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SAR Test Report

Prepared for: Garmin International, Inc.

Model: A03070/A03071

Description: Short Range Transceiver

Serial Number: N/A

For FCC and IEC

Date of Issue: December 12, 2017

On the behalf of the applicant:

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Poona Saber
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I attest to the accuracy and completeness of these measurements taken and the data presented, and for the qualifications of all persons taking them. It is further stated that upon the basis of the measurements made, the equipment evaluated is capable of compliance for localized specific absorption rate (SAR) for uncontrolled environment/general population exposure limits specified in ANSI/IEEE Std. C95.1-1999.

Test Report Revision History

Revision	Date	Revised By	Reason for Revision
1.0	11/06/2017	Poona Saber	Original Document
2.0	11/15/2017	Poona Saber	Removed test setup photos from this report
3.0	12/12/2017	Poona Saber	Updated standard versions on page 4 Revised header of the plot on page 18 and added reference procedure on page 17 Updated Appendix A



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Introduction

This measurement report demonstrates that Garmin Base Unit as described within this report complies with the Specific Absorption Rate (SAR) RF exposure requirements specified in ANSI/IEEE Std. C95.1-2005, FCC 47 CFR §2.1093 and RSS-102 for General Population/Uncontrolled Exposure.

The test results herein were based on a representative sample and therefore only apply to the sample tested. A description of the device under test, device operating configuration and test conditions, measurement and site description, methodology and procedures used in the evaluation, equipment used, detailed summary of the test results and the various provisions of the rules are included in this dosimetry assessment test report.

Test and Measurement Data

The wireless device referenced in this report was found to be compliant for localized SAR for uncontrolled/general population exposure limits as specified in ANSI/IEEE Std.C95.1-2005 and has been tested in accordance with measurement procedures specified in IEEE 1528-2013 and EN/IEC 62209

References	Description
FCC KDB 447498 D01v06r02	General SAR Guidance
FCC KDB 865664 D01	SAR measurement 100 MHz to 6 GHz v01r04
FCC KDB 865664 D02	SAR Reporting v01r02
IEEE Std. 1528-2013	IEEE Recommended Practice for Determining the Peak Spatial-Averaged Specific Absorption Rate (SAR) in the Human Head from Wireless Communication Devices: Measurement Techniques, June 2013
IEC 62209-1:2016	Procedure to measure the Specific Absorption Rate (SAR) for hand-held devices used in close proximity of the ear (frequency range 300MHz to 3GHz), February 2005
IEC 62209-2:2010	Procedure to measure the Specific Absorption Rate (SAR) for hand-held devices used in close proximity of the ear (frequency range 30MHz to 6GHz), February 2010



EUT Description

EUT:	Garmin Inbound Base Unit
Test Dates:	10/3/2017-10/6/2017
RF Exposure Environment:	Uncontrolled Exposure/General Population
RF Exposure Category:	Portable
Power Supply:	Internal Battery
Antenna:	Integral
Production/prototype:	Production
Modulations Tested:	Zigbee-DCSS
Duty Cycle:	100%
TX Range:	2400-2483.5 MHz
Max SAR Measured:	0.06 W/kg per 1g- Body Tissue simulating liquid 0.0253 W/kg per 10g- Body Tissue simulating liquid

SAR Measurement Results For Body Tissue Simulating Liquid For FCC based on 1g measurements

SAR MEASUREMENT RESULTS General Population/Uncontrolled Exposure FCC/IC Spatial Peak SAR Limit 1.6W/kg									
Channel	Freq (MHz)	Antenna	Power (dBm)	Test Mode	Battery Type	EUT Position and Separation Distance	SAR 1g (mW/g) 100% Duty Cycle	Drift %	Compensated SAR
Mid	2445	0	19	Zigbee	Li-ion	Back Side	0.00708	-3.2	0.00708
Mid	2445	1	18.8	Zigbee	Li-ion	Back Side	0.013	9.19	0.014
Mid	2445	0	19	Zigbee	Li-ion	Left Side	0.00838	-0.24	0.00838
Mid	2445	1	18.8	Zigbee	Li-ion	Left Side	0.00419	15.4	0.00483
Mid	2445	0	19	Zigbee	Li-ion	Right Side	1.43e-006	49.47	1.7 e-006
Mid	2445	1	18.8	Zigbee	Li-ion	Right Side	0.011	-11.7	0.012
Mid	2445	0	19	Zigbee	Li-ion	Front Side	0.057	-0.79	0.057
Mid	2445	1	18.8	Zigbee	Li-ion	Front Side	0.060	-1.2	0.060
Mid	2445	0	19	Zigbee	Li-ion	Short Edge Up	0.00259	36	0.00352
Mid	2445	1	18.8	Zigbee	Li-ion	Short Edge Up	0.00259	0	0.00259

SAR Measurement Results For Body Tissue Simulating Liquid For IEC based on 10g measurements

SAR MEASUREMENT RESULTS									
General Population/Uncontrolled Exposure									
FCC/IC Spatial Peak SAR Limit 2W/kg									
Channel	Freq (MHz)	Antenna	Power (dBm)	Test Mode	Battery Type	EUT Position and Separation Distance	SAR 10g (mW/g) 100% Duty Cycle	Drift %	Compensated SAR
Mid	2445	0	19	Zigbee	Li-ion	Back Side	0.00294	-3.2	0.00294
Mid	2445	1	18.8	Zigbee	Li-ion	Back Side	0.0056	9.19	0.00611
Mid	2445	0	19	Zigbee	Li-ion	Left Side	0.00306	-0.24	0.00306
Mid	2445	1	18.8	Zigbee	Li-ion	Left Side	0.00142	15.4	0.00163
Mid	2445	0	19	Zigbee	Li-ion	Right Side	1.43E-007	49.47	2.13 E-007
Mid	2445	1	18.8	Zigbee	Li-ion	Right Side	0.00451	-11.7	0.005
Mid	2445	0	19	Zigbee	Li-ion	Front Side	0.023	-0.79	0.023
Mid	2445	1	18.8	Zigbee	Li-ion	Front Side	0.0253	-1.2	0.0253
Mid	2445	0	19	Zigbee	Li-ion	Short Edge Up	0.00033	36	0.00044
Mid	2445	1	18.8	Zigbee	Li-ion	Short Edge Up	6.15E-008	0	6.15E-008

Drift Measurements & measured SAR compensation:

The drift is recorded as the percent difference of the secondary reference measurement, *Ref secondary* (SAR or conducted power), from the primary reference measurement, *Ref primary*:

$$\text{Drift} = 100\% \cdot (\text{Ref secondary} - \text{Ref primary}) / \text{Ref primary}$$

Commercial handsets should have SAR drifts within $\pm 5\%$. Some devices could have significant fluctuations in output power that are not classifiable as undesirable power drift but rather are a characteristic of the normal operating behavior of the device. In this case, other methods such as SAR scaling shall be considered so that a conservative SAR is obtained.

If the SAR drift is within 5%, then it shall be treated either as an uncertainty (i.e., random error) or a systematic offset. If the drift is larger than 5%, the measurement drift shall be considered a systematic offset rather than an uncertainty. If treated as a systematic offset and correction of the zoom scan values has not been performed as previously described, apply a correction to the measured SAR value, i.e., by adding the absolute difference to the determined value if the drift is either negative or positive:

$$\text{SAR compensated} = \text{SAR measured} \cdot (1 + |\text{Drift}|/100\%)$$

Test separation distance:

EUT is categorized as body-worn accessory SAR compliance and the minimum distance of testing was determined as 0 mm for the side that has magnets on as that is the side that sits on the clips accessory which goes on glasses or neck or body. For other sides of the EUT as it is undefined and used on the body of the user a conservative minimum test separation of 5 mm was used.

SAR test Reduction:

Per KDB 447498 D01 testing of other required channels within the operating mode of a frequency is not required when the reported 1-g or 10-g SAR for the mid-band or highest output power channel is ≤ 0.4 W/kg or 1.0 W/kg, for 1-g or 10-g respectively, when the transmission band is ≥ 200 MHz

Multiple Transmitter Evaluation

Test Distance: 0mm		
Mode	SAR Test Exclusion Threshold(mW) Per KDB 447498 D01v05r01	Highest Power(mW)
BLE	10	4.63
Zigbee	10	95.49

Note: Radio does not support simultaneous transmission.

Per table above the Stand-alone SAR evaluation is required Zigbee but, the BLE is excluded.

SAR Definition

Specific Absorption Rate (SAR) is defined as the time derivative (rate) of the incremental energy (dU) absorbed by (dissipated in) an incremental mass (dm) contained in a volume element (dV) of a given density (ρ). It is also defined as the rate of RF energy absorption per unit mass at a point in an absorbing body (see Fig. 1.1).

$$SAR = \frac{d}{dt} \left(\frac{dU}{dm} \right) = \frac{d}{dt} \left(\frac{dU}{\rho dV} \right)$$

Figure 1.1

SAR Mathematical Equation

SAR is expressed in units of Watts per Kilogram (W/kg).

$$SAR = \sigma E^2 / \rho$$

where:

σ - conductivity of the tissue - simulant material (S/m)

ρ - mass density of the tissue - simulant material (kg/m³)

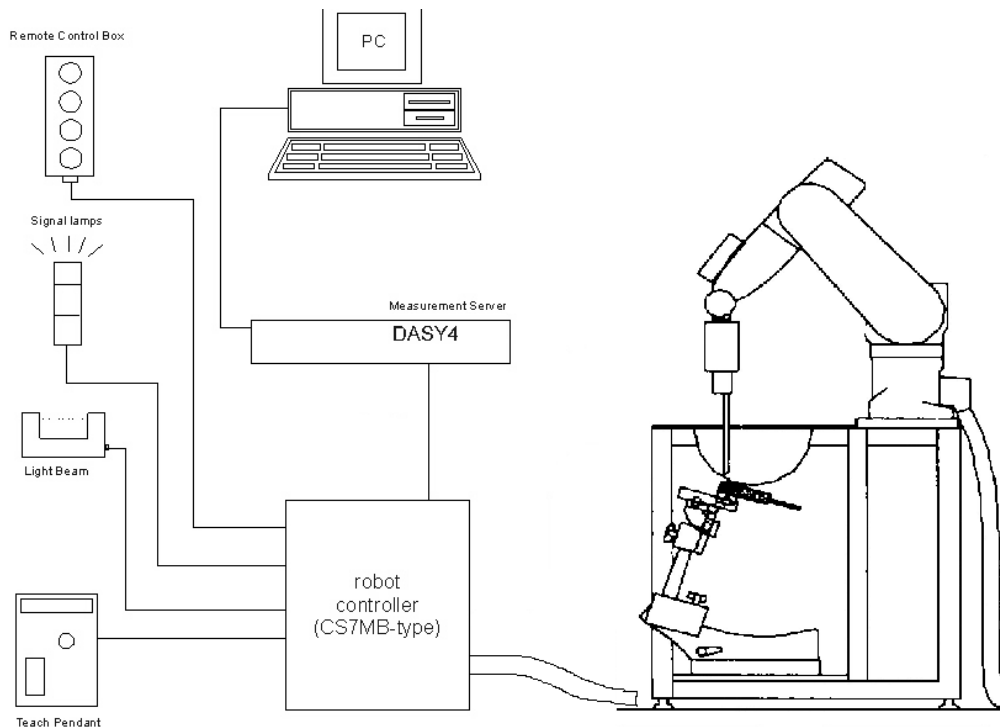
E - Total RMS electric field strength (V/m)

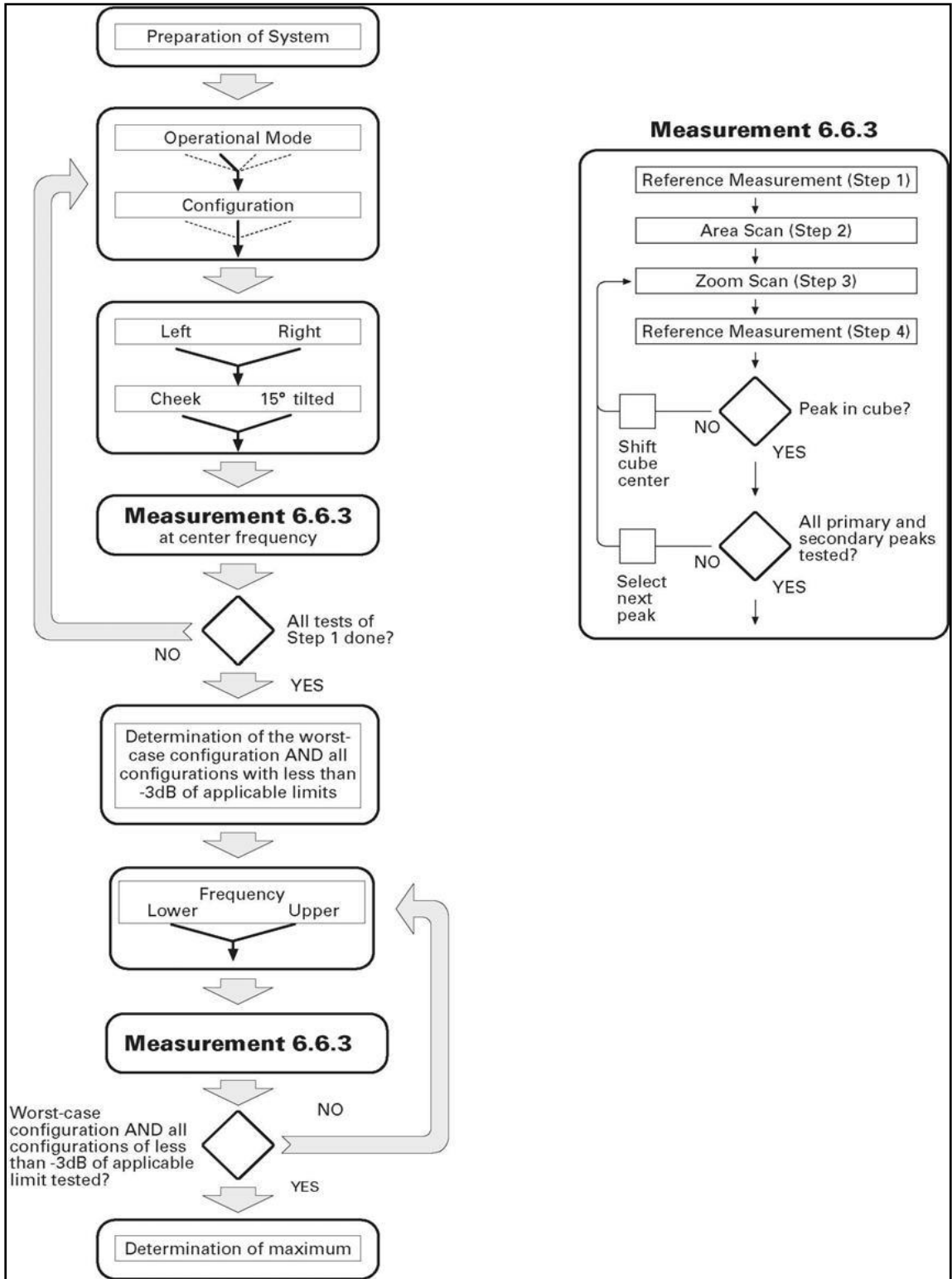
NOTE: The primary factors that control rate of energy absorption were found to be the wavelength of the incident field in relations to the dimensions and geometry of the irradiated organism, the orientation of the organism in relation to the polarity of field vectors, the presence of reflecting surfaces, and whether conductive contact is made by the organism with a ground plane.

SAR Measurement System

The SAR measurements used for this evaluation were performed using a DASY4 Dosimetric Assessment System (DASY™) manufactured by Schmid & Partner Engineering AG (SPEAG™) of Zurich, Switzerland. The DASY4 measurement system is comprised of the measurement server, robot controller, computer, near-field probe, probe alignment sensor, specific anthropomorphic mannequin (SAM) phantom, and various planar phantoms for brain and/or body SAR evaluations. The robot is a six-axis industrial robot performing precise movements to position the probe to the location (points) of maximum electromagnetic field (EMF). The Cell controller system contain the power supply, robot controller, teach pendant (Joystick), and remote control, is used to drive the robot motors. The Staubli robot is connected to the cell controller to allow software manipulation of the robot. A data acquisition electronic (DAE) circuit performs the signal amplification, signal multiplexing, AD-conversion, offset measurements, mechanical surface detection, collision detection, etc. is connected to the Electro-optical coupler (EOC). The EOC performs the conversion from the optical into digital electric signal of the DAE and transfers data to the DASY4 measurement server. The DAE3 utilizes 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.

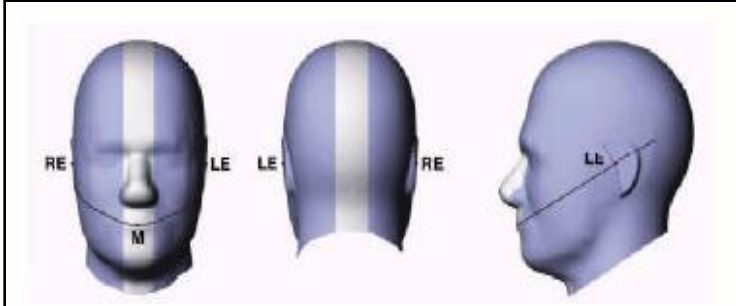
Transmission to the DASY4 measurement server is accomplished through an optical downlink for data and status information and an optical uplink for commands and clock lines. The mechanical probe-mounting device includes two different sensor systems for frontal and sidewise probe contacts. The sensor systems are also used for mechanical surface detection and probe collision detection. The robot uses its own controller with a built in VME-bus computer.



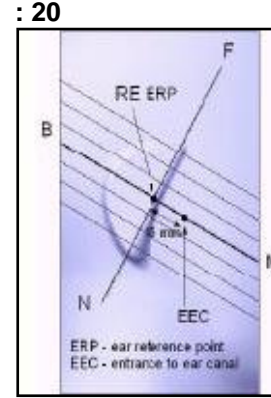


EAR Reference Point

Figure 12.1 shows the front, back and side views of the SAM Twin Phantom. The point M is the reference point for the center of the mouth, LE is the left ear reference point (ERP), and RE is the right ERP. The ERPs are 15mm posterior to the entrance to the ear canal (EEC) along the B-M line (Back-Mouth), as shown in Figure 12.2. The plane passing through the two ear canals and M is defined as the Reference Plane. The line N-F (Neck-Front) is perpendicular to the reference plane and passing through the RE (or LE) is called the Reference Pivoting. Line B-M is perpendicular to the N-F line. Both N-F and B-M lines are marked on the external phantom shell to facilitate handset positioning.

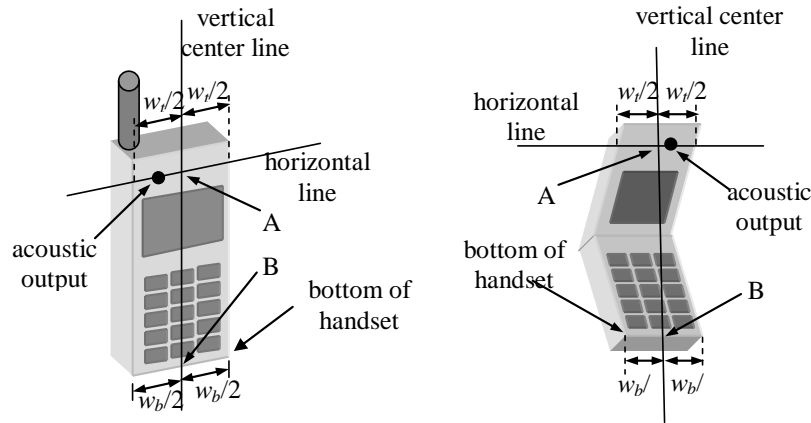


Front, back and side view of SAM Twin Phantom



Handset Reference Points

Two imaginary lines on the handset were established: the vertical centerline and the horizontal line. The test device was placed in a normal operating position with the test device reference point located along the vertical centerline on the front of the device aligned to the ear reference point. The test device reference point was then located at the same level as the center of the ear reference point. The test device was positioned so that the vertical centerline was bisecting the front surface of the handset at its top and bottom edges, positioning the ear reference point on the outer surface of the both the left and right head phantoms on the ear reference point.



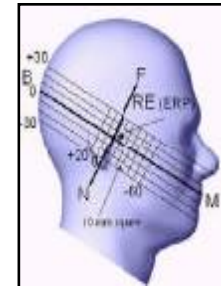
Handset Vertical Center & Horizontal Line Reference Points

Positioning for Cheek/Touch

1. The test device was positioned with the handset 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, such that the plane defined by the vertical center line and the horizontal line of the phone is approximately parallel to the sagittal plane of the phantom.
2. The handset was translated towards the phantom along the line passing through RE & LE until the handset touches the ear.
3. While maintaining the handset in this plane, the handset was rotated around the LE-RE line until the vertical centerline was in the plane normal to MB-NF including the line MB (reference plane).
4. The phone was then rotated around the vertical centerline until the phone (horizontal line) was symmetrical with respect to the line NF.
5. While maintaining the vertical centerline in the reference plane, keeping point A on the line passing through RE and LE, and maintaining the phone contact with the ear, the handset was rotated about the line NF until any point on the handset made contact with a phantom point below the ear (cheek).



Front, Side and Top View of Cheek/Touch Position



Positioning for Cheek/Touch

1. With the test device aligned in the Cheek/Touch Position:
2. While maintaining the orientation of the phone, the phone was retracted parallel to the reference plane far enough to enable a rotation of the phone by 15 degree.
3. The phone was then rotated around the horizontal line by 15 degree.
4. While maintaining the orientation of the phone, the phone was moved parallel to the reference plane until any part of the phone touches the head. (In this position, point A was located on the line RE-LE). The tilted position is obtained when the contact is on the pinna. If the contact was at any location other than the pinna, the angle of the phone would then be reduced. The tilted position was obtained when any part of the phone was in contact of the ear as well as a second part of the phone was in contact with the head.

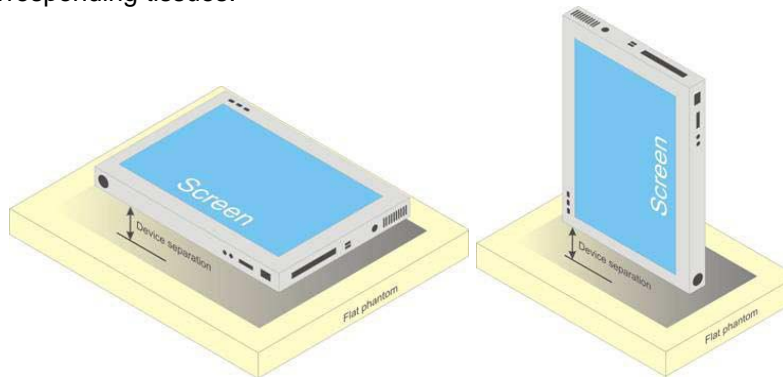


Front, Side and Top View of Ear/15 Tilt Position

Body Worn Configurations

The body-worn configurations shall be tested with the supplied accessories (belt-clips, holsters, etc.) attached to the device in normal use configuration.

For body-worn and other configurations a flat phantom shall be used which is comprised of material with electrical properties similar to the corresponding tissues.



EVALUATION PROCEDURES

The evaluation was performed in the applicable area of the phantom depending on the type of device being tested.

- i. For devices held to the ear during normal operation, both the left and right ear positions were evaluated using the SAM phantom.
- ii. For body-worn and face-held devices a planar phantom was used.
- iii. The SAR was determined by a pre-defined procedure within the DASY4 software. Upon completion of a reference check, the exposed region of the phantom was scanned near the inner surface with a grid spacing of 15mm x 15mm.
- iv. An area scan was determined as follows:
 - a. Based on the defined area scan grid, a more detailed grid is created to increase the points by a factor of 10. The interpolation function then evaluates all field values between corresponding measurement points.
 - b. A linear search is applied to find all the candidate maxima. Subsequently, all maxima are removed that are >2 dB from the global maximum. The remaining maxima are then used to position the cube scans.
- v. A 1g and 10g spatial peak SAR was determined as follows:
 - a. For frequencies $\leq 4.5\text{GHz}$ a 32mm x 32mm x 34mm (7x7x7 data points) zoom scan was assessed at the position where the greatest V/m was detected. For frequencies $\geq 4.5\text{GHz}$ a 28mm x 28mm x 24mm (7x7x9 data points) zoom scan was assessed at the position where the greatest V/m was detected. The data at the surface was extrapolated since the distance from the probes sensors to the surface is 3.9cm. A least squares fourth-order polynomial was used to generate points between the probe detector and the inner surface of the phantom.
 - b. Interpolated data is used to calculate the average SAR over 1g and 10g cubes by spatially discretizing the entire measured cube. The volume used to determine the averaged SAR is a 1mm grid (42875 interpolated points).
- vi. Z-Scan was determined as follows:
- vii. The Z-scan measures points along a vertical straight line. The line runs along a line normal to the inner surface of the phantom surface.

Data Evaluation Procedures

The DASY4 post processing software (SEMCAD) automatically executes the following procedures to calculate the field units from the microvolt readings at the probe connector. The parameters used in the evaluation are stored in the configuration modules of the software:

Probe Parameters:	- Sensitivity	$Norm_i, a_{i0}, a_{i1}, a_{i2}$
	- Conversion Factor	$ConvF_i$
	- Dipole Compression Point	dcp_i
Device parameters:	- Frequency	f
	- Crest factor	cf
Media parameters:	- Conductivity	σ
	- Density	ρ

These parameters must be set correctly in the software. They can be found in the component documents or can be imported into the software from the configuration files issued for the DASY components. In the direct measuring mode of the multimeter option, the parameters of the actual system setup are used. In the scan visualization and export modes, the parameters stored in the corresponding document files are used. The first step of the evaluation is a linearization of the filtered input signal to account for the compression characteristics of the detector diode. The compensation depends on the input signal, the diode type and the DC - transmission factor from the diode to the evaluation electronics. If the exciting field is pulsed, the crest factor of the signal must be known to correctly compensate for peak power. The formula for each channel can be given as:

$$V_i = U_i + U_i^2 \cdot \frac{cf}{dcp_i}$$

with V_i = Compensated signal of channel i (i = x, y, z)
 U_i = Input signal of channel i (i = x, y, z)
 cf = Crest factor of exciting field (DASY parameter)
 dcp_i = Diode compression point (DASY parameter)

From the compensated input signals the primary field data for each channel can be evaluated:

$$\begin{aligned} \text{E - fieldprobes :} \quad E_i &= \sqrt{\frac{V_i}{Norm_i \cdot ConvF}} \\ \text{H - fieldprobes :} \quad H_i &= \sqrt{V_i} \cdot \frac{a_{i0} + a_{i1}f + a_{i2}f^2}{f} \end{aligned}$$

with V_i = Compensated signal of channel i (i = x, y, z)
 $Norm_i$ = Sensor sensitivity of channel i (i = x, y, z)
 $\mu V / (V/m)^2$ for E-field probes
 $ConvF$ = Sensitivity enhancement in solution
 a_{ij} = Sensor sensitivity factors for H-field probes
 f = Carrier frequency (GHz)
 E_i = Electric field strength of channel i in V/m
 H_i = Magnetic field strength of channel i in A/m



The RSS value of the field components gives the total field strength (Hermitian magnitude):

$$E_{tot} = \sqrt{E_x^2 + E_y^2 + E_z^2}$$

The primary field data are used to calculate the derived field units.

$$SAR = E_{tot}^2 \cdot \frac{\sigma}{\rho \cdot 1'000}$$

With SAR = local specific absorption rate in mW/g

E_{tot} = total field strength in V/m

σ = conductivity in [mho/m] or [Siemens/m]

ρ = equivalent tissue density in g/cm³

Note that the density is normally set to 1 (or 1.06), to account for actual brain density rather than the density of the simulation liquid.

The power flow density is calculated assuming the excitation field as a free space field.

$$P_{pwe} = \frac{E_{tot}^2}{3770} \quad \text{or} \quad P_{pwe} = H_{tot}^2 \cdot 37.7$$

With P_{pwe} = Equivalent power density of a plane wave in mW/cm²

E_{tot} = total electric field strength in V/m

H_{tot} = total magnetic field strength in A/m

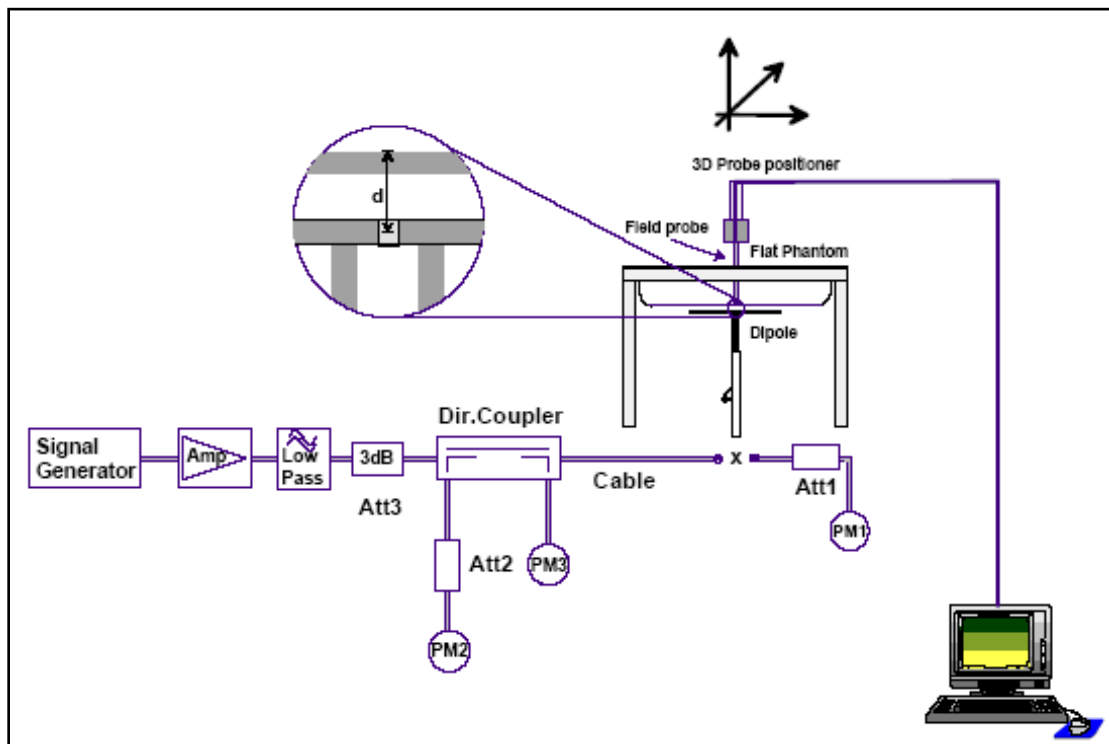
System Performance Check

Prior to the SAR evaluation a system check was performed with a 2450MHz and 5750MHz dipole. The dielectric parameters of the simulated brain fluid were measured prior to the system performance check using an 85070B Dielectric Probe Kit and an 8753D Network Analyzer. A forward power of 100mW/250mW was applied to the dipole and the system was verified to a tolerance of $\pm 10\%$. All results were normalized to 1W.

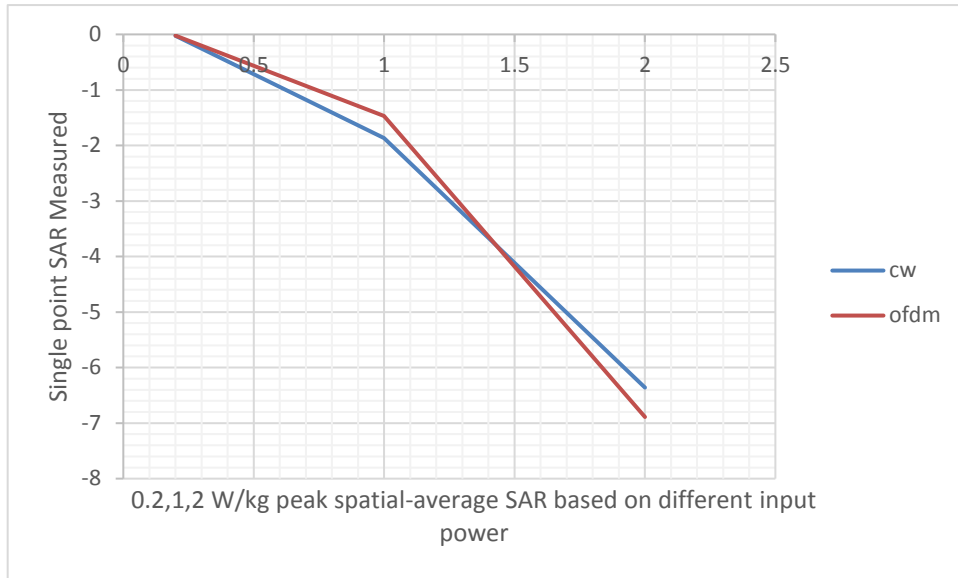
For signals with high peak to average power ratios (> 5 dB) such as those used in OFDM or similar systems, the procedure for calibration was repeated with OFDM injected into dipole with the same average power level as CW and the result was within 10% of the calibration certificate of the probe

Test Date	Fluid Type (MHz)	SAR 1g(W/kg)		Permittivity Constant ϵ_r		Conductivity σ (mho/m)		Ambient Temp. (C)	Fluid Temp (C)	Fluid Depth (cm)
		IEEE Target	Measured	IEEE Target	Measured	IEEE Target	Measured			
10/03/17	Body 2450 MHz	12.9	12.87	52.7	51.93	1.95	1.47	24	22	≥ 15

Note: The ambient and fluid temperatures were measured prior to the fluid parameter check and the system performance check. The temperatures listed in the table above were consistent for all measurement periods.



In addition to above SAR probe linearity may be verified by single point SAR measurements at the peak SAR location without moving the dipole test setup and with the probe tip positioned at $\frac{1}{2}$ the probe tip diameter from the phantom surface. Single point SAR measurements are performed at approximately 0.2 W/kg, 1.0 W/kg and 2.0 W/kg by adjusting the dipole power accordingly for both OFDM and CW signals and the plot for comparison is depicted below. Procedures from section 8.3.6 of IEEE-1528_2013 has been followed to achieve the plot below for comparison of using CW and OFDM Signals.



Linearity plot for both CW and OFDM signals



Tissue Verification

Mixture Type	2450 MHz Body	
Date(s) Measured	10/3/17	
	Target	Measured
Dielectric Constant ϵ_r	52.7	51.93
Conductivity σ (mho/m)	1.95	1.47

EXPOSURE LIMITS	SAR (W/kg)	
	(General Population / Uncontrolled Exposure Environment)	(Occupational / Controlled Exposure Environment)
Spatial Average (averaged over the whole body)	0.08	0.4
Spatial Peak (averaged over any 1g of tissue)	1.60	8.0
Spatial Peak hands/wrists/feet/ankles (averaged over 10g)	4.0	20.0

Notes:

1. Uncontrolled exposure environments are locations where there is potential exposure of individuals who have no knowledge or control of their potential exposure.
2. Controlled exposure environments are locations where there is potential exposure of individuals who have knowledge of their potential exposure and can exercise control over their exposure.



Robot System Specifications

Positioner:

Robot: Staubli Robot Model: RX60
Repeatability: 0.02 mm
No. of axis: 6

Data Acquisition Electronic (DAE) System:

DAE3

Computer Controller:

Processor: Intel core 3.2GHz
Operating System: Windows 7

Data Converter:

Features: Signal Amplifier, multiplexer, A/D converter, and control logic
Software: DASY4 software
Connecting Lines: Optical downlink for data and status info.
Optical uplink for commands and clock

Dasy4 Measurement Server:

Function: Real-time data evaluation for field measurements and surface detection
Hardware: PC/104 166MHz Pentium CPU; 32 MB chip disk; 64 MB RAM
Connections: COM1, COM2, DAE, Robot, Ethernet, Service Interface

E-Field Probe:

Model: ES3DV3
Construction: Triangular core mechanical detection system
Frequency: 10 MHz to 4 GHz
Linearity: ± 0.2 dB (30 MHz to 4 GHz)



Phantom(s):

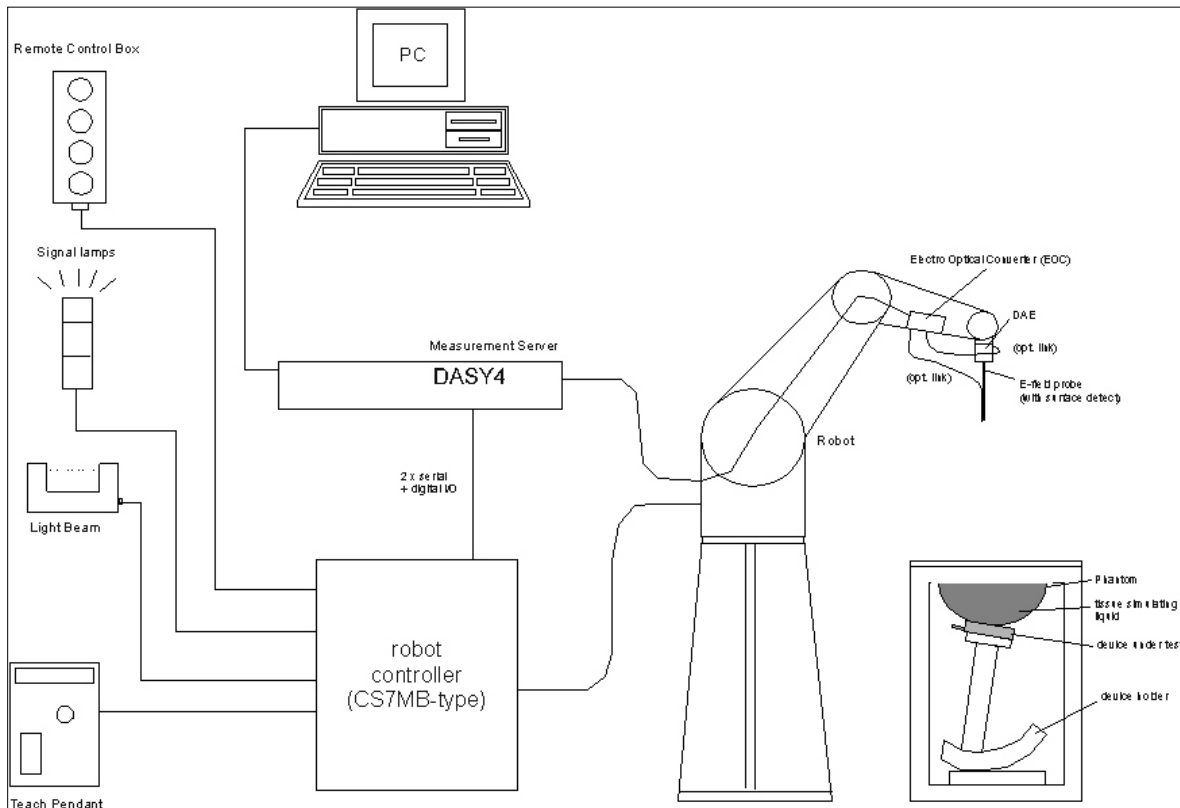
Validation & Evaluation Phantom

Type: SAM V4.0C
Shell Material: Fiberglass
Thickness: 2.0 ±0.1 mm
Volume: Approx. 20 liters

Validation & Evaluation Phantom

Type: Oval Flat Phantom ELI v6.0
Shell Material: Fiberglass
Thickness: 2.0 ±0.2 mm
Volume: 30 liters

SAR Measurement System



Measurement System Diagram

RX60 Robot

The Stäubli RX60L Robot is a standard high precision 6-axis robot with an arm extension for accommodating the data acquisition electronics (DAE).

Robot Controller

The CS7 Robot Controller system drives the robot motors. The system consists of a power supply, robot controller, and remote control with teach pendant and additional circuitry for robot safety such as warning lamps, etc.

Light Beam Switch

The Light Beam Switch (Probe alignment tool) allows automatic “tooling” of the probe. During the process, the actual position of the probe tip with respect to the robot arm is measured as well as the probe length and the horizontal probe offset. The software then corrects all movements, so that the robot coordinates are valid for the probe tip. The repeatability of this process is better than 0.1 mm. If a position has been taught with an aligned probe, the same position will be reached with another aligned probe within 0.1 mm, even if the other probe has different dimensions. During probe rotations, the probe tip will keep its actual position.

Data Acquisition Electronics

The Data Acquisition Electronics consists of a highly sensitive electrometer grade preamplifier with auto-zeroing, a channel and gain switching multiplexer, a fast 16-bit A/D converter and a command decoder and control logic unit. Some of the tasks the DAE performs is signal amplification, signal multiplexing, A/D conversion, and offset measurements. The DAE also contains the mechanical probe-mounting device, which contains two different sensor systems for frontal and sideways probe contacts used for probe collision detection and mechanical surface detection for controlling the distance between the probe and the inner surface of the phantom shell. Transmission from the DAE to the measurement server, via the EOC, is through an optical downlink for data and status information as well as an optical uplink for commands and the clock.

Electro-Optical Converter (EOC)

The Electro-Optical Converter performs the conversion between the optical and electrical of the signals for the digital communication to the DAE and for the analog signal from the optical surface detection. The EOC connects to, and transfers data to, the DASY4 measurement server. The EOC also contains the fiber optical surface detection system for controlling the distance between the probe and the inner surface of the phantom shell.

Measurement Server

The Measurement Server performs time critical tasks such as signal filtering, all real-time data evaluation for field measurements and surface detection, controls robot movements, and handles safety operation. The PC-operating system cannot interfere with these time critical processes. A watchdog supervises all connections, and disconnection of any of the cables to the measurement server will automatically disarm the robot and disable all program-controlled robot movements.

Dosimetric Probe

Dosimetric Probe is a symmetrical design with triangular core that incorporates three 3 mm long dipoles arranged so that the overall response is close to isotropic. The probe sensors are covered by an outer protective shell, which is resistant to organic solvents i.e. glycol. The probe is equipped with an optical multi-fiber line, ending at the front of the probe tip, for optical surface detection. This line connects to the EOC box on the robot arm and provides automatic detection of the phantom surface. The optical surface detection works in transparent liquids and on diffuse reflecting surfaces with a repeatability of better than ± 0.1 mm.

SAM Phantom

The SAM (Specific Anthropomorphic Mannequin) twin phantom is a fiberglass shell phantom with 2mm shell thickness (except the ear region where shell thickness increases to 6mm) integrated into a wooden table. The shape of the shell corresponds to the phantom defined by SCC34-SC2. It enables the dosimetric evaluation of left hand, right hand phone usage as well as body mounted usage at the flat phantom region. The flat section is also used for system validation and the length and width of the flat section are at least $0.75 \lambda_0$ and $0.6 \lambda_0$ respectively at frequencies of 824 MHz and above (λ_0 = wavelength in air).

Reference markings on the phantom top allow the complete setup of all predefined phantom positions and measurement grids by manually teaching three points in the robot. A white cover is provided to cover the phantom during off-periods preventing water evaporation and changes in the liquid parameters. Free space scans of devices on the cover are possible. The phantom is filled with a tissue simulating liquid to a depth of at least 15 cm at each ear reference point. The bottom plate of the wooden table contains three pair of bolts for locking the device holder.

ELI Phantom

The planar phantom is constructed of Plexiglas material with a 2.0 mm shell thickness for face-held and body-worn SAR evaluations of handheld radio transceivers. The planar phantom is mounted on the wooden table of the DASY4 system.

Device Holder

The device holder is designed to cope with the different measurement positions in the three sections of the SAM phantom given in the standard. It has two scales, one for device rotation (with respect to the body axis) and one for device inclination (with respect to the line between the ear openings). The rotation center for both scales is the ear opening, thus the device needs no repositioning when changing the angles. The plane between the ear openings and the mouth tip has a rotation angle of 65°.

The DASY device holder has been made out of low-loss POM material having the following dielectric parameters: relative permittivity $\epsilon = 3$ and loss tangent $\delta = 0.02$. The amount of dielectric material has been reduced in the closest vicinity of the device, since measurements have suggested that the influence of the clamp on the test results could thus be lowered.

The dielectric properties of the liquid conform to all the tabulated values [2-5]. Liquids are prepared according to Annex A and dielectric properties are measured according to Annex B.

System Validation Kits

Power Capability: Dipoles > 100 W ($f < 1\text{GHz}$); > 40 W ($f > 1\text{GHz}$)
Confined Loop Antenna (CLA-150) > 10W

Dipoles: Symmetrical dipole with 1/4 balun enables measurement of feed point impedance with NWA Matched for use near flat phantoms filled with brain simulating solutions Includes distance holder and tripod adaptor.

CLA-150: The source is a resonant loop antenna which is integrated in a metallic structure to isolate the resonant structure from the environment.

Frequency: 150, 300, 450, 835, 1900, 2450 MHz, 5-6GHz

Return Loss: Dipoles >20 dB at specified validation position
CLA >10dB

Dimensions: 150 MHz Confined Loop Antenna (CLA-150), 222 x 95 mm
450 MHz Dipole: Length: 272.0 mm; Overall Height: 330 mm; Diameter: 6 mm
835 MHz Dipole: Length: 161.0 mm; Overall Height: 340 mm; Diameter: 3.6 mm
1900 MHz Dipole: Length: 67.7 mm; Overall Height: 300 mm; Diameter: 3.6 mm
2450 MHz Dipole: Length: 52.0 mm; Overall Height: 390 mm; Diameter: 3.6 mm
5-6 GHz Dipole: Length: 26.0 mm; Overall Height: 170 mm; Diameter: 3.6 mm

Test Equipment Utilized

Test Equipment	Serial Number	Calibration Date
DASY4 System Robot RX60	FO3/5X20A1/C/01	N/A
DAE3	493	Sep 18, 2017
D2450V2	979	Feb 29, 2016
D5GHz V2	1233	Feb 26, 2016
SAM Phantom V4.0C	N/A	N/A
Oval Flat Phantom ELI v6.0	N/A	N/A
ES3DV3	3035	Sep 18, 2017
NRP-Z21 Power sensor	103714	Feb 11, 2016
NRP-Z21 Power sensor	102001	Feb 11, 2016
85070B dielectric probe kit	N/A	N/A
Agilent E4437B signal generator	US39260968	May 5, 2017
Mini-circuits amplifier	N/A	N/A

Measurement Uncertainties

Note: Measurement Uncertainties below are only presented as information to user.

UNCERTAINTY ASSESSMENT 300MHz-3GHz for Device Evaluation

Error Description	Tol. ±%	Prob. Dist.	Div.	C_i 1g	C_i 10g	Std Unc ±% (1g)	Std Unc ±% (10g)	V_i Or V_{eff}
Measurement System								
Probe calibration	4.8	N	1	1	1	4.8	4.8	N/A
Axial isotropy of the probe	4.7	R	$\sqrt{3}$	0.7	0.7	1.9	1.9	N/A
Spherical isotropy of the probe	9.6	R	$\sqrt{3}$	0.7	0.7	3.9	3.9	N/A
Boundary effects	1.0	R	$\sqrt{3}$	1	1	4.8	4.8	N/A
Probe linearity	4.7	R	$\sqrt{3}$	1	1	2.7	2.7	N/A
Detection limit	1.0	R	$\sqrt{3}$	1	1	0.6	0.6	N/A
Readout electronics	1.0	N	1	1	1	1.0	1.0	N/A
Response time	0.8	R	$\sqrt{3}$	1	1	0.5	0.5	N/A
Integration time	2.6	R	$\sqrt{3}$	1	1	0.8	0.8	N/A
RF ambient conditions	3.0	R	$\sqrt{3}$	1	1	0.43	0.43	N/A
Mech. constraints of robot	0.4	R	$\sqrt{3}$	1	1	0.2	0.2	N/A
Probe positioning	2.9	R	$\sqrt{3}$	1	1	1.7	1.7	N/A
Extrapolation & integration	1.0	R	$\sqrt{3}$	1	1	2.3	2.3	N/A
Test Sample Related								
Device positioning	2.9	N	1	1	1	2.23	2.23	145
Device holder uncertainty	3.6	N	1	1	1	5.0	5.0	5
Power drift	5.0	R	$\sqrt{3}$			2.9	2.9	N/A
Phantom and Setup								
Phantom uncertainty	4.0	R	$\sqrt{3}$	1	1	2.3	2.3	N/A
Liquid conductivity (target)	5.0	R	$\sqrt{3}$	0.64	0.43	1.8	1.2	N/A
Liquid conductivity (measured)	2.5	N	1	0.64	0.43	1.6	1.1	N/A
Liquid permittivity (target)	5.0	R	$\sqrt{3}$	0.6	0.5	1.7	1.4	N/A
Liquid permittivity (measured)	2.5	N	1	0.6	0.5	1.5	1.2	N/A
Combined Standard Uncertainty (k=1)	RSS					10.3	10.0	330
Expanded Uncertainty (k=2) 95% Confidence Level						20.6	20.1	

Worst-case uncertainty for DASY4 assessed according to IEEE P1528.

The budget is valid for the frequency range 300MHz to 3GHz and represents a worst-case analysis.



UNCERTAINTY ASSESSMENT 300MHz-3GHz System Performance

Error Description	Tol. ±%	Prob. Dist.	Div.	C_i 1g	C_i 10g	Std Unc ±% (1g)	Std Unc ±% (10g)	V_i or V_{eff}
Measurement System								
Probe calibration	5.9	N	1	1	1	5.9	5.9	∞
Axial Isotropy	4.7	R	√3	1	1	2.7	2.7	∞
Hemispherical Isotropy	9.6	R	√3	0	0	0	0	∞
Boundary effects	1.0	R	√3	1	1	0.6	0.6	∞
Linearity	4.7	R	√3	1	1	2.7	2.7	∞
System Detection limit	1.0	R	√3	1	1	0.6	0.6	∞
Readout electronics	0.3	N	1	1	1	0.3	0.3	∞
Response time	0	R	√3	1	1	0	0	∞
Integration time	0	R	√3	1	1	0	0	∞
RF Ambient Noise	3.0	R	√3	1	1	1.7	1.7	∞
RF Ambient Reflections	3.0	R	√3	1	1	1.7	1.7	∞
Probe Positioner	0.4	R	√3	1	1	0.2	0.2	∞
Probe positioning	2.9	R	√3	1	1	1.7	1.7	∞
Algorithms for Max. SAR Eval.	1.0	R	√3	1	1	0.6	0.6	∞
Dipole								
Dipole Axis to Liquid Distance	2.0	R	√3	1	1	1.2	1.2	∞
Input power and SAR drift meas.	4.7	R	√3	1	1	2.7	2.7	∞
Phantom and Tissue Parameters								
Phantom uncertainty	4.0	R	√3	1	1	2.3	2.3	∞
Liquid conductivity (target)	5.0	R	√3	0.64	0.43	1.8	1.2	∞
Liquid conductivity (measured)	2.5	N	1	0.64	0.43	1.6	1.1	∞
Liquid permittivity (target)	5.0	R	√3	0.6	0.5	1.7	1.4	∞
Liquid permittivity (measured)	2.5	N	1	0.6	0.5	1.5	1.2	∞
Combined Standard Uncertainty						9.2	8.9	
Coverage Factor for 95%						kp=2		
Expanded Uncertainty						18.4	17.8	

Uncertainty of a system performance check with DASY4 system
 The budget is valid for the frequency range 300MHz to 3GHz and represents a worst-case analysis.

UNCERTAINTY ASSESSMENT 5-6GHz for Device Evaluation

Error Description	Tol. ±%	Prob. Dist.	Div.	C_i 1g	C_i 10g	Std Unc ±% (1g)	Std Unc ±% (10g)	v_i or v_{eff}
Measurement System								
Probe calibration	6.8	N	1	1	1	6.8	6.8	∞
Axial Isotropy	4.7	R	√3	0.7	0.7	1.9	1.9	∞
Hemispherical Isotropy	9.6	R	√3	0.7	0.7	3.9	3.9	∞
Boundary effects	2.0	R	√3	1	1	1.2	1.2	∞
Linearity	4.7	R	√3	1	1	2.7	2.7	∞
System Detection limit	1.0	R	√3	1	1	0.6	0.6	∞
Readout electronics	0.3	N	1	1	1	0.3	0.3	∞
Response time	0.8	R	√3	1	1	0.5	0.5	∞
Integration time	2.6	R	√3	1	1	1.5	1.5	∞
RF Ambient Noise	3.0	R	√3	1	1	1.7	1.7	∞
Probe Positioner	0.8	R	√3	1	1	0.5	0.5	∞
Probe positioning	5.7	N	1	1	1	5.7	5.7	∞
Algorithms for Max. SAR Eval.	4.0	R	√3	1	1	0.6	0.6	∞
Dipole								
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	√3	1	1	2.9	2.9	∞
Phantom and Tissue Parameters								
Phantom uncertainty	4.0	R	√3	1	1	2.3	2.3	∞
Liquid conductivity (target)	5.0	R	√3	0.64	0.43	1.8	1.2	∞
Liquid conductivity (measured)	2.5	N	1	0.64	0.43	1.6	1.1	∞
Liquid permittivity (target)	5.0	R	√3	0.6	0.5	1.7	1.4	∞
Liquid permittivity (measured)	2.5	N	1	0.6	0.5	1.5	1.2	∞
Combined Std. Uncertainty						12.8	12.6	330
Expanded Std. Uncertainty						25.6	25.2	

Worst-Case uncertainty budget for DASY4 valid for the frequency range 5 - 6GHz. Probe calibration error reflects uncertainty of the narrow-bandwidth EX3DVx probe conversion factor (±50MHz).

UNCERTAINTY ASSESSMENT 5-6GHz for Performance Check

Error Description	Tol. ±%	Prob. Dist.	Div.	C_i 1g	C_i 10g	Std Unc ±% (1g)	Std Unc ±% (10g)	V_i or V_{eff}
Measurement System								
Probe calibration	6.8	N	1	1	1	6.8	6.8	∞
Axial Isotropy	4.7	R	√3	1	1	2.7	2.7	∞
Hemispherical Isotropy	0	R	√3	1	1	0	0	∞
Boundary effects	2.0	R	√3	1	1	1.2	1.2	∞
Linearity	4.7	R	√3	1	1	2.7	2.7	∞
System Detection limit	1.0	R	√3	1	1	0	0	∞
Readout electronics	0.3	N	1	1	1	0	0	∞
Response time	0	R	√3	1	1	0.5	0.5	∞
Integration time	0	R	√3	1	1	1.5	1.5	∞
RF Ambient Noise	3.0	R	√3	1	1	1.7	1.7	∞
Probe Positioner	0.8	R	√3	1	1	0.5	0.5	∞
Probe positioning	5.7	N	1	1	1	5.7	5.7	∞
Algorithms for Max. SAR Eval.	4.0	R	√3	1	1	0.6	0.6	∞
Dipole								
Dipole Axis to Liquid Distance	2.0	R	√3	1	1	1.2	1.2	∞
Input power and SAR drift meas.	4.7	R	√3	1	1	2.7	2.7	∞
Phantom and Tissue Parameters								
Phantom uncertainty	4.0	R	√3	1	1	2.3	2.3	∞
Liquid conductivity (target)	5.0	R	√3	0.64	0.43	1.8	1.2	∞
Liquid conductivity (measured)	2.5	N	1	0.64	0.43	1.6	1.1	∞
Liquid permittivity (target)	5.0	R	√3	0.6	0.5	1.7	1.4	∞
Liquid permittivity (measured)	2.5	N	1	0.6	0.5	1.5	1.2	∞
Combined Standard Uncertainty						11.4	11.1	∞
Coverage Factor for 95%		kp=2						
Expanded Uncertainty						22.7	22.3	

Uncertainty of the system performance check in the 5-6 GHz range. Probe calibration error reflects uncertainty of the narrow-bandwidth EX3DVx probe conversion factor (±50MHz).

References

1. KDB 865664 D01 SAR Measurement 100 MHz to 6 GHz v01r04
2. KDB 447498 D01 General RF exposure Guidance
3. KDB 248227 D01 802.11 Wi-Fi SAR v02r02
4. IEEE Standards Coordinating Committee 34, IEEE 1528-2013, Recommended Practice for Determining the Peak Spatial-Average Specific Absorption Rate (SAR) in the Human Body Due to Wireless Communications Devices.
5. Health Canada, Limits of Human Exposure to Radiofrequency Electromagnetic Fields in the Frequency Range from 3 kHz to 300 GHz Safety Code 6.
6. Industry Canada, Evaluation Procedure for Mobile and Portable Radio Transmitters with respect to Health Canada's Safety Code 6 for Exposure of Humans to Radio Frequency Fields, Radio Standards Specification RSS-102 Issue 5. March 2015



All Fluid depths were checked and were within 15 centimeters.



Fluid Depth

List of Appendices

- APPENDIX A – SAR MEASUREMENT DATA
- APPENDIX B – SYSTEM PERFORMANCE CHECK
- APPENDIX C – PROBE CALIBRATION CERTIFICATE
- APPENDIX D – DIPOLE CALIBRATION CERTIFICATE
- APPENDIX E – MEASURED FLUID DIELECTRIC PARAMETERS
- APPENDIX F – DAE CALIBRATION CERTIFICATE

END OF TEST REPORT