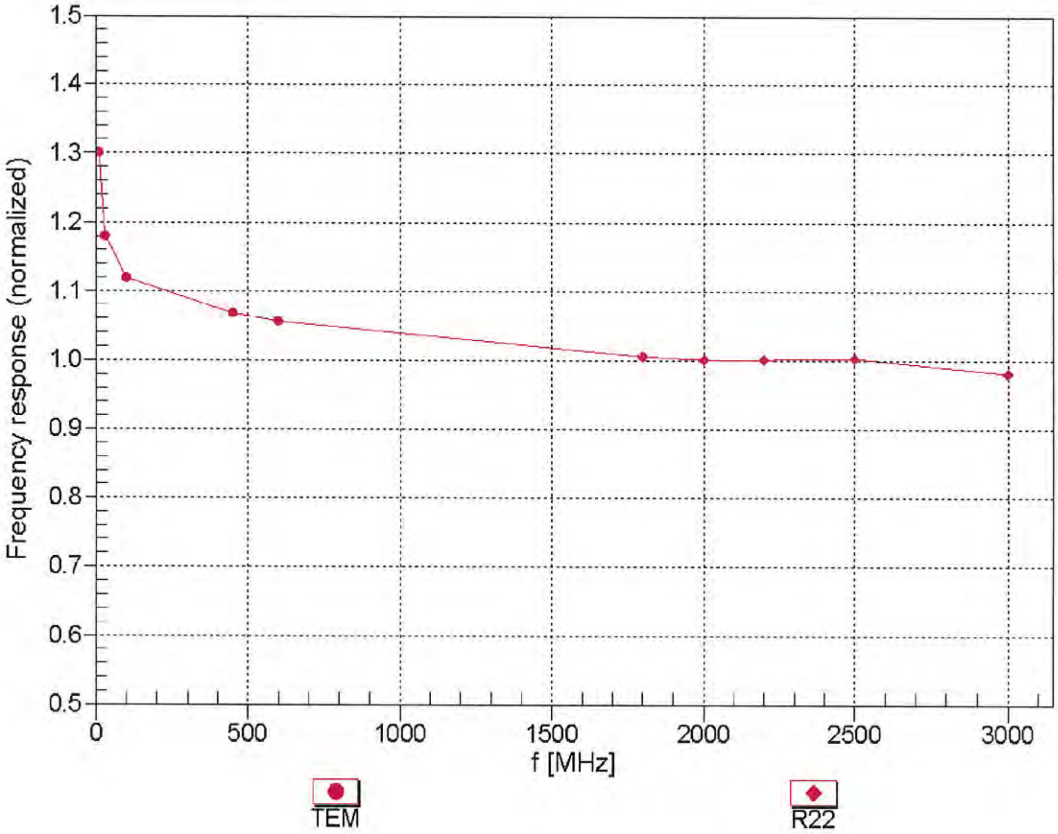
Calibration Parameter Determined in Body Tissue Simulating Media

f (MHz) [C]	Relative Permittivity [F]	Conductivity (S/m) [F]	ConvF X	ConvF Y	ConvF Z	Alpha [G]	Depth [G] (mm)	Unc (k=2)
300	58.2	0.92	11.86	11.86	11.86	0.05	1.20	± 13.3 %
450	56.7	0.94	11.71	11.71	11.71	0.10	1.20	± 13.3 %
750	55.5	0.96	10.63	10.63	10.63	0.52	0.81	± 12.0 %
900	55.0	1.05	10.31	10.31	10.31	0.48	0.80	± 12.0 %
1750	53.4	1.49	8.76	8.76	8.76	0.38	0.80	± 12.0 %
1810	53.3	1.52	8.51	8.51	8.51	0.33	0.90	± 12.0 %
1950	53.3	1.52	8.57	8.57	8.57	0.31	0.98	± 12.0 %
2150	53.1	1.66	8.36	8.36	8.36	0.39	0.81	± 12.0 %
2450	52.7	1.95	7.96	7.96	7.96	0.35	0.86	± 12.0 %
2600	52.5	2.16	7.73	7.73	7.73	0.27	0.95	± 12.0 %
5200	49.0	5.30	4.88	4.88	4.88	0.40	1.90	± 13.1 %
5500	48.6	5.65	4.32	4.32	4.32	0.45	1.90	± 13.1 %
5800	48.2	6.00	4.41	4.41	4.41	0.45	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.

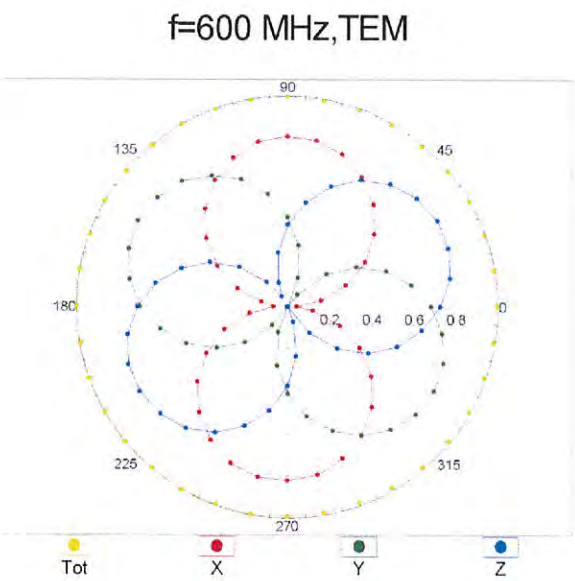
Frequency Response of E-Field

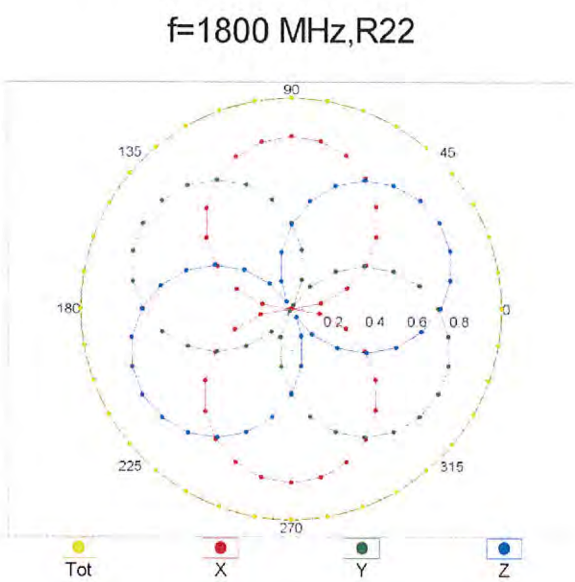
(TEM-Cell:ifi110 EXX, Waveguide: R22)

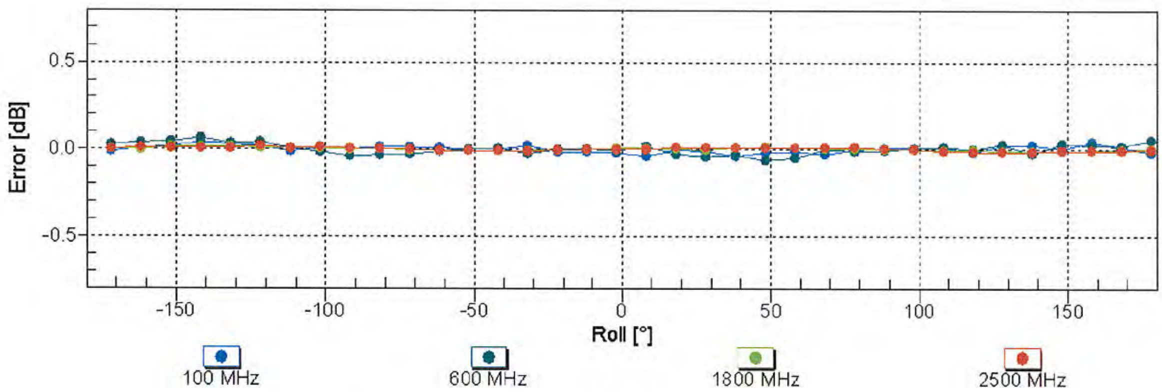


Uncertainty of Frequency Response of E-field: ± 6.3% (k=2)

Receiving Pattern (ϕ), ϑ = 0°

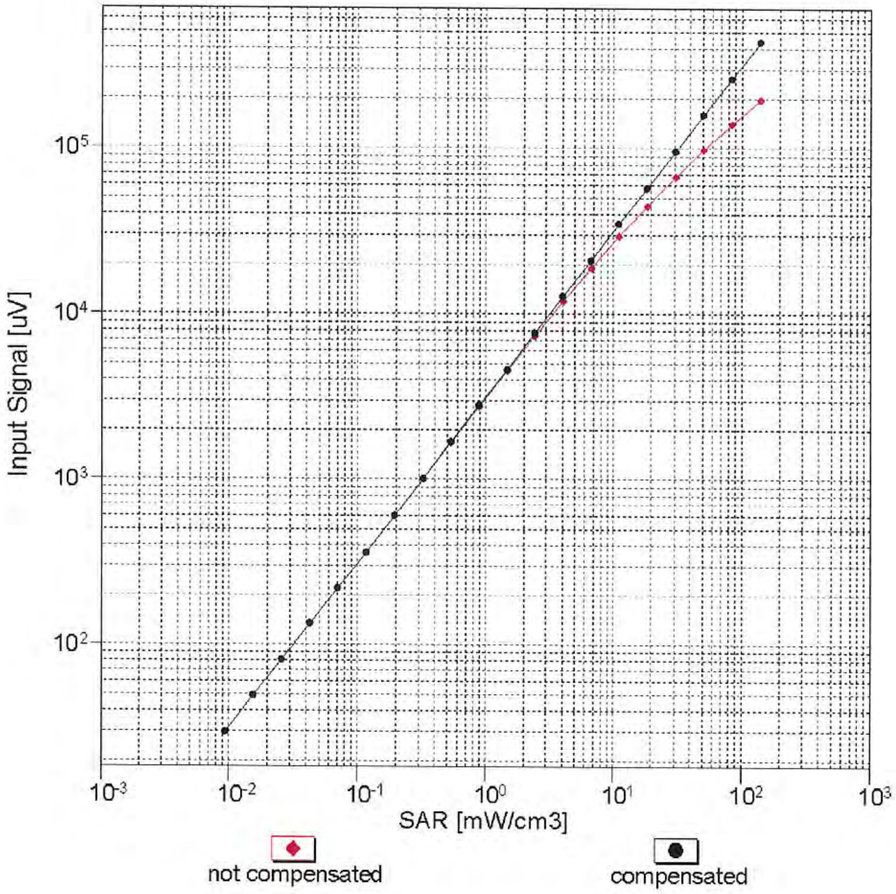


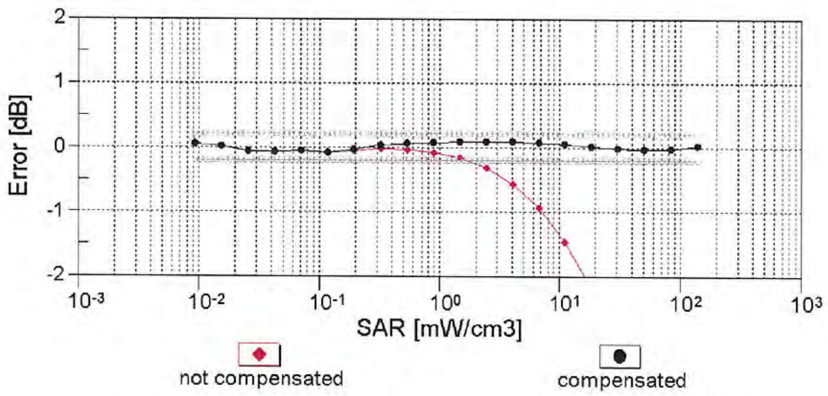




Uncertainty of Axial Isotropy Assessment: ± 0.5% (k=2)

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

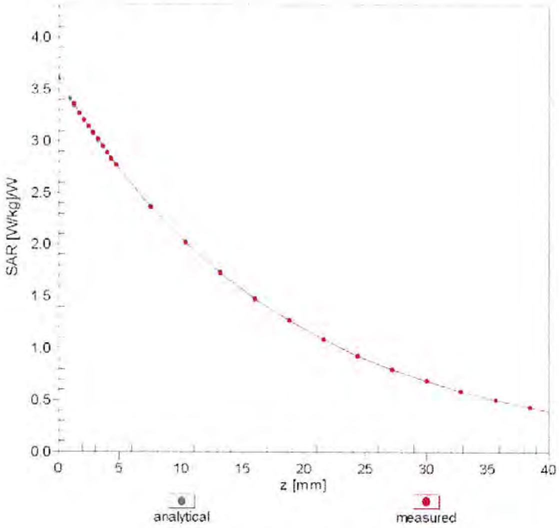




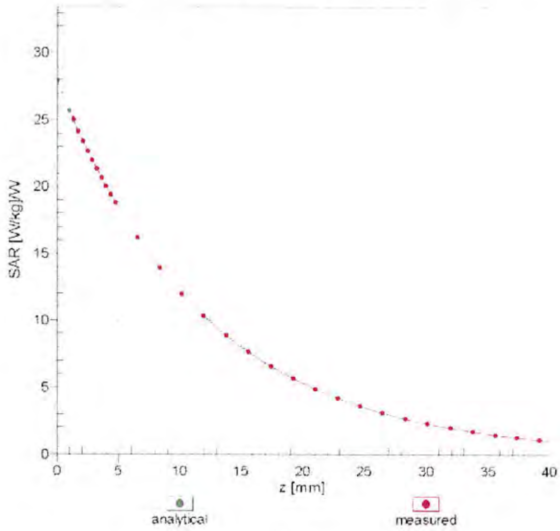
Uncertainty of Linearity Assessment: ± 0.6% (k=2)

Conversion Factor Assessment

f = 900 MHz,WGLS R9 (H_convF)

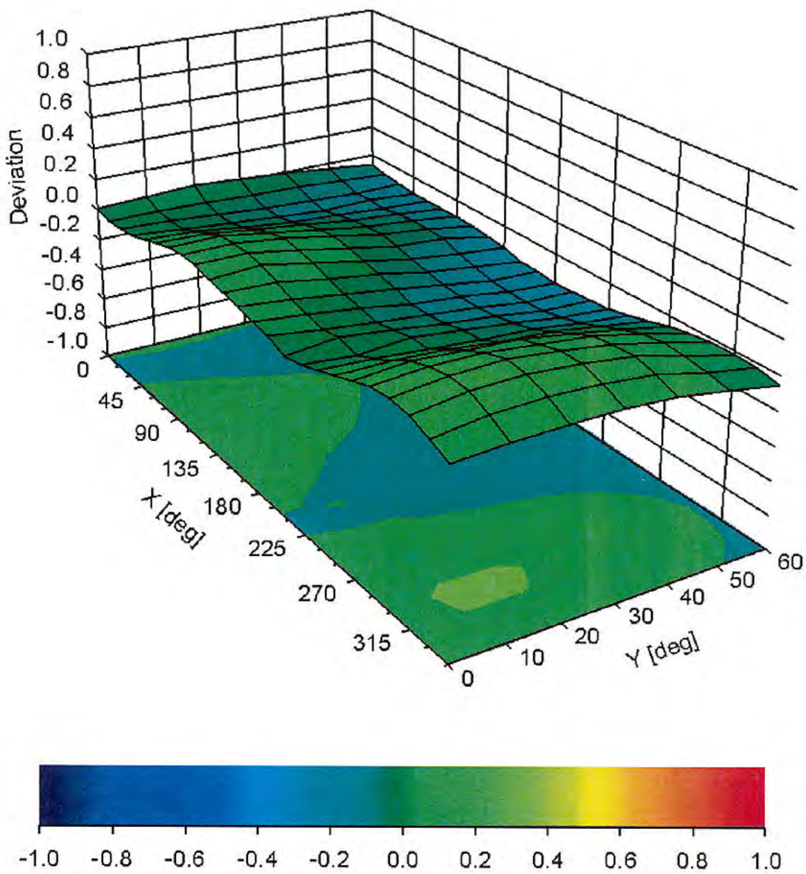


f = 1810 MHz,WGLS R22 (H_convF)



Deviation from Isotropy in Liquid

Error (ϕ, ϑ), f = 900 MHz



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

DASY/EASY - Parameters of Probe: EX3DV4 - SN:3893

Other Probe Parameters

Sensor Arrangement	Triangular
Connector Angle (°)	-21.9
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