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-1507-4918-TFC093SR-V01
Testing Laboratory .... :	Eurofins Product Service GmbH
Address .... :	Storkower Str. 38c 15526 Reichenwalde Germany
Accreditation .... :	A2LA Accredited Testing Laboratory, Certificate No.: 1983.01 FCC Filed Test Laboratory, Reg.-No.: 96970 IC OATS Filing assigned code: 3470A
Applicant's name .... :	ABB Oy, Drives and Controls
Address .... :	Hiomotie 13 00380 Helsinki FINLAND
Test specification:	
Standard.. :	FCC 47 CFR Part 2 §2.1093 447498 D01 General RF Exposure Guidance v05r02 IEEE Std. 1528 - 2013 IC RSS-102 Issue 5 Safety Code 6 (2015)
Non-standard test method…………..:	None
Test scope………….. .... :	complete Radio compliance test
Equipment under test (EUT):	
Product description	Assistant control panel with Bluetooth interface
Model No.	ACS-AP-W
Additional Model(s)	ACH-AP-W
Brand Name(s)	ABB
Hardware version	C
Firmware / Software version	v 4.90
Contains	FCC-ID: 2AFNGAPWSERIES IC: 20555-APWSERIES
Test result	**Passed**

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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:	2015-07-22	
Date (s) of performance of tests:	2015-10-26	
Compiled by:	Matthias Handrik	
Tested by (+ signature): (Responsible for Test)	Matthias Handrik	Handrik
Approved by (+ signature): (Head of Lab)	Christian Weber	C. Weber
Date of issue:	2015-10-27	
Total number of pages:	71	

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:

First" model: ACS-AP-W

"Second" model: ACH-AP-W

The "second" variant is called "HVAC assistant control panel with Bluetooth interface". The most important difference is that HVAC markets require different start-stop logic for controlling the frequency converter. In HVAC variant, the logic is Hand – Auto – Off, while normal industrial modes have only On – Off.

The Bluetooth part and PCB are exactly similar:

- layout : no changes - schematic: no changes
- RF part: no changes
- Bluetooth profiles, QDID: no changes
- plastic covers: different printings on push-buttons, different colors of plastics

Full Test was performed on the version ACS-AP-W

Version History

Version	Issue Date	Remarks	Revised by
01	2015-10-27	Initial Release	

REPORT INDEX

1 Equipment (Test item) Description

Description	Assistant control panel with Bluetooth interface	
Model	ACS-AP-W	
Additional Model(s)	ACH-AP-W	
Brand Name(s)	ABB	
Serial number	None	
Hardware version	C	
Software / Firmware version	v 4.90	
Contains FCC-ID	2AFNGAPWSERIES	
Contains IC	20555-APWSERIES	
Equipment type	End product	
Prototype or production unit	Production Unit	
Device category	Handset	
Environment	General public	
Radio technologies	Bluetooth Bluetooth Low Energy	
Operating frequency ranges	Bluetooth: 2402 MHz - 2480 MHz Bluetooth Low Energy: 2402 MHz - 2480 MHz	
Modulations	GFSK, π/4-DQPSK, 8-DPSK	
Antenna	Type	integrated
	Model	F-Antenna PCB
	Manufacturer	unspecified
	Gain	1.7 dBi
Power supply	V_{NOM}	24 VDC
AC/DC-Adaptor	Model	N/A
	Vendor	N/A
	Input	N/A
	Output	N/A
Accessories	None	
Manufacturer	ABB Oy, Drives and Controls Hiomotie 13 00380 Helsinki FINLAND	

1.1 Equipment photos

EUT ACS-AP-W TOP

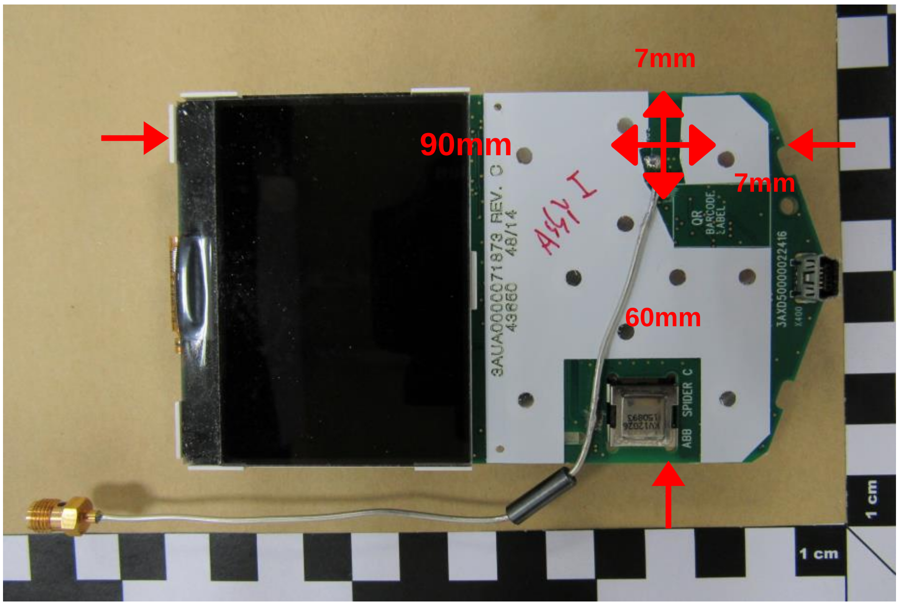

EUT ACS-AP-W BOTTOM


EUT ACH-AP-W TOP


EUT ACH-AP-W BOTTOM


EUT PCB BOTTOM

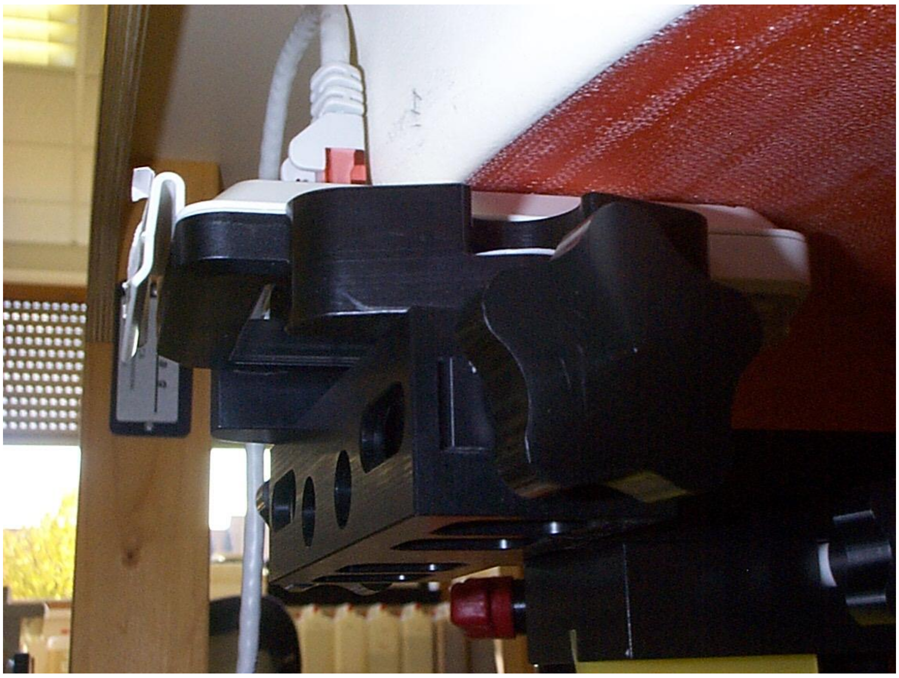

EUT PCB TOP


Antenna distance


Antenna distance TOP/BOTTOM 10mm

1.2 Equipment setup photos

EUT BACK 0mm


EUT BOTTOM 0mm


EUT TOP 0mm


EUT RIGHT 0mm


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
AE	Laptop	DELL	Latitude E640	
SIM	Bluetooth tester	R&S	CBT	

AE : Auxiliary/Associated Equipment, or

SIM : Simulator (Not Subjected to Test)

1.5 Supported standalone operating modes

Mode	Modulation	Frequency range	Duty cycle
Bluetooth	GFSK, π/4-DQPSK, 8-DPSK	2402 – 2480 MHz	78%
Bluetooth Low Energy	GFSK	2402 – 2480 MHz	100%

1.6 Conducted Power Values

According to KDB 447498 D01 v05r02 the conducted power values of all operating modes have been measured in order to determine the worst case source-based averaged power values. The measurements were performed for all operating modes.

Bluetooth Low Energy – Output Power	
Frequency [MHz]	Output power [dBm]
	GFSK
2402	6.84
2441	6.75
2480	6.82
Date, Operator:	23.10.2015 , M. Handrik

Bluetooth Low Energy – Maximum tune up output Power	
Frequency [MHz]	Output power [dBm]
	GFSK
2402	8.84
2441	8.75
2480	8.82
Date, Operator:	23.10.2015 , M. Handrik

Bluetooth BR+EDR – Average Output Power			
Frequency [MHz]	Source-base time-average power [dBm]		
	BR (GFSK)	EDR (PI/4-DQPSK)	EDR (8-DPSK)
	DH5	2-DH5	3-DH5
2402	10.61	6.27	6.84
2441	10.66	6.23	6.84
2480	10.54	6.21	6.87
Date, Operator:	23.10.2015 , M. Handrik		

Bluetooth BR+EDR – Maximum tune up output Power			
Frequency [MHz]	Source-base time-average power [dBm]		
	BR (GFSK)	EDR (PI/4-DQPSK)	EDR (8-DPSK)
	DH5	2-DH5	3-DH5
2402	12.61	8.27	8.84
2441	12.66	8.23	8.84
2480	12.54	8.21	8.87
Date, Operator:	23.10.2015 , M. Handrik		

1.7 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:

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

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

SAR Test Exclusion FCC																
Mode	P [mW]	Ant.	Reg.	EUT Edge												
				Top		Left		Right		Bottom		Back		Front	
				Antenna distance to user [mm]	SAR Test Exclusion Threshold [≤3.0]	Antenna distance to user [mm]	SAR Test Exclusion Threshold mW]	Antenna distance to user [mm]	SAR Test Exclusion Threshold [≤3.0]	Antenna distance to user [mm]	SAR Test Exclusion Threshold [≤3.0]	Antenna distance to user [mm]	SAR Test Exclusion Threshold [≤3.0]	Antenna distance to user [mm]	SAR Test Exclusion Threshold mW]
Bluetooth, 2442MHz, DH5	18.45	1	FCC	10	2.9	60	196	7	**4.1**	10	2.9	7	**4.1**	90	496
Bluetooth Low Energy, 2402 MHz	7.66	1	FCC	10	1.2	60	196	7	1.7	10	1.2	7	1.7	90	496
Comments: All bold Threshold values are above the limit and have to be measured																
Date, Operator:	23.10.2015 , M. Handrik															

1.8 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

SAR Test Exemption IC

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]
Bluetooth, 2442MHz, DH5	18.45	1	IC	10	**7**	60	309	7	**4**	10	**7**	7	**4**	90	309
Bluetooth Low Energy, 2402 MHz	7.65	1	IC	10	**7**	60	309	7	**4**	10	**7**	7	**4**	90	309
Comments: All bold Threshold values are above the limit and have to be measured															
Date, Operator:			23.10.2015 , M. Handrik												

1.9 Supported concurrent (multi-transmitter) operating modes

No multi-transmitter evaluation.

1.10 Supported use cases

Use case	Distance to human body	corresponding test configuration
EUT placed at human body	0 mm (worst case)	body-worn device

1.11 Radio Test Modes

Mode	Settings
Bluetooth	Mode = DH5 Modulation = GFSK Duty cycle = 78% Power level = maximum Antenna = integrated
Bluetooth Low Energy	Mode = Bluetooth Low Energy Modulation = GFSK Duty cycle = 100% Power level = maximum (14) Antenna = integrated

1.12 Test Positions

Position	Description
TOP -0MM	EUT top side directly touching the phantom.
RIGHT-0MM	EUT right side directly touching the phantom.
BOTTOM-0MM	EUT bottom side directly touching the phantom.
BACK-0MM	EUT back side directly touching the phantom.

1.13 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	2015-09	2016-09
Dosimetric E-Field Probe	Schmid & Partner	ET3DV6	EF00279	2015-09	2016-09
Dosimetric E-Field Probe	Schmid & Partner	EX3DV4	EF00826	2015-10	2016-10
System Validation Kit	Schmid & Partner	D300V3	EF00299	2015-09	2018-09
System Validation Kit	Schmid & Partner	D450V3	EF00300	2015-09	2018-09
System Validation Kit	Schmid & Partner	D900V2	EF00281	2015-09	2018-09
System Validation Kit	Schmid & Partner	D1800V2	EF00282	2015-09	2018-09
System Validation Kit	Schmid & Partner	D1900V2	EF00283	2015-09	2018-09
System Validation Kit	Schmid & Partner	D2450V2	EF00284	2015-09	2018-09
System Validation Kit	Schmid & Partner	D5GHZV2	EF00827	2015-10	2018-10
Flat phantom	Schmid & Partner	V 4.4	EF00328	no calibration required	no calibration required
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	2013-08	2016-08
Power sensor	Rohde & Schwarz	NRV-Z2	EF00125	2015-09	2017-09
RF signal generator	Rohde & Schwarz	SMP 02	EF00165	2015-05	2017-05
Insertion unit	Rohde & Schwarz	URV5-Z4	EF00322	2015-10	2016-10
Directional Coupler	HP	HP 87300B	EF00288	functional test	functional test
Radio Communication Tester	Rohde & Schwarz	CMD65	EF00625	ICO (initial calibration only)	ICO (initial calibration only)
Universal Radio Communication Tester	Rohde & Schwarz	CMU 200	EF00304	2015-05	2016-05
Network Analyzer 300 kHz to 3 GHz	Agilent	8752C	EF00140	2015-06	2016-06
Dielectric Probe Kit	Agilent	85070C	EF00291	functional test	functional test
Dielectric Probe Kit	SPEAG	DAK-3.5	EF00945	2015-09	2016-09
DAK Measurement Software	SPEAG	DAKS	EF00965	-	-
Thermometer	LKM electronic GmbH	DTM3000	EF00967	2015-10	2016-10

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 865664	0.225	PASS	
447498 D01 General RF Exposure Guidance RSS-102 Section 3	Multi-band conformity	KDB Publication 447498 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.

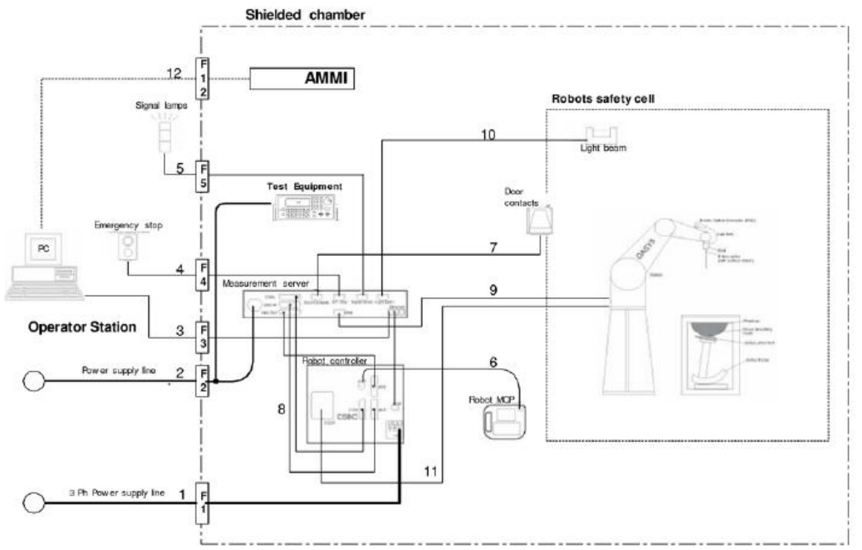
4.1 Complete SAR DASY5 Measurement System

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.

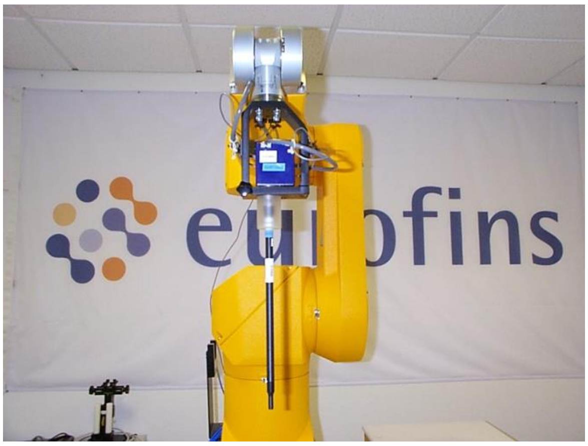
4.2 Robot Arm

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

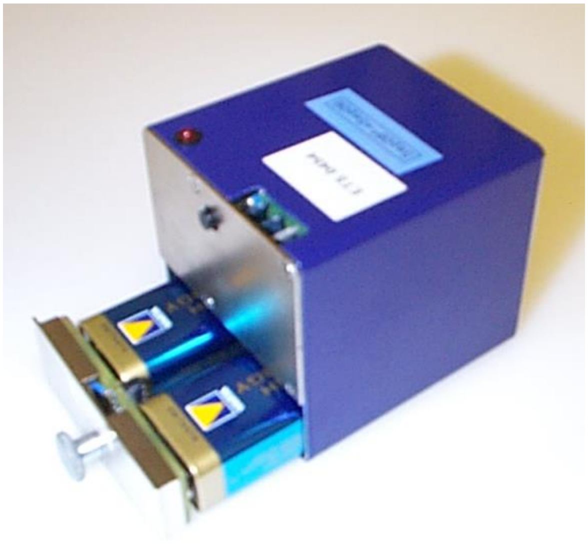


4.3 Data Acquisition Electronics

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 ≤ 3 GHz

Probe Specifications

Construction:

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

Calibration:

In air from 10 MHz to 2.5 GHz,
In brain and muscle simulating tissue at Frequencies of 835MHz, 900MHz, 1800MHz, 1900 MHz and 2450 MHz

Frequency:

10MHz to > 3GHz,
Linearity ±0.2dB (30MHz to 3GHz)

Directivity:

±0.2dB in HSL (rotation around probe axis)
±0.4dB in HSL (rotation normal to probe axis)

Dynamic Range:

5µW/g to > 100mW/g

Linearity:

±0.2dB

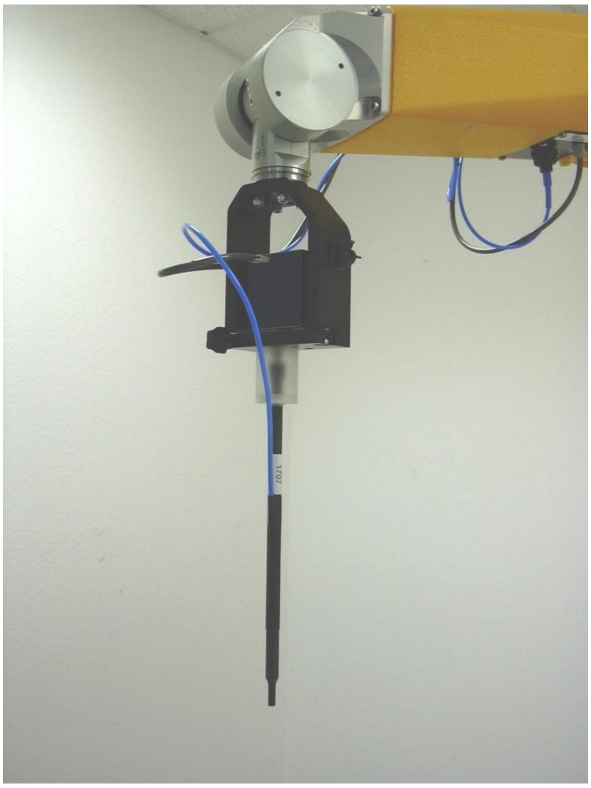
Dimensions:

Overall Length: 330mm (Tip: 16mm),
Tip Diameter: 6.8mm (Body: 12mm),
Distance from probe tip to dipole centers: 2.7mm

Application:

General dosimetry up to 3 GHz
Compliance tests of mobile phones
Fast automatic scanning in arbitrary phantoms

Isotropic E-Field Probe ET3DV6



4.5 Isotropic E-Field Probe ≤ 6 GHz

Isotropic E-Field Probe EX3DV4

<u>**Probe Specifications**</u>

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 5200, 5500, 5800

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

4.6 Test phantom and positioner

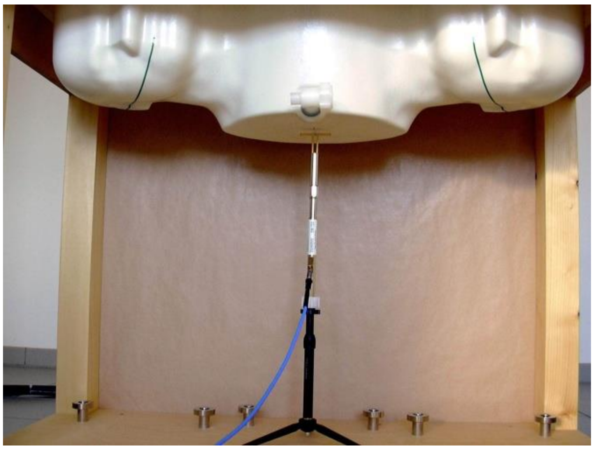
The positioner and test phantoms are manufactured by SPEAG. The test phantoms are used for all tests i.e. for both validation testing and device testing. The positioner and test phantom conforms to the requirements of EN 62209 and IEEE 1528.

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.

Probe Positioner	SAM Twin Phantom
	
ELI4 phantom	**Flat phantom**
	

4.7 System Validation Dipoles

A set of calibration dipoles (D2450V2) 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.

2450MHz 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:

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

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.

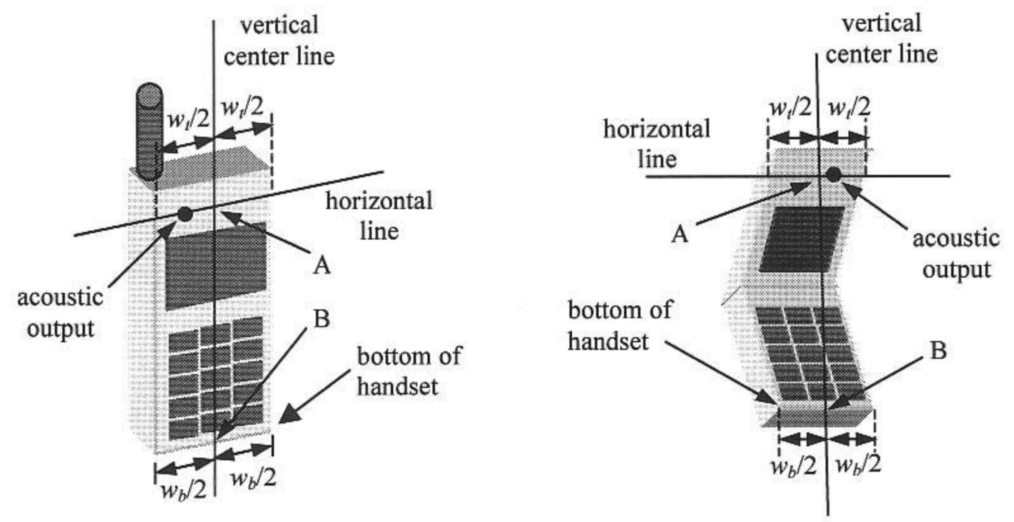
At the end of the measurement the reference point measured at the beginning of the measurement is measured again and from the difference the drift is calculated.

5.3 Reference lines and points for Handsets

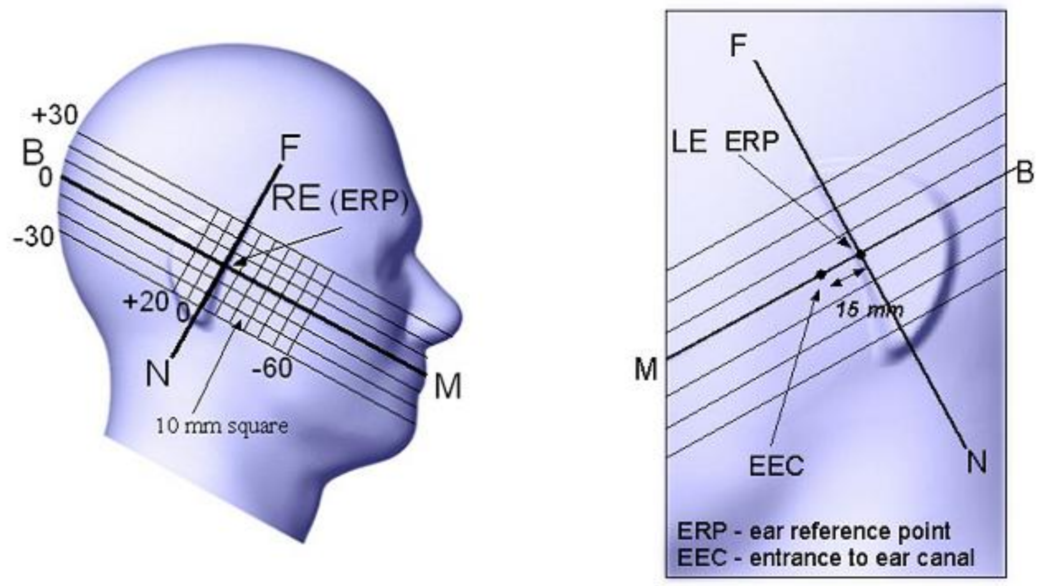
For all measurement positions of the EUT, the EUT has to be place in a specific orientation with respect to the phantom. The orientation of the EUT relative to the phantom is defined by reference lines and points.

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



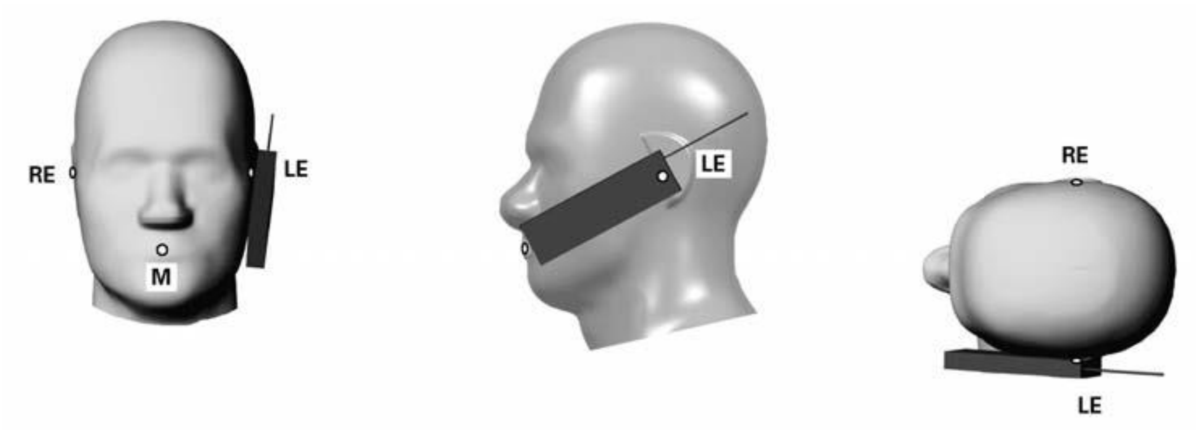
Reference lines and points on human head acc. to IEEE 1528



5.4 Test positions relative to the Head

Cheek position

Cheek positions according to IEEE 1528

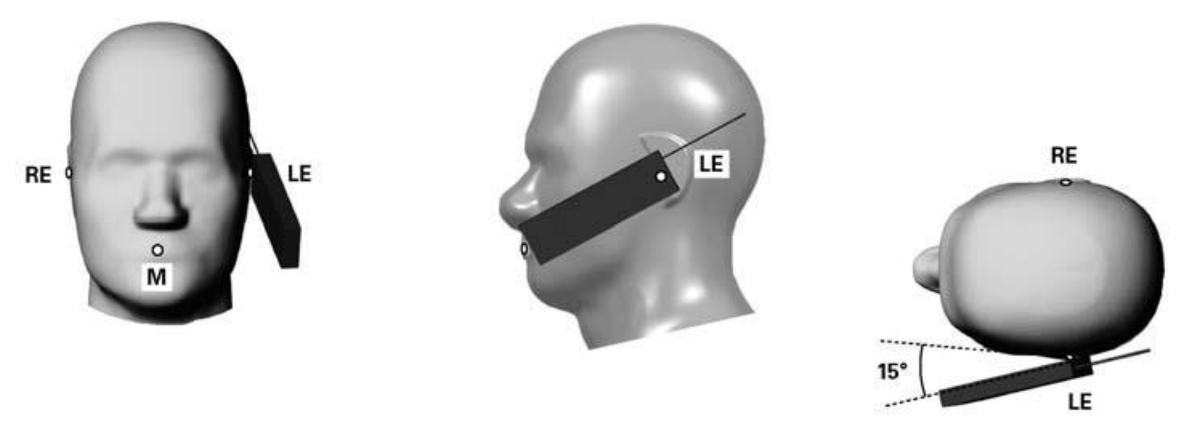


The handset is positioned close to the surface of the phantom such that point A is on the (virtual) extension of the line passing through points RE and LE on the phantom (see Figure), such that the plane defined by the vertical centerline and the horizontal line of the handset is approximately parallel 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

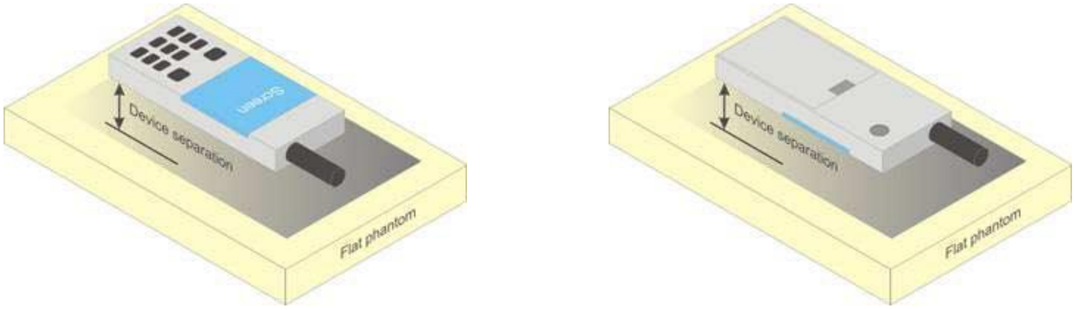
Tilt positions according to IEEE 1528



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

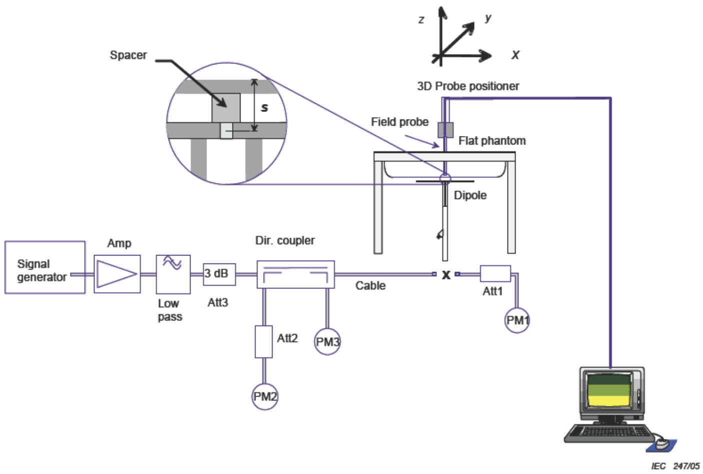
Test results

Frequency [MHz]	Tissue	Measured ε_r	Target ε_r	Delta ε_r [%]	Measured σ [S/m]	Target σ [S/m]	Delta σ [%]
2450	Body	50.6	52.7	-03.98	2.01	1.95	03.08
*2402	Body	50.3	52.8	-04.73	1.88	1.90	-00.02
*2442	Body	50.2	52.71	-04.76	1.95	1.94	00.01
*2480	Body	50.1	52.66	-04.86	2.01	1.99	00.02

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	
	2450 MHz	
Test mode	unmodulated CW	
Target Values		
Frequency [MHz]	Target SAR value [W/kg (1g)]	Permitted tolerance [%]
2450	12.5 @ 250mW	≤ ±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 [%]
2450	250	13.5	12.5	08.00
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)]
Bluetooth	TOP 0mm	39	2441	0.06	1.585	0.108	0.171	1.6
Bluetooth	RIGHT 0mm	39	2441	-0.03	1.585	0.070	0.111	1.6
Bluetooth	BOTTOM 0mm	39	2441	0.06	1.585	0.075	0.119	1.6
Bluetooth	BACK-0mm	39	2441	-0.09	1.585	0.142	**0.225**	1.6
Bluetooth Low Energy	TOP 0mm	0	2402	-0.17	1.585	0.028	0.044	1.6
Bluetooth Low Energy	RIGHT 0mm	0	2402	0.02	1.585	0.019	0.030	1.6
Bluetooth Low Energy	BOTTOM 0mm	0	2402	0.01	1.585	0.017	0.027	1.6
Bluetooth Low Energy	BACK 0mm	0	2402	-0.02	1.585	0.034	**0.054**	1.6
Overall maximum SAR value [W/kg (1g)]							**0.225**	1.6

Comments:*tune up limit power (mW) / measured conducted power (mW) = scaling factor
** attached measurement plot: highest SAR value for the communication system

SAR measurements were started with the highest power channel of the transmission band under investigation. Other measurement channels were omitted when the SAR value of the highest power channel was below 0.8 W/kg according to KDB 447498 D01 v05r02.

According to KDB 865664 D02 v01r01 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.