

SAR TEST REPORT

Test item : Swing U
Model No. : NTRM-U-2
Order No. : DEMC1405-02054
Date of receipt : 2014-05-28
Test duration : 2014-06-26
Date of issue : 2014-07-09
Use of report : FCC Original Grant

Applicant : NetHom Co. Ltd.
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Test rule part : CFR §2.1093
Test environment : See appended test report
Test result : ☒ Pass ☐ Fail

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Test Report Version

Test Report No.	Date	Description
DRTFCC1407-0903	Jul. 09, 2014	Final version for approval

1. DESCRIPTION OF DEVICE

Environmental evaluation measurements of specific absorption rate (SAR) distributions in emulated human head and body tissues exposed to radio frequency (RF) radiation from wireless portable devices for compliance with the rules and regulations of the U.S. Federal Communications Commission (FCC).

General Information:

Equipment type	Swing U		
FCC ID	2ACH7-NTRM-U-2		
Equipment model name	NTRM-U-2		
Equipment add model name	N/A		
Equipment serial no.	Identical prototype		
Mode(s) of Operation	RFID		
TX Frequency Range	910.2 ~ 920.0 MHz (RFID)		
RX Frequency Range	910.2 ~ 920.0 MHz (RFID)		
Equipment Class	Band	Measured Conducted Power [dBm]	Reported SAR
			10g SAR (W/kg) Body
DSS	RFID	25.72	3.100
Simultaneous SAR per KDB 690783 D01v01r03			3.153
FCC Equipment Class	DSS - Spread Spectrum Transmitter		
Date(s) of Tests	2014-06-26		
Antenna Type	Internal Type Antenna		
Functions	● BT(2.4GHz) supported ● RFID is supported.		

1.1 Guidance Applied

- IEEE 1528-2003
- FCC KDB Publication 447498 D01v05r02 (General SAR Guidance)
- FCC KDB Publication 865664 D01 SAR Measurement 100 MHz to 6 GHz v01r03

1.2 Device Overview

Band & Mode	Operating Modes	Tx Frequency
RFID	Data	910.2 ~ 920.0 MHz
Bluetooth	Data	2402 ~ 2480 MHz

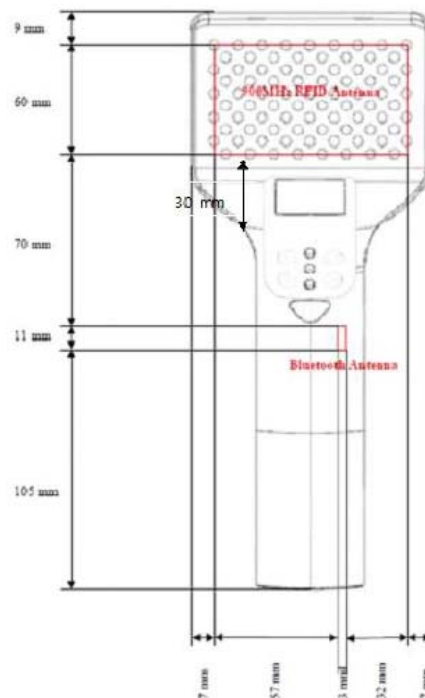
1.3 Nominal and Maximum Output Power Specifications

This device operates using the following maximum and nominal output power specifications. SAR values were scaled to the maximum allowed power to determine compliance per KDB Publication 447498 D01v05r02.

Band & Mode		Modulated Average [dBm]
RFID	Maximum	26.5
	Nominal	25.5
Bluetooth 1 Mbps	Maximum	5.0
	Nominal	4.0
Bluetooth 2 Mbps	Maximum	3.0
	Nominal	2.0
Bluetooth 3 Mbps	Maximum	3.0
	Nominal	2.0

1.4 DUT Antenna Locations

DUT Antenna Locations (Front Side View):



Note 1: Exact antenna dimensions and separation distances are shown in the "Antenna Location_2ACH7-NTRM-U-2" in the FCC Filing.

1.5 SAR Test Exclusions Applied

(A) RFID & BT

Per FCC KDB 447498 D01v05r02, the SAR exclusion threshold for distances < 50 mm is defined by the following equation:

$$[(\text{max. power of channel, including tune-up tolerance, mW}) / (\text{min. test separation distance, mm})] \cdot [\sqrt{f_{\text{(GHz)}}}] \leq 3.0 \text{ for 1-g SAR and } \leq 7.5 \text{ for 10-g extremity SAR}$$

Based on the maximum conducted Power of **RFID** (rounded to the nearest mW) and the antenna to user separation distance, **RFID 10g Extremity SAR was required**; $[(447/30) * \sqrt{0.920}] = \underline{14.3} > 7.5$

Based on the maximum conducted power of **Bluetooth** (rounded to the nearest mW) and the antenna to user separation distance, **Bluetooth 10g Extremity SAR was not required**; $[(3/5) * \sqrt{2.480}] = \underline{1.0} < 7.5$.

Per KDB Publication 447498 D01v05r02, the maximum power of the channel was rounded to the nearest mW before calculation.

1.6 Device Serial Numbers

Band & Mode	Body Serial Number
RFID	FCC #1

2. INTROCUCTION

The FCC and Industry Canada have adopted the guidelines for evaluating the environmental effects of radio frequency (RF) radiation in ET Docket 93-62 on Aug. 6, 1996 and Health Canada Safety Code 6 to protect the public and workers from the potential hazards of RF emissions due to FCC-regulated portable devices.

The FCC has adopted the guidelines for evaluating the environmental effects of radio frequency radiation in ET Docket 93-62 on Aug. 6, 1996 to protect the public and workers from the potential hazards of RF emissions due to FCC-regulated portable devices. The safety limits used for the environmental evaluation measurements are based on the criteria published by the American National Standards Institute (ANSI) for localized specific absorption rate (SAR) in IEEE/ANSI C95*.1-2005 Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz. 1992 by the Institute of Electrical and Electronics Engineers, Inc., New York, New York 10017. The measurement procedure described in IEEE/ANSI C95.3-1992 Recommended Practice for the Measurement of Potentially Hazardous Electromagnetic Fields - RF and Microwave is used for guidance in measuring SAR due to the RF radiation exposure from the Equipment Under Test (EUT). These criteria for SAR evaluation are similar to those recommended by the National Council on Radiation Protection and Measurements (NCRP) in Biological Effects and Exposure Criteria for Radio frequency Electromagnetic Fields," NCRP Report No. 86 NCRP, 1986, Bethesda, MD 20814. SAR is a measure of the rate of energy absorption due to exposure to an RF transmitting source. SAR values have been related to threshold levels for potential biological hazards.

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. 2.1)

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

Fig. 2.1 SAR Mathematical Equation

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

$$SAR = \frac{\sigma \cdot E^2}{\rho}$$

where:

- σ = conductivity of the tissue-simulating material (S/m)
- ρ = mass density of the tissue-simulating 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.

3. DESCRIPTION OF TEST EQUIPMENT

3.1 SAR MEASUREMENT SETUP

Measurements are performed using the DASY5 automated dosimetric assessment system. The DASY5 is made by Schmid & Partner Engineering AG (SPEAG) in Zurich, Switzerland and consists of high precision robotics system (Staubli), robot controller, desktop computer, near-field probe, probe alignment sensor, and the generic twin phantom containing the brain equivalent material. The robot is a six-axis industrial robot performing precise movements to position the probe to the location (points) of maximum electromagnetic field (EMF) (see Fig. 3.1).

A cell controller system contains the power supply, robot controller teach pendant (Joystick), and a remote control used to drive the robot motors. The PC consists of the Intel Core i7-3770 3.40 GHz desktop computer with Windows NT system and SAR Measurement Software DASY5, A/D interface card, monitor, mouse, and keyboard. The Staubli Robot is connected to the cell controller to allow software manipulation of the robot. A data acquisition electronic (DAE) circuit that 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 PC plug-in card.

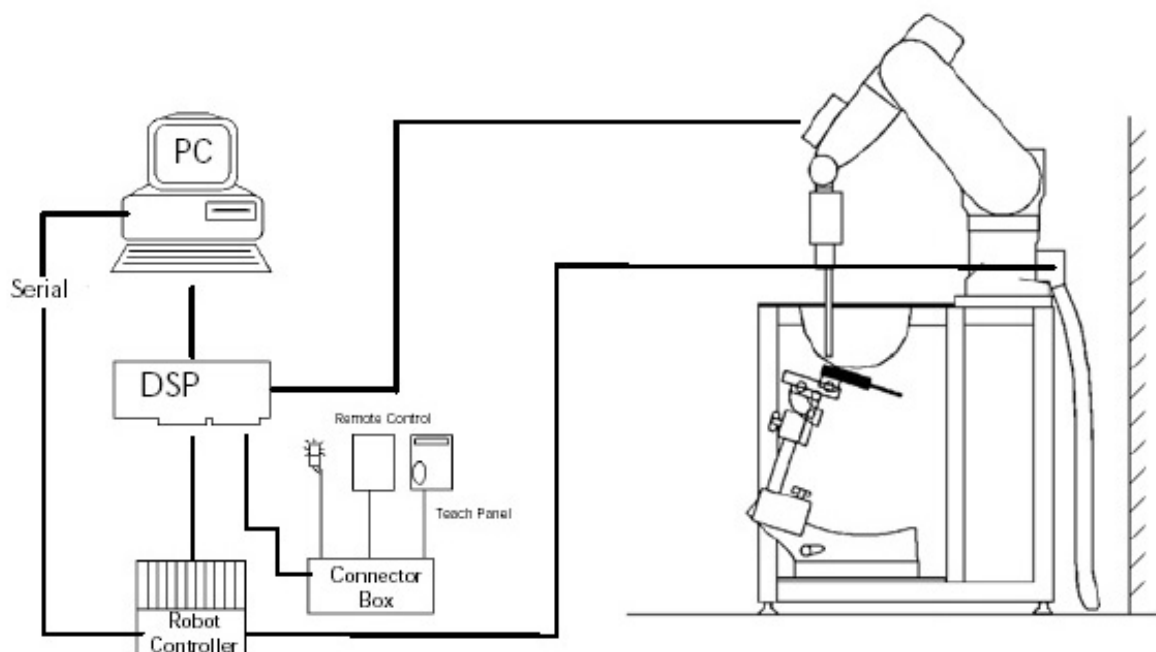


Figure 3.1 SAR Measurement System Setup

The DAE4 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 PC-card 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. They are also used for mechanical surface detection and probe collision detection. The robot uses its own controller with a built in VME-bus computer. The system is described in detail.

3.2 EX3DV4 Probe Specification

Calibration	In air from 10 MHz to 6 GHz
	In brain and muscle simulating tissue at Frequencies of 450 MHz, 600 MHz, 750 MHz, 835 MHz, 900 MHz, 1750 MHz, 1900 MHz, 2300 MHz, 2450 MHz, 2600 MHz, 3500 MHz, 5200 MHz, 5300 MHz, 5500 MHz, 5600 MHz, 5800 MHz
Frequency	10 MHz to 6 GHz
Linearity	± 0.2 dB (30 MHz to 6 GHz)
Dynamic	10 μ W/g to > 100 mW/g
Range	Linearity : ± 0.2 dB
Dimensions	Overall length : 337 mm
Tip length	20 mm
Body diameter	12 mm
Tip diameter	2.5 mm
Distance from probe tip to sensor center	1.0 mm
Application	SAR Dosimetry Testing
	Compliance tests of mobile phones

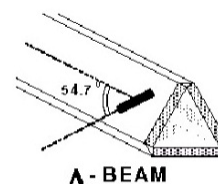


Figure 3.2 Triangular Probe Configurations



Figure 3.3 Probe Thick-Film Technique



DAE System

The SAR measurements were conducted with the dosimetric probe EX3DV4, designed in the classical triangular configuration (see Fig. 3.2) and optimized for dosimetric evaluation. The probe is constructed using the thick film technique; with printed resistive lines on ceramic substrates. The probe is equipped with an optical multitier line ending at the front of the probe tip. It is connected to the EOC box on the robot arm and provides an automatic detection of the phantom surface. Half of the fibers are connected to a pulsed infrared transmitter, the other half to a synchronized receiver. As the probe approaches the surface, the reflection from the surface produces a coupling from the transmitting to the receiving fibers. This reflection increases first during the approach, reaches maximum and then decreases. If the probe is flatly touching the surface, the coupling is zero. The distance of the coupling maximum to the surface is independent of the surface reflectivity and largely independent of the surface to probe angle. The DASY5 software reads the reflection during a software approach and looks for the maximum using a 2nd order fitting. The approach is stopped at reaching the maximum.

3.3 Probe Calibration Process

3.3.1 E-Probe Calibration

Dosimetric Assessment Procedure

Each probe is calibrated according to a dosimetric assessment procedure with accuracy better than +/- 10%. The spherical isotropy was evaluated with the procedure and found to be better than +/-0.25dB. The sensitivity parameters (NormX, NormY, NormZ), the diode compression parameter (DCP) and the conversion factor (ConvF) of the probe is tested.

Free Space Assessment

The free space E-field from amplified probe outputs is determined in a test chamber. This is performed in a TEM cell for frequencies below 1 GHz, and in a waveguide above 1GHz for free space. For the free space calibration, the probe is placed in the volumetric center of the cavity at the proper orientation with the field. The probe is then rotated 360 degrees.

Temperature Assessment *

E-field temperature correlation calibration is performed in a flat phantom filled with the appropriate simulated brain tissue. The measured free space E-field in the medium, correlates to temperature rise in a dielectric medium. For temperature correlation calibration a RF transparent the remits or based temperature probe is used in conjunction with the E-field probe.

$$SAR = C \frac{\Delta T}{\Delta t}$$

where:

Δt = exposure time (30 seconds),

C = heat capacity of tissue (brain or muscle),

ΔT = temperature increase due to RF exposure.

$$SAR = \frac{|E|^2 \cdot \sigma}{\rho}$$

where:

σ = simulated tissue conductivity,

ρ = Tissue density (1.25 g/cm³ for brain tissue)

SAR is proportional to $\Delta T / \Delta t$, the initial rate of tissue heating, before thermal diffusion takes place. Now it's possible to quantify the electric field in the simulated tissue by equating the thermally derived SAR to the E- field;

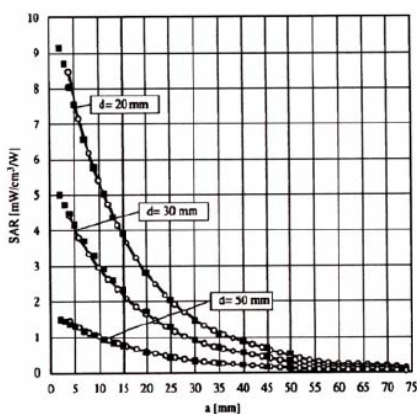


Figure 3.4 E-Field and Temperature Measurements at 900MHz

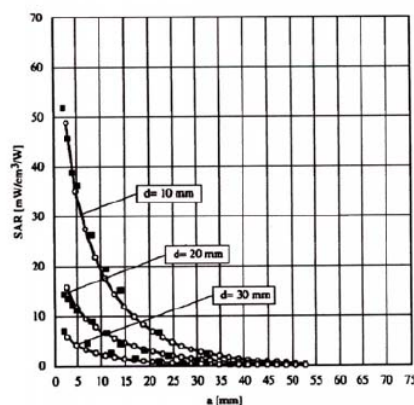


Figure 3.5 E-Field and Temperature Measurements at 1800MHz

3.4 Data Extrapolation

The DASY5 software automatically executes the following procedures to calculate the field units from the microvolt readings at the probe connector. 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 like below;

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

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:

E-field probes:

$$E_i = \sqrt{\frac{V_i}{Norm_i \cdot ConvF}}$$

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 of enhancement in solution
 E_i = electric field strength of channel i in V/m

The RSS value of the field components gives the total field strength (Hermetian 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.

$$SAR = E_{tot}^2 \cdot \frac{\sigma}{\rho \cdot 1000}$$

with SAR = local specific absorption rate in W/g
 E_{tot} = total field strength in V/m
 σ = conductivity in [mho/m] or [Siemens/m]
 ρ = equivalent tissue density in g/cm³

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

$$P_{free} = \frac{E_{tot}^2}{3770}$$

with P_{pwe} = equivalent power density of a plane wave in W/cm²
 E_{tot} = total electric field strength in V/m

3.5 ELI PHANTOM

Phantom for compliance testing of handheld and body-mounted wireless devices in the frequency range of 30 MHz to 6 GHz. ELI has been optimized regarding its performance and can be integrated into our standard phantom tables. A cover prevents evaporation of the liquid. Reference markings on the phantom allow installation of the complete setup, including all predefined phantom positions and measurement grids, by teaching three points. The phantom is compatible with all SPEAG dosimetric probes and dipoles.

ELI V5.0 has the same shell geometry and is manufactured from the same material as ELI4, but has reinforced top structure. (see fig. 3.7)



Figure 3.7 ELI Phantom

ELI Phantom Specification:

Shell Thickness	2 ± 0.2 mm (bottom plate)
Dimensions	Major axis: 600 mm Minor axis: 400 mm
Filling Volume	Approx. 30 liters

3.6 Device Holder for Transmitters

In combination with the Twin SAM Phantom V5.0 or ELI4, the Mounting Device enables the rotation of the mounted transmitter device in spherical coordinates. Rotation point is the ear opening point. Transmitter devices can be easily and accurately positioned according to IEC, IEEE, FCC or other specifications. The device holder can be locked for positioning at different phantom sections (left head, right head, flat).

Note: A simulating human hand is not used due to the complex anatomical and geometrical structure of the hand that may produce infinite number of configurations. To produce the worst-case condition (the hand absorbs antenna output power), the hand is omitted during the tests.



Figure 3.8 Mounting Device

3.7 Brain & Muscle Simulation Mixture Characterization

The brain and muscle mixtures consist of a viscous gel using hydrox-ethylcellulose (HEC) gelling agent and saline solution (see Table 3.1). Preservation with a bactericide is added and visual inspection is made to make sure air bubbles are not trapped during the mixing process. The mixture is calibrated to obtain proper dielectric constant (permittivity) and conductivity of the desired tissue. The mixture characterizations used for the brain and muscle tissue simulating liquids are according to the data by C. Gabriel and G. Harts grove.



Figure 3.9 Simulated Tissue

Table 3.1 Composition of the Tissue Equivalent Matter

Ingredients (% by weight)	Frequency (MHz)									
	835		900		1900		2450		5200 ~ 5800	
Tissue Type	Head	Body	Head	Body	Head	Body	Head	Body	Head	Body
Water	40.19	50.75	41.45	52.50	55.24	70.23	71.88	73.40	65.52	80.00
Salt (NaCl)	1.480	0.940	1.450	1.400	0.310	0.290	0.160	0.060	-	-
Sugar	57.90	48.21	56.00	45.00	-	-	-	-	-	-
HEC	0.250	-	1.000	1.000	-	-	-	-	-	-
Bactericide	0.180	0.100	0.100	0.100	-	-	-	-	-	-
Triton X-100	-	-	-	-	-	-	19.97	-	17.24	-
DGBE	-	-	-	-	44.45	29.48	7.990	26.54	-	-
Diethylene glycol hexyl ether	-	-	-	-	-	-	-	-	17.24	-
Polysorbate (Tween) 80	-	-	-	-	-	-	-	-	-	20.00
Target for Dielectric Constant	41.5	55.2	41.5	55.0	40.0	53.3	39.2	52.7	-	-
Target for Conductivity (S/m)	0.90	0.97	0.97	1.05	1.40	1.52	1.80	1.95	-	-

Salt:	99 % Pure Sodium Chloride	Sugar:	98 % Pure Sucrose
Water:	De-ionized, 16M resistivity	HEC:	Hydroxyethyl Cellulose
DGBE:	99 % Di(ethylene glycol) butyl ether,[2-(2-butoxyethoxy) ethanol]		
Triton X-100(ultra pure):	Polyethylene glycol mono[4-(1,1,3,3-tetramethylbutyl)phenyl] ether		

3.8 SAR TEST EQUIPMENT

Table 3.2 Test Equipment Calibration

	Type	Manufacturer	Model	Cal.Date	Next.Cal.Date	S/N
☒	SEMITEC Engineering	SEMITEC	N/A	N/A	N/A	Shield Room
☒	Robot	SCHMID	TX90XL	N/A	N/A	F13/5P9GA1/A/01
☒	Robot Controller	SCHMID	C58C	N/A	N/A	F13/5P9GA1/C/01
☒	Joystick	SCHMID	N/A	N/A	N/A	S-12450905
☒	Intel Core i7-3770 3,40 GHz Windows 7 Professional	N/A	N/A	N/A	N/A	N/A
☒	Probe Alignment Unit LB	N/A	N/A	N/A	N/A	SE UKS 030 AA
☒	Mounting Device	SCHMID	Holder	N/A	N/A	SD000H01HA
☐	Laptop Holder	SCHMID	SMLH1001CD	N/A	N/A	N/A
☐	Twin SAM Phantom	SCHMID	QD000P40CD	N/A	N/A	1782
☐	Twin SAM Phantom	SCHMID	QD000P40CD	N/A	N/A	1783
☒	2mm Oval Phantom ELI5	SCHMID	QDOVA002AA	N/A	N/A	1237
☒	Data Acquisition Electronics	SCHMID	DAE4	2013-09-09	2014-09-09	1394
☒	Dosimetric E-Field Probe	SCHMID	EX3DV4	2013-09-10	2014-09-10	3930
☐	Dummy Probe	N/A	N/A	N/A	N/A	N/A
☐	835 MHz SAR Dipole	SCHMID	D835V2	2013-09-05	2015-09-05	4d159
☒	900 MHz SAR Dipole	SCHMID	D900V2	2014-05-16	2016-05-16	1d138
☐	1 900 MHz SAR Dipole	SCHMID	D1900V2	2013-09-05	2015-09-05	5d176
☐	2 450 MHz SAR Dipole	SCHMID	D2450V2	2013-09-10	2015-09-10	920
☒	Network Analyzer	Agilent	E5071C	2013-10-21	2014-10-21	MY46106970
☒	Signal Generator	Agilent	ESG-3000A	2013-06-27	2014-06-27	US37230529
☒	Amplifier	EMPOWER	BBS3Q7ELU	2013-09-12	2014-09-12	1020
☐	High Power RF Amplifier	EMPOWER	BBS3Q8CCJ	2013-10-22	2014-10-22	1005
☒	Power Meter	HP	EPM-442A	2014-02-28	2015-02-28	GB37170267
☒	Power Meter	Anritsu	ML2495A	2014-03-12	2015-03-12	1306007
☒	Wide Bandwidth Power Sensor	Anritsu	MA2490A	2014-03-12	2015-03-12	1249001
☒	Power Sensor	HP	8481A	2014-02-28	2015-02-28	3318A96566
☒	Power Sensor	HP	8481A	2014-01-07	2015-01-07	3318A96030
☒	Dual Directional Coupler	Agilent	778D-012	2014-01-07	2015-01-07	50228
☐	Directional Coupler	HP	773D	2013-06-27	2014-06-27	2389A00640
☒	Low Pass Filter 1.5GHz	Micro LAB	LA-15N	2014-01-07	2015-01-07	N/A
☐	Low Pass Filter 3.0GHz	Micro LAB	LA-30N	2013-09-12	2014-09-12	N/A
☐	Low Pass Filter 6.0GHz	Micro LAB	LA-60N	2014-02-27	2015-02-27	03942
☒	Attenuators(3 dB)	Agilent	8491B	2013-06-27	2014-06-27	MY39260700
☒	Attenuators(10 dB)	WEINSCHEL	23-10-34	2014-01-07	2015-01-07	BP4387
☐	Step Attenuator	HP	8494A	2013-09-12	2014-09-12	3308A33341
☒	Dielectric Probe kit	SCHMID	DAK-3.5	2014-01-07	2015-01-07	1092

NOTE: The E-field probe was calibrated by SPEAG, by temperature measurement procedure. Dipole Verification measurement is performed by DT&C before each test. The brain and muscle simulating material are calibrated by DT&C using the dielectric probe system and network analyzer to determine the conductivity and permittivity (dielectric constant) of the brain-equivalent material.

4. TEST SYSTEM SPECIFICATIONS

Automated TEST SYSTEM SPECIFICATIONS:

Positioner

Robot	Stäubli Unimation Corp. Robot Model: TX90XL
Repeatability	0.02 mm
No. of axis	6

Data Acquisition Electronic (DAE) System

Cell Controller

Processor	Intel Core i7-3770
Clock Speed	3.40 GHz
Operating System	Windows 7 Professional
Data Card	DASY5 PC-Board

Data Converter

Features	Signal, multiplexer, A/D converter. & control logic
Software	DASY5
Connecting Lines	Optical downlink for data and status info Optical uplink for commands and clock

PC Interface Card

Function	24 bit (64 MHz) DSP for real time processing Link to DAE 4 16 bit A/D converter for surface detection system serial link to robot direct emergency stop output for robot
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E-Field Probes

Model	EX3DV4 S/N: 3930
Construction	Triangular core fiber optic detection system
Frequency	10 MHz to 6 GHz
Linearity	± 0.2 dB (30 MHz to 6 GHz)

Phantom

Phantom	ELI Phantom (V5.0)
Shell Material	Composite
Thickness	2 ± 0.2 mm (bottom plate)



Figure 4.1 DASY5 Test System

5. SAR MEASUREMENT PROCEDURE

5.1 Measurement Procedure

The evaluation was performed using the following procedure compliant to FCC KDB Publication 865664 D01v01r03 and IEEE 1528-2013:

1. The SAR distribution at the exposed side of the head or body was measured at a distance no greater than 5.0 mm from the inner surface of the shell. The area covered the entire dimension of the device-head and body interface and the horizontal grid resolution was determined per FCC KDB Publication 865664 D01v01r03 (See Table 5-1) and IEEE 1528-2013.
2. The point SAR measurement was taken at the maximum SAR region determined from Step 1 to enable the monitoring of SAR fluctuations/drifts during the 1g/10g cube evaluation. SAR at this fixed point was measured and used as a reference value.
3. Based on the area scan data, the peak of the region with maximum SAR was determined by spline interpolation. Around this point, a volume was assessed according to the measurement resolution and volume size requirements of FCC KDB Publication 865664 D01v01r03 (See Table 5-1) and IEEE 1528-2013. On the basis of this data set, the spatial peak SAR value was evaluated with the following procedure (see references or the DASY manual online for more details):
 - a. SAR values at the inner surface of the phantom are extrapolated from the measured values along the line away from the surface with spacing no greater than that in Table 3-1. The extrapolation was based on a least-squares algorithm. A polynomial of the fourth order was calculated through the points in the z-axis (normal to the phantom shell).
 - b. After the maximum interpolated values were calculated between the points in the cube, the SAR was averaged over the spatial volume (1g or 10g) using a 3D-Spline interpolation algorithm. The 3D-spline is composed of three one-dimensional splines with the “Not a knot” condition (in x, y, and z directions). The volume was then integrated with the trapezoidal algorithm. One thousand points (10 x 10 x 10) were obtained through interpolation, in order to calculate the averaged SAR.
 - c. All neighboring volumes were evaluated until no neighboring volume with a higher average value was found.
4. The SAR reference value, at the same location as step 2, was re-measured after the zoom scan was complete to calculate the SAR drift. If the drift deviated by more than 5%, the SAR test and drift measurements were repeated.

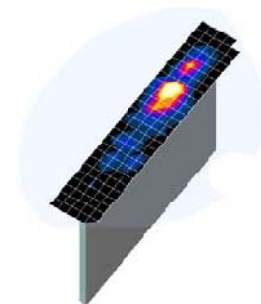


Figure 5.1
Sample SAR Area Scan

Frequency	Maximum Area Scan Resolution (mm) (Δx_{area} , Δy_{area})	Maximum Zoom Scan Resolution (mm) (Δx_{zoom} , Δy_{zoom})	Maximum Zoom Scan Spatial Resolution (mm)			Minimum Zoom Scan Volume (mm) (x,y,z)
			Uniform Grid	Graded Grid		
			$\Delta z_{zoom}(n)$	$\Delta z_{zoom}(1)^*$	$\Delta z_{zoom}(n>1)^*$	
≤ 2 GHz	≤ 15	≤ 8	≤ 5	≤ 4	$\leq 1.5^* \Delta z_{zoom}(n-1)$	≥ 30
2-3 GHz	≤ 12	≤ 5	≤ 5	≤ 4	$\leq 1.5^* \Delta z_{zoom}(n-1)$	≥ 30
3-4 GHz	≤ 12	≤ 5	≤ 4	≤ 3	$\leq 1.5^* \Delta z_{zoom}(n-1)$	≥ 28
4-5 GHz	≤ 10	≤ 4	≤ 3	≤ 2.5	$\leq 1.5^* \Delta z_{zoom}(n-1)$	≥ 25
5-6 GHz	≤ 10	≤ 4	≤ 2	≤ 2	$\leq 1.5^* \Delta z_{zoom}(n-1)$	≥ 22

Table 5.1 Area and Zoom Scan Resolutions per FCC KDB Publication 865664 D01v01r03*

*Also compliant to IEEE 1528-2013 Table 6

6. TEST CONFIGURATION POSITIONS

6.1 Device Holder

The device holder is made out of low-loss POM material having the following dielectric parameters: relative permittivity $\epsilon = 3$ and loss tangent $\delta = 0.02$.

6.2 Body Configurations

In all cases SAR measurements are performed to investigate the worst-case positioning. Worst-case positioning is then documented and used to perform Body SAR testing.

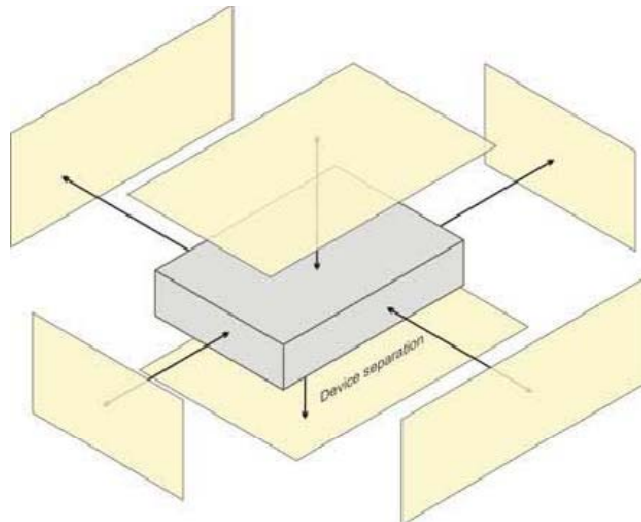


Figure 6.7 Sample Body Diagram

6.3 Extremity Exposure Configurations

Devices that are designed or intended for use on extremities or mainly operated in extremity only exposure conditions; i.e., hands, wrists, feet and ankles, may require extremity SAR evaluation. When the device also operates in close proximity to the user's body, SAR compliance for the body is also required. The 1-g body and 10-g extremity SAR Exclusion Thresholds found in KDB Publication 447498 D01v05r02 should be applied to determine SAR test requirements.

7. RF EXPOSURE LIMITS

Uncontrolled Environment:

UNCONTROLLED ENVIRONMENTS are defined as locations where there is the exposure of individuals who have no knowledge or control of their 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.

Controlled Environment:

CONTROLLED ENVIRONMENTS are defined as locations where there is exposure that may be incurred by persons who are aware of the potential for exposure, (i.e. as a result of employment or occupation). In general, occupational/controlled exposure limits are 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.

Table 7.1.SAR Human Exposure Specified in ANSI/IEEE C95.1-2005

	HUMAN EXPOSURE LIMITS	
	General Public Exposure (W/kg) or (mW/g)	Occupational Exposure (W/kg) or (mW/g)
SPATIAL PEAK SAR * (Brain)	1.60	8.00
SPATIAL AVERAGE SAR ** (Whole Body)	0.08	0.40
SPATIAL PEAK SAR *** (Hands / Feet / Ankle / Wrist)	4.00	20.0

1. The Spatial Peak value of the SAR averaged over any 1 gram of tissue (defined as a tissue volume in the shape of a cube) and over the appropriate averaging time.
2. The Spatial Average value of the SAR averaged over the whole body.
3. The Spatial Peak value of the SAR averaged over any 10 grams of tissue (defined as a tissue volume in the shape of a cube) and over the appropriate averaging time.

Uncontrolled Environments are defined as locations where there is the exposure of individuals who have no knowledge or control of their exposure.

Controlled Environments are defined as locations where there is exposure that may be incurred by persons who are aware of the potential for exposure, (i.e.as a result of employment or occupation).

8. FCC MEASUREMENT PROCEDURES

Power measurements were performed using a base station simulator under digital average power.

8.1 Measured and Reported SAR

Per FCC KDB Publication 447498 D01v05r02, When SAR is not measured at the maximum power level allowed for production units, the results must be scaled to the maximum tune-up tolerance limit according to the power applied to the individual channels tested to determine compliance. For simultaneous transmission, the measured aggregate SAR must be scaled according to the sum of the differences between the maximum tune-up tolerance and actual power used to test each transmitter. When SAR is measured at or scaled to the maximum tune-up tolerance limit, the results are referred to as reported SAR. The highest reported SAR results are identified on the grant of equipment authorization according to procedures in KDB 690783 D01v01r03.

8.2 Procedures Used to Establish RF Signal for SAR

The device was placed in a RF shielded chamber. Establishing connections in this manner ensure a consistent means for testing SAR and are recommended for evaluating SAR. Devices under test were evaluated prior to testing, with a fully charged battery and were configured to operate at maximum output power. In order to verify that the device was tested throughout the SAR test at maximum output power, the SAR measurement system measures a "point SAR" at an arbitrary reference point at the start and end of the 1 gram SAR evaluation, to assess for any power drifts during the evaluation. If the power drift deviated by more than 5%, the SAR test and drift measurements were repeated.

This device was tested with continuous modulated transmission and below duty cycle.

- Duty Cycle = On time / (On time + OFF time)

Channel	Frequency(MHz)	Duty Cycle
F1	910.2	1
F2	915.0	1
F3	920.0	1

9. RF CONDUCTED POWERS

9.1 RFID Conducted Powers

Band	Frequency	Channel	RFID Conducted Power (dBm)
	(MHz)		
RFID	910.2	F1	25.72
	915.0	F2	25.65
	920.0	F3	25.68

Table 9.1 RFID Average RF Power



Figure 9.1 Power Measurement Setup

Note: Bluetooth module in device already got FCC certification. Please refer to Bluetooth power of report (FCC ID: S7AIW03)

10. SYSTEM VERIFICATION

10.1 Tissue Verification

MEASURED TISSUE PARAMETERS										
Date(s)	Tissue Type	Ambient Temp.[°C]	Liquid Temp.[°C]	Measured Frequency [MHz]	Target Dielectric Constant, ϵ_r	Target Conductivity, σ (S/m)	Measured Dielectric Constant, ϵ_r	Measured Conductivity, σ (S/m)	Er Deviation [%]	σ Deviation [%]
Jun. 26. 2014	900 Body	21.3	21.5	900.0	55.000	1.050	54.284	1.065	-1.30	1.43
				910.2	55.000	1.057	54.219	1.075	-1.42	1.70
				915.0	55.000	1.060	54.185	1.080	-1.48	1.89
				920.0	54.990	1.062	54.150	1.086	-1.53	2.26

Tissue Verification Note:

Note: The above measured tissue parameters were used in the DASY software. The DASY software was used to perform interpolation to determine the dielectric parameters at the SAR test device frequencies (per KDB 865664 and IEEE 1528-2013 6.6.1.2). The tissue parameters listed in the SAR test plots may slightly differ from the table above due to significant digit rounding in the software.

Measurement Procedure for Tissue verification:

- 1) The network analyzer and probe system was configured and calibrated
- 2) The probe was immersed in the sample which was placed in a nonmetallic container. Trapped air bubbles beneath the flange were minimized by placing the probe at a slight angle.
- 3) The complex admittance with respect to the probe aperture was measured
- 4) The complex relative permittivity, for example from the below equation (Pournaropoulos and Misra):

$$Y = \frac{j2\omega\epsilon_r\epsilon_0}{[\ln(b/a)]^2} \int_a^b \int_a^b \int_0^\pi \cos\phi' \frac{\exp[-j\omega r(\mu_0\epsilon_r\epsilon_0)^{1/2}]}{r} d\phi' d\rho' d\rho$$

where Y is the admittance of the probe in contact with the sample, the primed and unprimed coordinates refer to source and observation points, respectively, $r^2 = \rho^2 + \rho'^2 - 2\rho\rho'\cos\phi'$, ω is the angular frequency, and $j = \sqrt{-1}$.

10.2 Test System Verification

Prior to assessment, the system is verified to the $\pm 10\%$ of the specifications at 900 MHz by using the SAR Dipole kit(s). (Graphic Plots Attached)

Table 10.1 System Verification Results

SYSTEM DIPOLE VERIFICATION TARGET & MEASURED												
SAR System #	Freq. [MHz]	SAR Dipole kits	Date(s)	Liquid	Ambient Temp.[°C]	Liquid Temp.[°C]	Probe S/N	Input Power (mW)	1 W Target SAR _{10g} (W/kg)	Measured SAR _{10g} (W/kg)	1 W Normalized SAR _{10g} (W/kg)	Deviation [%]
C	900	D900V2, SN: 1d138	Jun. 26. 2014	Body	21.3	21.5	3930	250	6.79	1.57	6.28	-7.51

Note1 : System Verification was measured with input 250 mW and normalized to 1W.

Note2 : To confirm the proper SAR liquid depth, the z-axis plots from the system verifications were included since the system verifications were performed using the same liquid, probe and DAE as the SAR tests in the same time period.

Note3: Full system validation status and results can be found in Attachment 3.

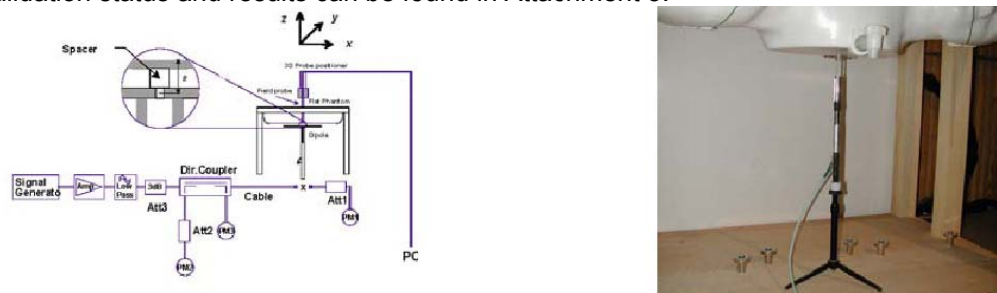


Figure 10.1 Dipole Verification Test Setup

11. SAR TEST RESULTS

11.1 Standalone Body SAR Results

Table 11.1 RFID Body SAR

MEASUREMENT RESULTS

FREQUENCY		Mode/ Band	Service	Maximum Allowed Power [dBm]	Conducted Power [dBm]	Drift Power [dB]	Spacing [Side]	Device Serial Number	Duty Cycle	10g SAR (W/kg)	Scaling Factor	10g Scaled SAR (W/kg)	Plots #
MHz	Ch												
915.0	F2	RFID	RFID	26.5	25.65	-0.070	0 mm [Top]	FCC #1	1:1	0.997	1.216	1.212	
915.0	F2	RFID	RFID	26.5	25.65	-0.160	0 mm [Bottom]	FCC #1	1:1	0.00145	1.216	0.002	
915.0	F2	RFID	RFID	26.5	25.65	-0.010	0 mm [Front #1]	FCC #1	1:1	1.250	1.216	1.520	
915.0	F2	RFID	RFID	26.5	25.65	-0.160	0 mm [Front #2]	FCC #1	1:1	0.317	1.216	0.385	
910.2	F1	RFID	RFID	26.5	25.72	-0.040	0 mm [Rear]	FCC #1	1:1	2.590	1.197	3.100	A1
915.0	F2	RFID	RFID	26.5	25.65	-0.020	0 mm [Rear]	FCC #1	1:1	2.370	1.216	2.882	
920.0	F3	RFID	RFID	26.5	25.68	0.000	0 mm [Rear]	FCC #1	1:1	2.430	1.208	2.935	
915.0	F2	RFID	RFID	26.5	25.65	-0.020	0 mm [Right]	FCC #1	1:1	0.111	1.216	0.135	
915.0	F2	RFID	RFID	26.5	25.65	-0.050	0 mm [Left]	FCC #1	1:1	0.050	1.216	0.061	
910.2	F1	RFID	RFID	26.5	25.72	-0.010	0 mm [Rear]	FCC #1	1:1	2.570	1.197	3.076	
ANSI / IEEE C95.1-2005- SAFETY LIMIT Spatial Peak Uncontrolled Exposure/General Population Exposure								Body 4.0 W/kg (mW/g) averaged over 10 gram					

Note: Front configuration tested twice. Refer to Test photo(SAR).

Blue entries represent repeatability measurements.

11.2 SAR Test Notes

General Notes:

- The test data reported are the worst-case SAR values according to test procedures specified in IEEE 1528-2003, and FCC KDB Publication 447498 D01v05r02.
- Batteries are fully charged at the beginning of the SAR measurements. A standard battery was used for all SAR measurements.
- Liquid tissue depth was at least 15.0 cm for all frequencies.
- The manufacturer has confirmed that the device(s) tested have the same physical, mechanical and thermal characteristics and are within operational tolerances expected for production units.
- SAR results were scaled to the maximum allowed power to demonstrate compliance per FCC KDB Publication 447498 D01v05r02.
- Device was tested using a fixed spacing for body testing. A separation distance of 0 mm was considered because the manufacturer has determined that there will be body available in the marketplace for users to support this separation distance.
- Per FCC KDB 865664 D01v01r03, variability SAR tests were performed when the measured SAR results for a frequency band were greater than 2.0 W/kg. Repeated SAR measurements are highlighted in the tables above for clarity. Please see Section 14 for variability analysis.
- This device tested with 2 front positions (front #1, #2). Please refer to test photos.

RFID Notes:

- RFID is only transmitted when user press the button,

12. FCC MULTI-TX AND ANTENNA SAR CONSIDERATIONS

12.1 Introduction

The following procedures adopted from FCC KDB Publication 447498 D01v05r02 are applicable to handsets with built-in unlicensed transmitters such as Bluetooth devices which may simultaneously transmit with the licensed transmitter.

12.2 Simultaneous Transmission Procedures

This device contains transmitters that may operate simultaneously. Therefore simultaneous transmission analysis is required. Per FCC KDB 447498 D01v05r02 IV.C.1.iii and IEEE 1528-2013 Section 6.3.4.1.2, simultaneous transmission SAR test exclusion may be applied when the sum of the 10g SAR for all the simultaneous transmitting antennas in a specific a physical test configuration is ≤ 4.0 W/kg. When standalone SAR is not required to be measured, per FCC KDB 447498 D01v05r02 4.3.2 2), the following equation must be used to estimate the standalone 10g SAR for simultaneous transmission assessment involving that transmitter.

$$(\text{max. power of channel, including tune-up tolerance, mW}) / (\text{min. test separation distance, mm}) \cdot [\sqrt{f_{\text{GHz}}/x}] \text{ W/kg for test separation distances } \leq 50 \text{ mm};$$

where $x = 7.5$ for 1-g SAR, and $x = 18.75$ for 10-g SAR.

Table 13.1 Estimated SAR

Mode	Frequency	Maximum Allowed Power		Separation Distance (Body)	Estimated SAR (Body)
	[MHz]	[dBm]	[mW]	[mm]	[W/kg]
Bluetooth	2480	5.0	3.0	5	0.053

Note: Per FCC KDB Publication 447498 D01v05r02, when the test separation distance is < 5 mm (Touching), a distance of 5 mm is applied to determine estimated SAR. And the maximum power of the channel was rounded to the nearest mW before calculation.

12.3 Simultaneous Transmission Capabilities

According to FCC KDB Publication 447498 D01v05r02, transmitters are considered to be transmitting simultaneously when there is overlapping transmission, with the exception of transmissions during network hand-offs with maximum hand-off duration less than 30 seconds. Possible transmission paths for the DUT are shown in Figure 12.1 and are color-coded to indicate communication modes which share the same path. Modes which share the same transmission path cannot transmit simultaneously with one another.



Figure 12.1 Simultaneous Transmission Paths

This device contains multiple transmitters that may operate simultaneously, and therefore requires a simultaneous transmission analysis according to FCC KDB Publication 447498 D01v05r02 3) procedures.

Table 12.2 Simultaneous Transmission Scenarios

Ref.	Simultaneous Transmit Configurations	Body
1	Bluetooth + RFID	Yes

12.4 Body Simultaneous Transmission Analysis

Table 12.3 Simultaneous Transmission Scenario with Bluetooth (Body at 0 mm)

Simult TX	Configuration	RFID 10g SAR (W/kg)	Bluetooth 10g SAR (W/kg)	Σ SAR (W/kg)
Body SAR	Top	1.212	0.053	1.265
	Bottom	0.002	0.053	0.055
	Front	1.520	0.053	1.573
	Rear	3.100	0.053	3.153
	Right	0.135	0.053	0.188
	Left	0.061	0.053	0.114

Note: Bluetooth SAR was not required to be measured per FCC KDB 447498. Estimated SAR results were used in the above table to determine simultaneous transmission SAR test exclusion.

12.5 Simultaneous Transmission Conclusion

The above numerical summed SAR results for all the worst-case simultaneous transmission conditions were below the SAR limit. Therefore, the above analysis is sufficient to determine that simultaneous transmission cases will not exceed the SAR limit and therefore no measured volumetric simultaneous SAR summation is required per FCC KDB Publication 447498 D01v05r02.

13. SAR MEASUREMENT VARIABILITY

13.1 Measurement Variability

Per FCC KDB Publication 865664 D01v01r03, SAR measurement variability was assessed for each frequency band, which was determined by the SAR probe calibration point and tissue-equivalent medium used for the device measurements. When both head and body tissue-equivalent media were required for SAR measurements in a frequency band, the variability measurement procedures were applied to the tissue medium with the highest measured SAR, using the highest measured SAR configuration for that tissue-equivalent medium. These additional measurements were repeated after the completion of all measurements requiring the same head or body tissue-equivalent medium in a frequency band. The test device was returned to ambient conditions (normal room temperature) with the battery fully charged before it was re-mounted on the device holder for the repeated measurement(s) to minimize any unexpected variations in the repeated results.

SAR Measurement Variability was assessed using the following procedures for each frequency band:

1. When the original highest measured SAR is ≥ 2.0 W/kg, the measurement was repeated once.
2. A second repeated measurement was performed only if the ratio of largest to smallest SAR for the original and first repeated measurements was > 1.2 or when the original or repeated measurement was ≥ 3.625 W/kg ($\sim 10\%$ from the 10-g SAR limit).
3. A third repeated measurement was performed only if the original, first or second repeated measurement was ≥ 3.75 W/kg and the ratio of largest to smallest SAR for the original, first and second repeated measurements is > 1.2
4. Repeated measurements are not required when the original highest measured SAR is < 2.0 W/kg

Table 13.1 Body SAR Measurement Variability Results

Frequency		Mode	Service	# of Time Slots	Spacing [Side]	Measured SAR (1g)	1st Repeated SAR(1g)	Ratio	2nd Repeated SAR(1g)	Ratio	3rd Repeated SAR(1g)	Ratio
MHz	Ch.					(W/kg)	(W/kg)		(W/kg)		(W/kg)	
910.2	F1	RFID	RFID	N/A	0 mm [Rear]	2.590	2.570	1.01	N/A	N/A	N/A	N/A
ANSI / IEEE C95.1-2005– SAFETY LIMIT Spatial Peak Uncontrolled Exposure/General Population Exposure							Body 4.0 W/kg (mW/g) averaged over 10 gram					

13.2 Measurement Uncertainty

The measured SAR was < 3.75 W/kg for all frequency bands. Therefore, per KDB Publication 865664 D01v01r03, the standard measurement uncertainty analysis per IEEE 1528-2003 was not required.

14. IEEE P1528 –MEASUREMENT UNCERTAINTIES

900 MHz Body

Error Description	Uncertain value $\pm\%$	Probability Distribution	Divisor	(Ci) 1g	Standard (1g)	vi 2 or Veff
Measurement System						
Probe calibration	± 6.0	Normal	1	1	$\pm 6.0 \%$	∞
Axial isotropy	± 4.7	Rectangular	$\sqrt{3}$	1	$\pm 2.714 \%$	∞
Hemispherical isotropy	± 9.6	Rectangular	$\sqrt{3}$	1	$\pm 5.543 \%$	∞
Boundary Effects	± 0.8	Rectangular	$\sqrt{3}$	1	$\pm 0.462 \%$	∞
Probe Linearity	± 4.7	Rectangular	$\sqrt{3}$	1	$\pm 2.714 \%$	∞
Detection limits	± 0.25	Rectangular	$\sqrt{3}$	1	$\pm 0.144 \%$	∞
Readout Electronics	± 1.0	Normal	1	1	$\pm 1.0 \%$	∞
Response time	± 0.8	Rectangular	$\sqrt{3}$	1	$\pm 0.462 \%$	∞
Integration time	± 2.6	Rectangular	$\sqrt{3}$	1	$\pm 1.501 \%$	∞
RF Ambient Conditions	± 3.0	Rectangular	$\sqrt{3}$	1	$\pm 1.732 \%$	∞
Probe Positioner	± 0.4	Rectangular	$\sqrt{3}$	1	$\pm 0.231 \%$	∞
Probe Positioning	± 2.9	Rectangular	$\sqrt{3}$	1	$\pm 1.674 \%$	∞
Algorithms for Max. SAR Eval.	± 1.0	Rectangular	$\sqrt{3}$	1	$\pm 0.577 \%$	∞
Test Sample Related						
Device Positioning	± 2.9	Normal	1	1	$\pm 2.9 \%$	145
Device Holder	± 3.6	Normal	1	1	$\pm 3.6 \%$	5
Power Drift	± 5.0	Rectangular	$\sqrt{3}$	1	$\pm 2.887 \%$	∞
Physical Parameters						
Phantom Shell	± 4.0	Rectangular	$\sqrt{3}$	1	$\pm 2.309 \%$	∞
Liquid conductivity (Target)	± 5.0	Rectangular	$\sqrt{3}$	0.64	$\pm 2.887 \%$	∞
Liquid conductivity (Meas.)	± 4.1	Normal	1	0.64	$\pm 4.1 \%$	∞
Liquid permittivity (Target)	± 5.0	Rectangular	$\sqrt{3}$	0.6	$\pm 2.887 \%$	∞
Liquid permittivity (Meas.)	± 4.4	Normal	1	0.6	$\pm 4.4 \%$	∞
Combined Standard Uncertainty					$\pm 12.1 \%$	330
Expanded Uncertainty (k=2)					$\pm 24.2 \%$	

The above measurement uncertainties are according to IEEE P1528 (2003)

15.CONCLUSION

Measurement Conclusion

The SAR measurement indicates that the EUT complies with the RF radiation exposure limits of the FCC. These measurements are taken to simulate the RF effects exposure under the worst-case conditions. Precise laboratory measures were taken to assure repeatability of the tests. The tested device complies with the requirements in respect to all parameters subject to the test. The test results and statements relate only to the item(s) tested.

Please note that the absorption and distribution of electromagnetic energy in the body are very complex phenomena that depend on the mass, shape, and size of the body, the orientation of the body with respect to the field vectors, and the electrical properties of both the body and the environment. Other variables that may play a substantial role impossible biological effect are those that characterize the environment (e.g. ambient temperature, air velocity, relative humidity, and body insulation) and those that characterize the individual (e.g. age, gender, activity level, debilitation, or disease).

Because innumerable factors may interact to determine the specific biological outcome of an exposure to electromagnetic fields, any protection guide shall consider maximal amplification of biological effects as a result of field-body interactions, environmental conditions, and physiological variables.

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