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Dosimetric Assessment
Test Report

for the

Rajant BreadCrumb CX1-3600

Tested and Evaluated In Accordance With
IEEE 1528:2013, IEC 62209-2 & KDB 865664

Prepared for

Rajant Corporation
Keith Sullivan
400 East King Street
Malvern, PA 19335

Engineering Statement: The measurements shown in this report were made in accordance with the procedures specified in KDB and Industry Canada RSS-102 for uncontrolled exposure. I assume full responsibility for the accuracy and completeness of these measurements, 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.

SAR Evaluation
Certificate of Compliance

APPLICANT: Rajant Corporation

Applicant Name and Address: Keith Sullivan
400 East King Street
Malvern, PA 19335

Test Location: MET Laboratories, Inc.
3162 Belick Street
Santa Clara, CA 95054
USA

EUT:	BreadCrumb CX1-3600	
Test Dates:	July 5th- July 8th	
RF exposure environment:	General Population / Uncontrolled Exposure Environment	
RF exposure category:	Body Worn	
Power supply:	12V DC Battery	
Antenna:	External	
Production/prototype:	Production	
Modes of operation tested:	3.6 GHz (802.11n)	
Modulation tested:	OFDM	
Duty Cycle tested:	3.6 GHz 802.11n → 98%	
TX Range:	3650MHz- 3700MHz	
Max SAR Measured	**SAR 1g (W/kg)**	
	Phantom Flat Section (EUT with Belt Clip)	1.509

Asad Bajwa
Director, EMC

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1.0 INTRODUCTION

This measurement report demonstrates that Rajant CX1-3600 unit as described within this report complies with the Specific Absorption Rate (SAR) RF exposure requirements specified in ANSI/IEEE Std. C95.1-1999 and FCC 47 CFR §2.1093 for the Uncontrolled Exposure/General population environment. The test procedures described in IEEE 1528-2013, IEC 62209-2 and KDB 865664 were employed.

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 dosimetric assessment test report.

1.1 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).

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

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

$$\mathrm{SAR} = \sigma E^2 / \rho$$

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.

1.2 DESCRIPTION OF DEVICE UNDER TEST (EUT)

Applicant:	Rajant Corporation
Description of Test Item:	Rajant BreadCrumb CX1-3600 is a body worn PART 90Z wireless mesh networking device operating on 3650 MHz to 3700 MHz
Supply Voltage:	12V Battery
Antenna Type(s) Tested:	External
Accessories:	None
Modes of Operation:	802.11n 3.6 GHz (10MHz, 20MHz)
Duty Cycles:	98%
Application Type:	Evaluation for aggregated SAR levels
Exposure Category:	General Population / Uncontrolled Exposure Environment
FCC and IC Rule Part(s):	FCC 47 CFR §2.1093
Standards:	IEEE Std. 1528-2013, IEC 62209-2, KDB 865664

Table 1. Description of Device under Test

1.3 SAR MEASUREMENT SYSTEM

MET Laboratories, Inc SAR measurement facility utilizes the DASY4 Professional Dosimetric Assessment System (DASY™) manufactured by Schmid & Partner Engineering AG (SPEAG™) of Zurich, Switzerland for performing SAR compliance tests. 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 DAE4 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.

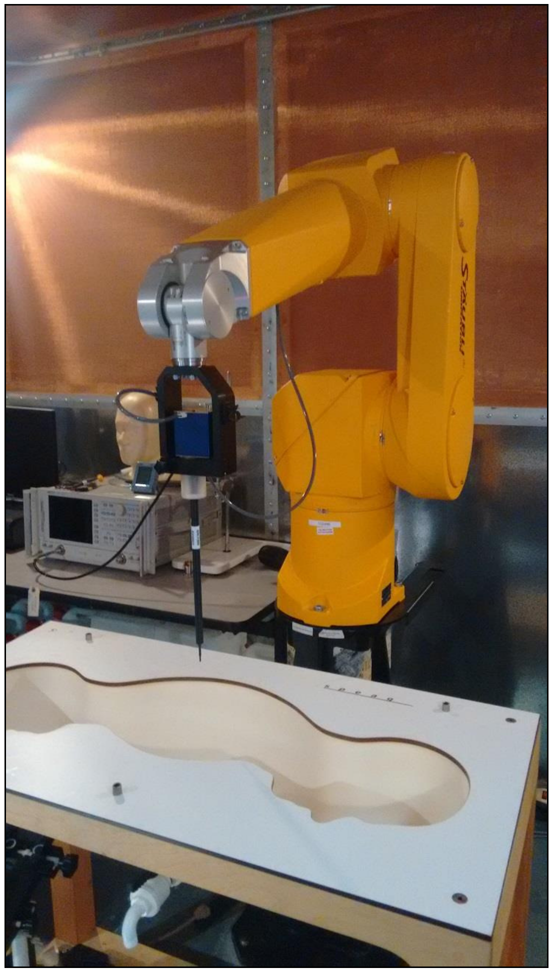


Figure 1. Staubli Robotic Arm

2.0 CONDUCTED POWER MEASUREMENT SUMMARY – FCC

CONDUCTED POWER MEASUREMENT RESULTS								
Channel	**BW (MHz)**	**Frequency (MHz)**	**Antenna 0 Power (dBm)**	**Antenna 0 Power (dBm)**	**Sum (dBm)**	**2+10log(2) (dB)**	**EIRP (dBm)**	**Limit (dBm)**
Low	20	3.6634	17.84	21.76	23.238	5.01029	28.2483	30
Mid	20	3.6784	18.6	21.67	23.411	5.01029	28.4213	30
High	20	3.6884	19.04	21.61	23.523	5.01029	28.5333	30
Low	10	3.6559	18.15	22.16	23.613	5.01029	28.6233	30
Mid	10	3.6734	18.72	21.88	23.592	5.01029	28.6023	30
High	10	3.6934	19.68	21.75	23.847	5.01029	28.8573	30

Table 2. Conducted Power Measurement Table

3.0 SAR MEASUREMENT SUMMARY – FCC

SAR BODY MEASUREMENT RESULTS							
Channel	**BW (MHz)**	**Frequency (MHz)**	**Position**	**Power Drift (%)**	**Measured SAR 1g (W/kg)**	**DC Corrected SAR 1g (W/kg)**	**Worst case tune-up corrected SAR 1g (W/kg)**
Low	20	3.6634	Belt Clip	-3.45	0.865	0.882	0.926
Mid	20	3.6784	Belt Clip	-1.23	1.340	1.366	1.434
High	20	3.6884	Belt Clip	-4.12	1.410	1.438	1.509
Low	10	3.6559	Belt Clip	-1.45	0.528	0.538	0.564
Mid	10	3.6734	Belt Clip	-2.76	0.877	0.894	0.938
High	10	3.6934	Belt Clip	-1.59	1.380	1.407	1.477

Table 3. 802.11n SAR-1 Body Measurement Results

SAR BODY MEASUREMENT RESULTS							
Channel	**BW (MHz)**	**Frequency (MHz)**	**Position**	**Power Drift (%)**	**Measured SAR 1g (W/kg)**	**DC Corrected SAR 1g (W/kg)**	**Worst case tune-up corrected SAR 1g (W/kg)**
Low	20	3.6634	Belt Clip	-3.45	0.681	0.694	0.728
Mid	20	3.6784	Belt Clip	-1.23	0.983	1.002	1.022
High	20	3.6884	Belt Clip	-4.12	1.012	1.032	1.052
Low	10	3.6559	Belt Clip	-1.45	0.495	0.504	0.529
Mid	10	3.6734	Belt Clip	-2.76	0.802	0.818	0.858
High	10	3.6934	Belt Clip	-1.59	1.017	1.037	1.088

Table 4. 802.11n SAR-2 Body Measurement Results

Note 1: Duty Cycle Corrected SAR = 100/98 x Measured SAR
Note 2: Power drift correction is only applicable if it is more than negative 5%
Note 3: Worst case tune up tolerance corrected SAR
= [(Conducted Power + 1dBm) / (Conducted Power)] x DC corrected SAR

SPLSR evaluation and Analysis

To calculate the separation ratio the following formula is used:

$(SAR1 + SAR2)^{1.5} / R$ where R is in mm must be ≤ 0.04

3.6634 MHz $(0.926 + 0.728)^{1.5} / 101 = 0.02$
3.6784 MHz $(1.434 + 1.022)^{1.5} / 101 = 0.03$
3.6884 MHz $(1.509 + 1.052)^{1.5} / 101 = 0.04$
3.6559 MHz $(0.564 + 0.529)^{1.5} / 101 = 0.01$
3.6734 MHz $(0.938 + 0.858)^{1.5} / 101 = 0.02$
3.6934 MHz $(1.477 + 1.088)^{1.5} / 101 = 0.04$

Per KDB 447498D01, when the sum of SAR is larger than the limit, SAR test exclusion is determined by the SAR sum to peak location separation ratio (SPLSR).

The simultaneous transmitting antennas in each operating mode and exposure condition combination must be considered one pair at a time to determine the SAR to peak location separation ratio to qualify for test exclusion.

The ratio is determined by $(SAR1 + SAR2)^{1.5} / R$ rounded to two decimal digits, and must be $\leq$ 0.04 for all antenna pairs in the configuration to qualify for 1g SAR exclusion.

SAR1 and SAR2 are the highest reported or estimated SAR for each antenna in the pair, and R is the separation distance between the peak SAR locations for the antenna pair in mm.

4.0 DETAILS OF SAR EVALUATION

The Rajant CX1-3600 device was determined to be compliant for localized Specific Absorption Rate based on the test provisions and conditions described below.

1. The EUT was tested for SAR on the flat section of the phantom with the belt clip.

2. OFDM signals were supplied to the antennas of each module at a power lever equal to that of normal operation.

3. Spectrum analyzer was used to measure the conducted output power before the SAR tests. The power drift measurement routine of the SAR system was used to determine if the power of the EUT stayed within the allowable limits.

4. The dielectric parameters of the simulated head and body fluid were measured prior to the evaluation using an 85070D Dielectric Probe Kit and an 8722D Network Analyzer.

5. The fluid and air temperature was measured prior to and after each SAR evaluation to ensure the temperature remained within ±2 dig C of the temperature of the fluid when the dielectric properties were measured.

6. During the SAR evaluations if a distribution produced several hotspots over the course of the area scan, each hotspot was evaluated separately.

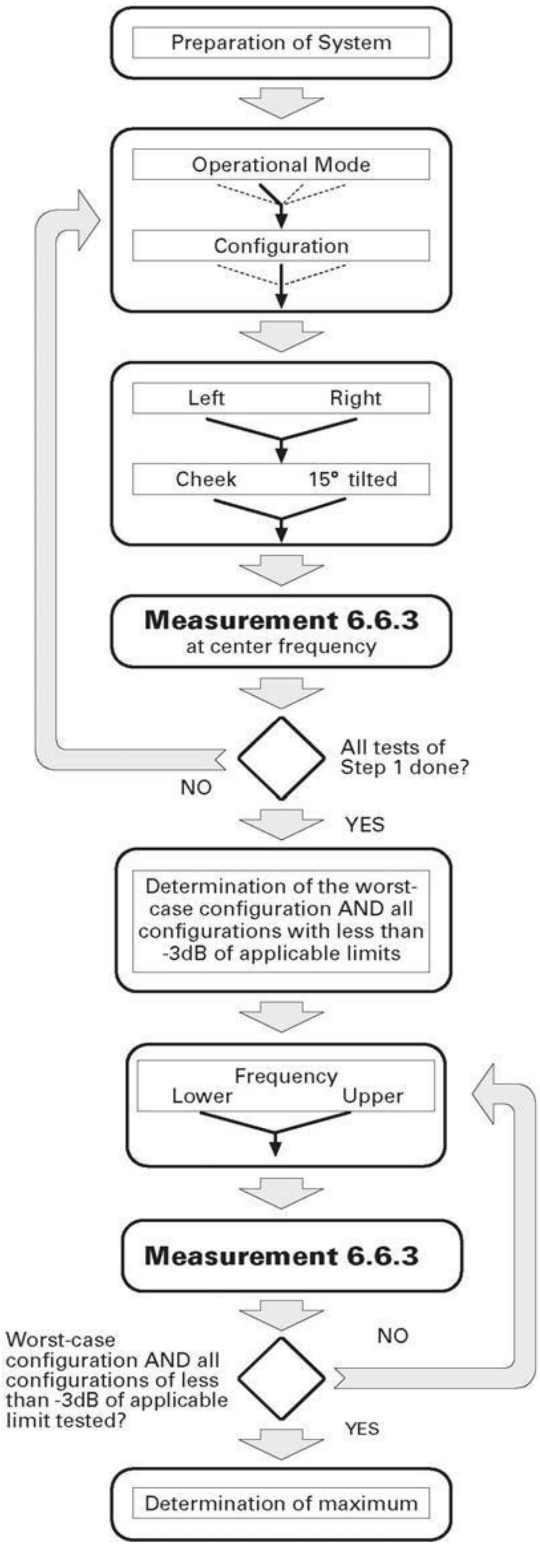
Figure 2. Rajant CX1-3600 Front

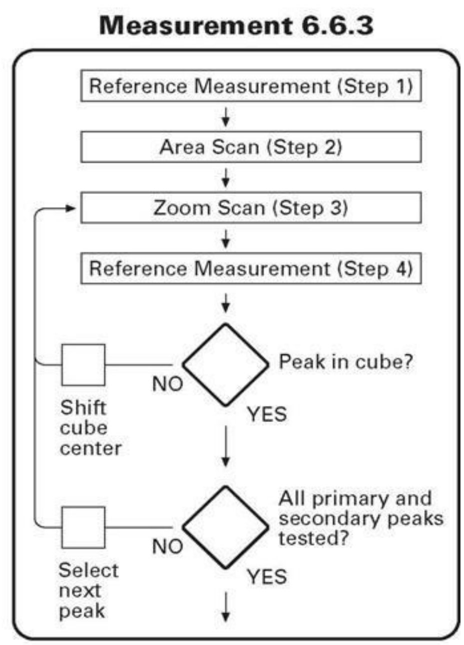
Figure 3. Rajant CX1-3600 Back

Figure 4. Rajant CX1-3600 with antenna separation illustrated

Figure 5. Rajant CX1-3600 with antenna separation illustrated

4.1 FLOW CHART OF THE RECOMMENDED PRACTICES AND PROCEDURES





4.2 EAR REFERENCE POINTS

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.

Figure 6. Front, back and side view of SAM Twin Phantom

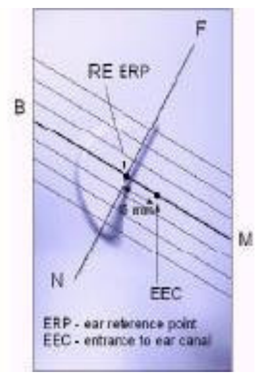


Figure 7. Side view of ERPs

4.3 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 (See Fig. 12.3). The test device reference point was than 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.

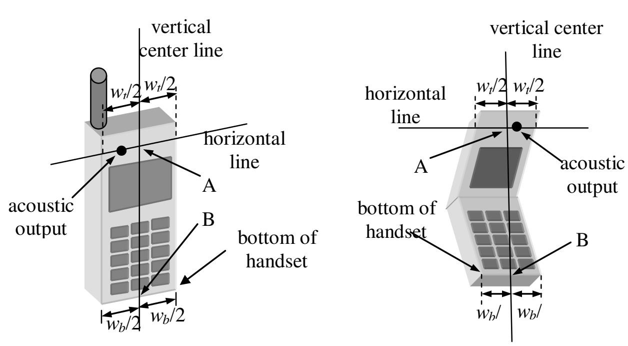


Figure 8. Handset Vertical Center & Horizontal Line Reference Points

4.4 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 hen rotated around the vertical centerline until the phone (horizontal line) was symmetrical was 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). See Figure 12.5).

Figure 9. Front, Side and Top View of Cheek/Touch Position

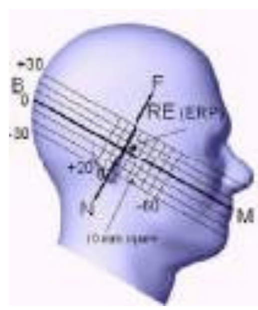


Figure 10. Side view with relevant markings

4.5 POSITIONING FOR EAR/15 DEGREE TILE

With the test device aligned in the Cheek/Touch Position:

1. 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.

2. The phone was then rotated around the horizontal line by 15 degree.

3. 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.

4.6 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.

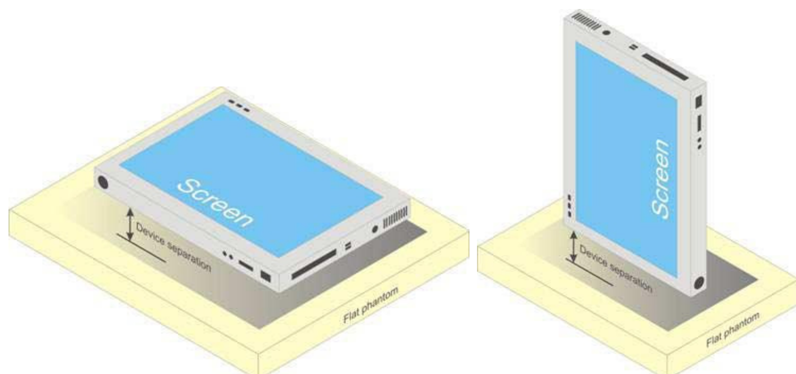


Figure 11. Illustration for Body Worn Positions.

4.7 EVALUATION PROCEDURES

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

1) For devices held to the ear during normal operation, both the left and right ear positions were evaluated using the SAM phantom.
2) For body-worn and face-held devices a planar phantom was used.

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.

An area scan was determined as follows:

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.

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.

A 1g and 10g spatial peak SAR was determined as follows:

For frequencies ≤4.5GHz 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 ≥4.5GHz 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.

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).

Z-Scan was determined as follows:

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.

4.8 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:

$$\mathrm{E-fieldprobes:} \qquad E_i = \sqrt{\frac{V_1}{Norm_i \cdot ConvF}}$$

$$\mathrm{H-fieldprobes:} \qquad H_i = \sqrt{V_i} \cdot \frac{a_{i0} + a_{i1} f + a_{i2} f^2}{f}$$

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

4.9 SAR SAFETY LIMITS

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

Table 4. SAR safety limits for FCC

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.

5.0 SYSTEM PERFORMANCE CHECK

Prior to the SAR evaluation a system check was performed in the planar section of the SAM phantom with a 3700MHz dipole. The dielectric parameters of the simulated body fluid were measured prior to the system performance check using an 85070D Dielectric Probe Kit and an 8722D Network Analyzer. A forward power of 100mW for 3700MHz was applied to the dipole and the system was verified to a tolerance of ±10%.

Test Date	Fluid Type (MHz)	SAR 1g (W/kg)		Permittivity Constant εr		Conductivity σ (mho/m)		Ambient Temp. (C)	Fluid Temp. (C)	Fluid Depth (cm)
		Calibrated Target	Measured	IEEE Target	Measured	IEEE Target	Measured			
7/5/2016	3700 Body	6.03 ±5%	6.32	51.1 ±5%	50.5	3.55 ±5%	3.41	23.0	22.0	≥15

Table 5. System performance check and body simulating fluid parameter check results

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

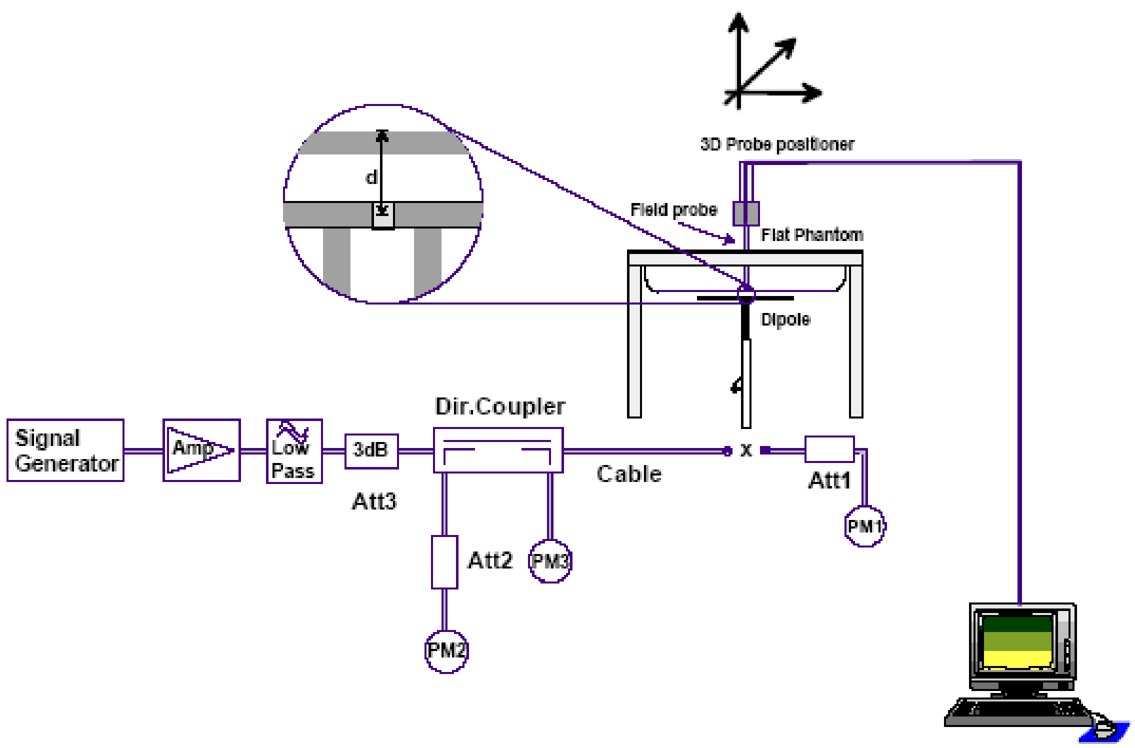


Figure 12. System performance check components

6.0 SIMULATED EQUIVALENT TISSUE

For the measurement of the field distribution inside the SAM phantom with DASY4, the phantom must be filled with 25 liters of homogeneous body simulating liquid. Target dielectric parameters for the body simulating liquid at 3700 MHz are defined in the standards for compliance testing (e.g CENELEC EN50361, IEEE P1528). For 3700 MHz range body tissue simulating fluids were obtained directly from SPEAG.

7.0 ROBOT SYSTEM SPECIFICATIONS

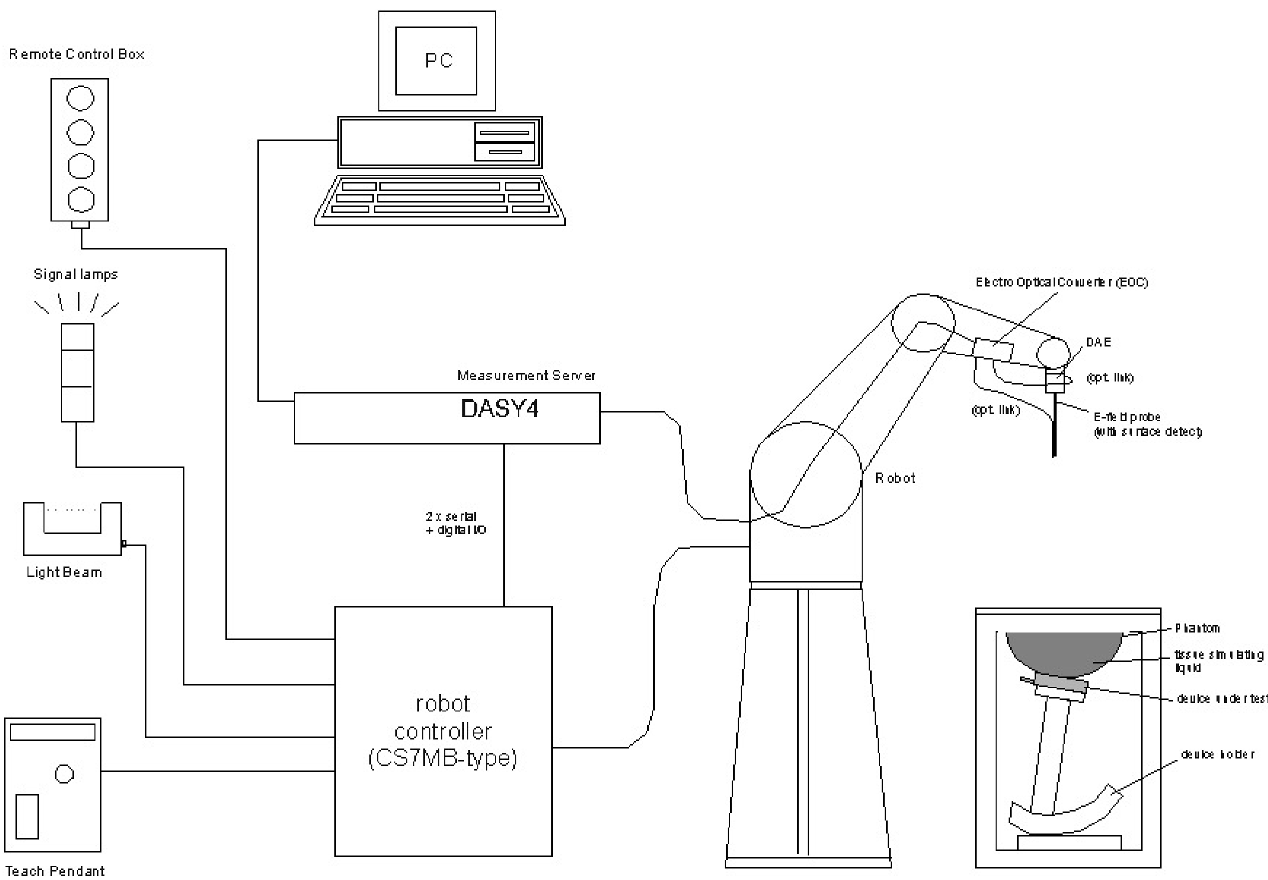


Figure 13. SAR Measurement System

7.1 SPECIFICATIONS

Positioner:

	Robot:	Staubli Unimation Corp. Robot Model: RX90
	Repeatability:	0.02 mm
	No. of axis:	6

7.2 DATA ACQUISITION ELECTRONIC (DAE) SYSTEM:

Cell Controller

	Processor:	Compaq Evo Clock Speed:2.4 GHz Operating System: Windows XP Professional

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 chipdisk; 64 MB RAM
	Connections:	COM1, COM2, DAE, Robot, Ethernet, Service Interface

E-Field Probe

	Model:	ET3DV6
	Serial No.:	1793
	Construction:	Triangular core fiber optic detection system
	Frequency:	10 MHz to 6 GHz
	Linearity:	± 0.2 dB (30 MHz to 3 GHz)

EX-Probe

	Model:	EX3DV4
	Serial No.	3511
	Construction:	Triangular core
	Frequency:	10 MHz to > 6 GHz
	Linearity:	± 0.2 dB (30 MHz to 3 GHz)

7.3 PHANTOM(S):

Validation & Evaluation Phantom

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

7.4 RX90BL ROBOT

The Stäubli RX90BL Robot is a standard high precision 6-axis robot with an arm extension for accommodating the data acquisition electronics (DAE).

7.5 ROBOT CONTROLLER

The CS7MB 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.

7.6 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.

Figure 14. Light beam switch

7.7 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 task 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.

Figure 15. Data acquisition electronics.

7.8 ELECTO-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.

Figure 16. Electro optical converter

7.9 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.

Figure 17. DASY4 measurement server

7.10 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 ±0.1mm.

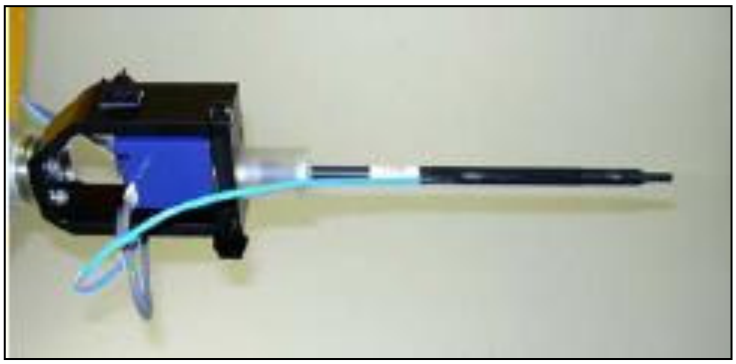


Figure 18. Electric field probe

7.11 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 λO and 0.6 λO respectively at frequencies of 824 MHz and above (λO = wavelength in air).

Figure 19. Specific anthropomorphic mannequin twin phantom

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.

7.12 PLANAR 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.

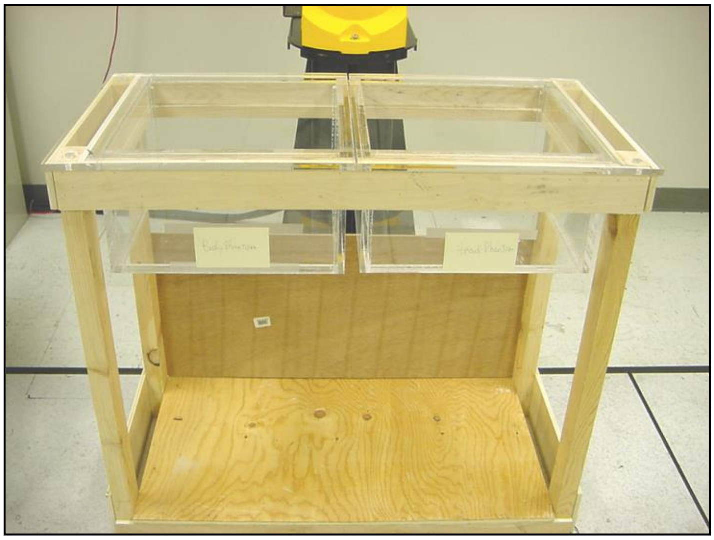


Figure 20. Planner phantom

7.13 VALIDATION PLANAR PHANTOM

The validation planar phantom is constructed of Plexiglas material with a 6.0 mm shell thickness for system validations at 450MHz and below. The validation planar phantom is mounted on the wooden table of the DASY4 system.

7.14 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 $\varepsilon = 3$ 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.

Figure 21. Device holder.

7.15 SYSTEM VALIDATION KITS

Power Capability: > 100 W (f < 1GHz); > 40 W (f > 1GHz)

Construction: Symmetrical dipole with l/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.

Frequency: 300, 450, 835, 1900, 2450 MHz, 3700MHz, 5-6GHz

Return loss: >20 dB at specified validation position

Dimensions:
300 MHz Dipole: Length: 396mm; Overall Height:430 mm; Diameter: 6 mm
450 MHz Dipole: Length: 270 mm; Overall Height: 347 mm; Diameter: 6 mm
835 MHz Dipole: Length: 161 mm; Overall Height: 270 mm; Diameter: 3.6 mm
1900 MHz Dipole: Length: 68 mm; Overall Height: 219 mm; Diameter: 3.6 mm
2450 MHz Dipole: Length: 51.5 mm; Overall Height: 300 mm; Diameter: 3.6 mm
3700 MHz Dipole: Length: 35 mm; Overall Height: 290mm; Diameter: 3.6 mm
5-6GHz Dipole: Length: 26.0 mm; Overall Height: 170 mm; Diameter: 3.6 mm

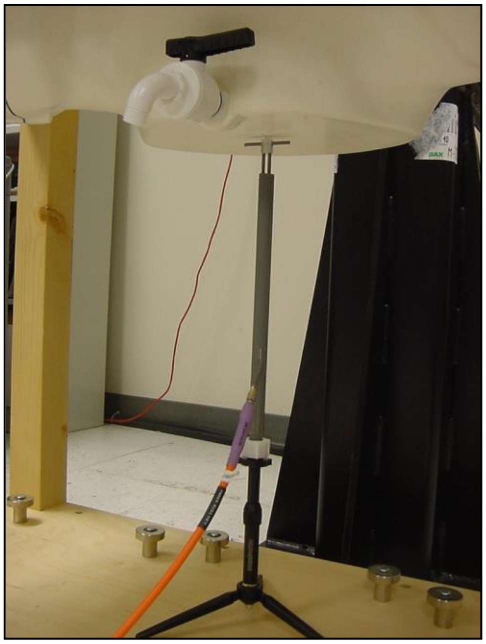


Figure 22. System validation using dipole antenna

8.0 TEST EQUIPMENT LIST

Test Equipment	Serial Number	Calibration Date	Due date
DASY4 System Robot RX90	FO3/SX19A1/A/01	N/A	N/A
EX3-7395	7395	3/31/2016	3/30/2017
DAE	584	10/20/2015	10/19/2016
D3700V2	1014	3/30/2016	3/29/2017
SAM Phantom V4.0C	N/A	N/A	N/A
Keysight Signal Generator	1S3905	3/30/2015	9/29/2016
EMCO Horn Antenna	1S2208	Functional Verification	
Agilent E4407B Spectrum Analyzer	1S3892	10/27/2015	10/26/2016
Agilent 8722D Network Analyzer	1S2272	9/3/2015	9/2/2016
Extech Power Supply (30 VDC)	4S3771	Functional Verification	
Mini-Circuits power amplifier	1S2447	Functional Verification	
Agilent power meter	1S2276	10/22/2015	10/21/2016
National Instrumenst USB power sensor	1S3838	6/29/2015	6/28/2017
Krytar Directional Coupler (1-20Ghz)	1S2034	Functional Verification	
HP High Temperature Dielectric Probe Kit 85070D Opt 1 (stand)	1T4366	04/30/2015	09/29/2016

Table 6. Test equipment list details

8.1 MEASUREMENT UNCERTANTIES

UNCERTAINTY ASSESSMENT 300MHz-3GHz

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	√3	0.7	0.7	1.9	1.9	N/A
Spherical isotropy of the probe	9.6	R	√3	0.7	0.7	3.9	3.9	N/A
Boundary effects	1.0	R	√3	1	1	4.8	4.8	N/A
Probe linearity	4.7	R	√3	1	1	2.7	2.7	N/A
Detection limit	1.0	R	√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	√3	1	1	0.5	0.5	N/A
Integration time	2.6	R	√3	1	1	0.8	0.8	N/A
RF ambient conditions	3.0	R	√3	1	1	0.43	0.43	N/A
Mech. constraints of robot	0.4	R	√3	1	1	0.2	0.2	N/A
Probe positioning	2.9	R	√3	1	1	1.7	1.7	N/A
Extrapolation & integration	1.0	R	√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	√3			2.9	2.9	N/A
Phantom and Setup								
Phantom uncertainty	4.0	R	√3	1	1	2.3	2.3	N/A
Liquid conductivity (target)	5.0	R	√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	√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	
Expanded Uncertainty (k=2) 95% Confidence Level						20.6	20.1	

Table 7. 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.

8.2 UNCERTAINTY FOR SYSTEM 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	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	

Table 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.

9.0 REFERENCES

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10.0 EUT TEST SETUP PHOTOS

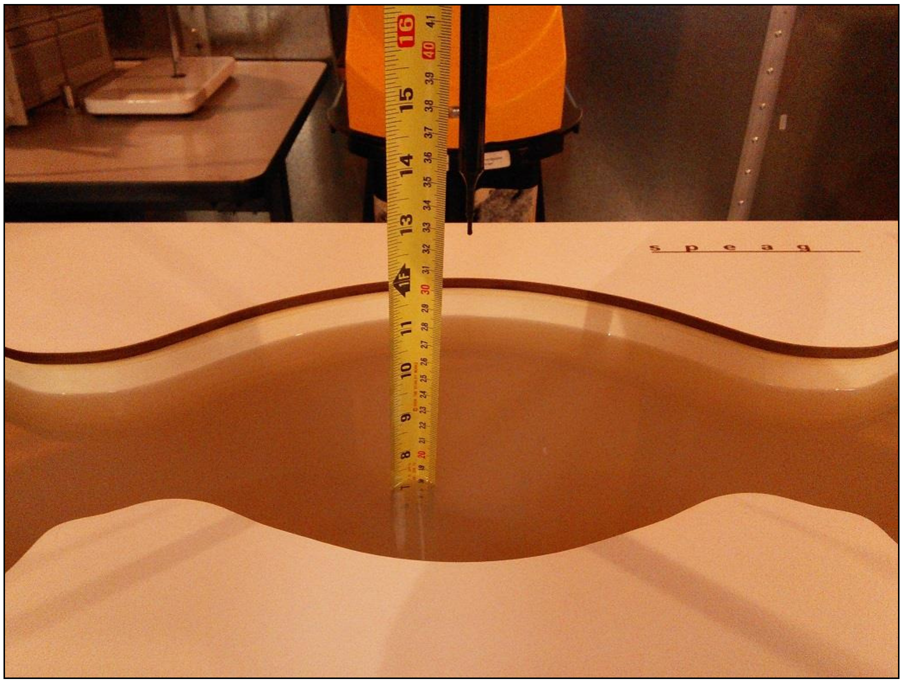

Figure 23. 3700 MHz body tissue simulating fluid

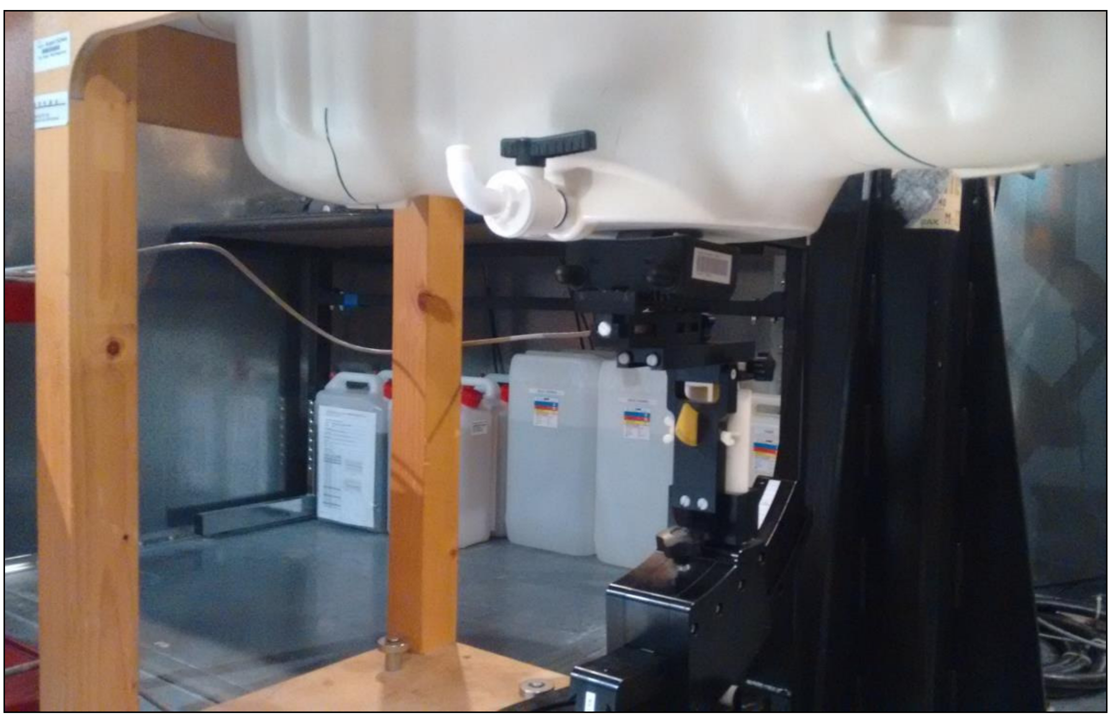

Figure 24. EUT under flat phantom center (EUT with belt clip)

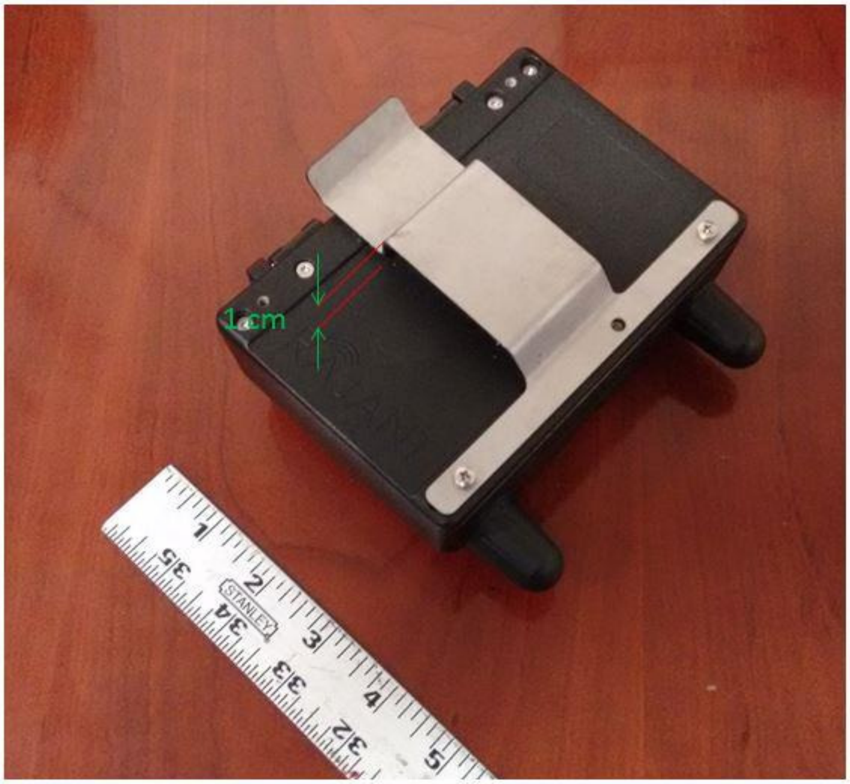

Figure 25. EUT with belt clip separation illustrated

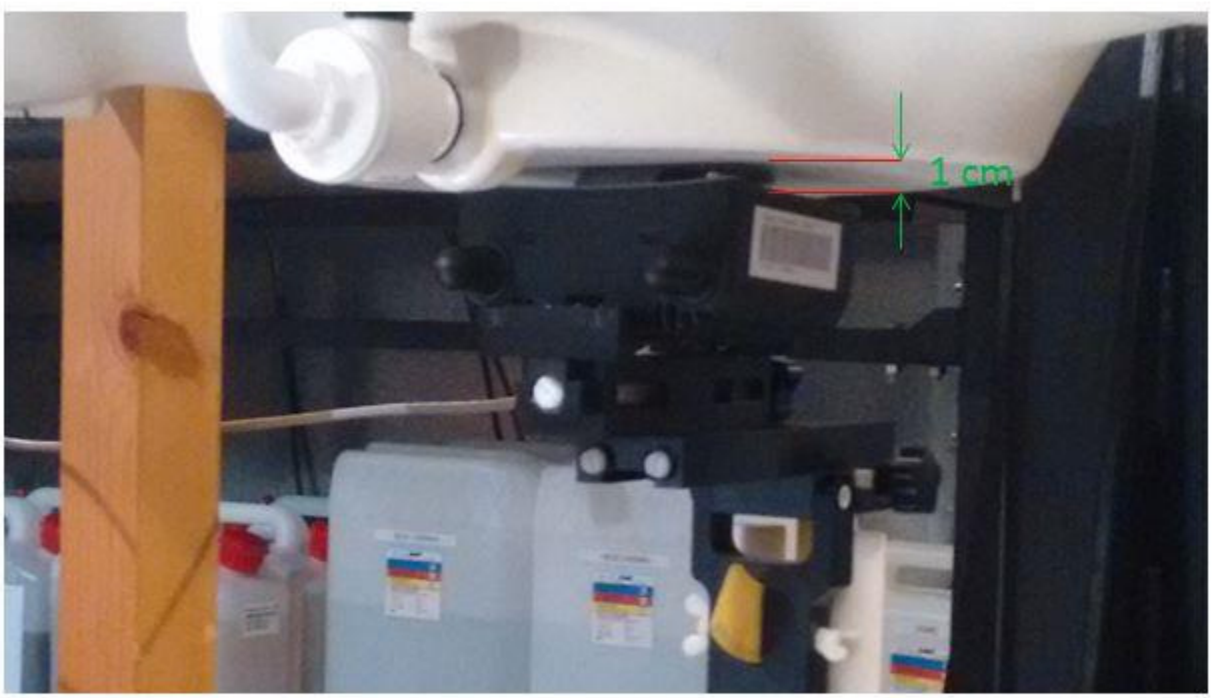

Figure 26. Close up showing 1 cm separation of EUT with phantom flat section

APPENDIX A

3700 MHz SAR MEASUREMENT DATA - FCC