# SAR EVALUATION REPORT

For

# Intel Corporation

2200 Mission College Blvd.,

Santa Clara, CA 95054, USA

**FCC ID: 2AB8ZND23**
**IC: 1000X-ND23**

| **Report Type:** | **Product Type:** |
|---|---|
| Original Report | Smart Watch |

| | |
|---|---|
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| **Report Number:** | R1611223-SAR |
| **Report Date:** | 2016-12-12 |
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| Summary of Test Results | | | |
|---|---|---|---|
| Rule Part(s): | FCC §2.1093, ISED RSS-102, Issue 5 | | |
| Test Procedure(s): | IEEE 1528: 2013, KDB 248227, KDB 447498,<br>KDB 865664, IEC 62209-2: 2010 | | |
| Device Category:<br>Exposure Category: | Portable Device<br>General Population/Uncontrolled Exposure | | |
| Device Type: | Portable Device | | |
| Modulation Type: | CCK, DSSS, OFDM, GFSK, QPSK, 8DPSK | | |
| TX Frequency Range: | 802.11b/g/n: 2412-2462 MHz<br>Bluetooth: 2402-2480 MHz<br>BLE: 2402-2480 MHz | | |
| Maximum Average Conducted Power: | Bluetooth: 9.22 dBm (Peak) | | 2.4 GHz |
| | BLE: 8.39 dBm (Peak) | | 2.4 GHz |
| | 802.11b/g/n: 15.46 dBm (Ave) | | 2.4 GHz |
| Antenna Type(s) Tested: | Internal Antennas | | |
| Body-Worn Accessories: | Watch Belt | | |
| Face-Head Accessories: | - | | |
| Battery Type (s) Tested: | Li-Polymer 3.8V/400mAh | | |
| Max. SAR Level (s) Measured: | **Level (W/Kg)** | **Position** | **Operational Mode** |
| | 0.0636 | Front, Speaker on | 2.4 GHz |
| | 0.3087 | Rear, Wrist-worn | |

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# DOCUMENT REVISION HISTORY

| Revision Number | Report Number | Description of Revision | Date of Revision |
|---|---|---|---|
| 0 | R1611223-SAR | Original Report | 2016-12-12 |

# 1 General Description

## 1.1 Product Description for Equipment under Test (EUT)

This test and measurement report was prepared on behalf of *Intel Corporation.*, and their product model: *UW63100,* FCC ID: 2AB8ZND23, IC: 1000X-ND23 or the "EUT" as referred to in this report. It is a smart watch with Wi-Fi and Bluetooth/BLE functions.

## 1.2 EUT Technical Specification

| Item | Description | |
|---|---|---|
| Modulation | CCK, DSSS, OFDM, GFSK, QPSK, 8PSK | |
| Frequency Range | 802.11b/g/n: 2412-2462 MHz<br>Bluetooth: 2402-2480 MHz<br>BLE: 2402-2480 MHz | |
| Maximum Conducted Power Tested: | Bluetooth: 9.22 dBm (Peak) | 2.4 GHz |
| | BLE: 8.39 dBm (Peak) | 2.4 GHz |
| | 802.11b/g/n: 15.46 dBm (Ave.) | 2.4 GHz |
| Power Source | Li-Polymer 3.8V/400mAh | |
| Normal Operation | Speaker on, Wrist-worn with accessories | |

## 1.3 Test Facility Registrations

BACLs test facilities that are used to perform Radiated and Conducted Emissions tests are currently recognized by the Federal Communications Commission as Accredited with NIST Designation Number US1129.

BACL's test facilities that are used to perform Radiated and Conducted Emissions tests are currently registered with Industry Canada under Registration Numbers: 3062A-1, 3062A-2, and 3062A-3.

BACL is a Chinese Taipei Bureau of Standards Metrology and Inspection (BSMI) validated Conformity Assessment Body (CAB), under Appendix B, Phase I Procedures of the APEC Mutual Recognition Arrangement (MRA). BACL's BSMI Lab Code Number is: SL2-IN-E-1002R

BACL's test facilities that are used to perform AC Line Conducted Emissions, Telecommunications Line Conducted Emissions, Radiated Emissions from 30 MHz to 1 GHz, and Radiated Emissions from 1 GHz to 6 GHz are currently recognized as Accredited in accordance with the Voluntary Control Council for Interference [VCCI] Article 15 procedures under Registration Number A-0027.

## 1.4 Test Facility Accreditations

Bay Area Compliance Laboratories Corp. (BACL) is:

2017 ***An independent, 3rd-Party, Commercial Test Laboratory accredited to ISO/IEC 17025:2005 by A2LA (Test Laboratory Accreditation Certificate Number 3297.02)*****,** in the fields of: Electromagnetic Compatibility and Telecommunications. Unless noted by an Asterisk (*) in the Compliance Matrix (See Section 3 of this Test Report), BACL's ISO/IEC 17025:2005 Scope of Accreditation includes all of the Test Method Standards and/or the Product Family Standards detailed in this Test Report..

BACL's ISO/IEC 17025:2005 Scope of Accreditation includes a comprehensive suite of EMC Emissions, EMC Immunity, Radio, RF Exposure, Safety and wireline Telecommunications test methods applicable to a wide range of product categories. These product categories include Central Office Telecommunications Equipment [including NEBS – Network Equipment Building Systems], Unlicensed and Licensed Wireless and RF devices, Information Technology Equipment (ITE); Telecommunications Terminal Equipment (TTE); Medical Electrical Equipment; Industrial, Scientific and Medical Test Equipment; Professional Audio and Video Equipment; Industrial and Scientific Instruments and Laboratory Apparatus; Cable Distribution Systems, and Energy Efficient Lighting.

B- ***A Product Certification Body accredited to ISO/IEC 17065:2012 by A2LA (Product Certification Body Accreditation Certificate Number 3297.03)*** to certify

- For the USA (Federal Communications Commission):
  - 1- All Unlicensed radio frequency devices within FCC Scopes A1, A2, A3, and A4;
  - 2- All Licensed radio frequency devices within FCC Scopes B1, B2, B3, and B4;
  - 3- All Telephone Terminal Equipment within FCC Scope C.
- For the Canada (Industry Canada):
  - 1 All Scope 1-Licence-Exempt Radio Frequency Devices;
  - 2 All Scope 2-Licensed Personal Mobile Radio Services;
  - 3 All Scope 3-Licensed General Mobile & Fixed Radio Services;
  - 4 All Scope 4-Licensed Maritime & Aviation Radio Services;
  - 5 All Scope 5-Licensed Fixed Microwave Radio Services
  - 6 All Broadcasting Technical Standards (BETS) in the Category I Equipment Standards List.
- For Singapore (Info-Communications Development Authority (IDA)):
  - 1 All Line Terminal Equipment: All Technical Specifications for Line Terminal Equipment – Table 1 of IDA MRA Recognition Scheme: 2011, Annex 2
  - 2. All Radio-Communication Equipment: All Technical Specifications for Radio-Communication Equipment – Table 2 of IDA MRA Recognition Scheme: 2011, Annex 2
- For the Hong Kong Special Administrative Region:
  - 1 All Radio Equipment, per KHCA 10XX-series Specifications;
  - 2 All GMDSS Marine Radio Equipment, per HKCA 12XX-series Specifications;
  - 3 All Fixed Network Equipment, per HKCA 20XX-series Specifications.
- For Japan:
  - 1 MIC Telecommunication Business Law (Terminal Equipment):
    - All Scope A1 – Terminal Equipment for the Purpose of Calls;
    - All Scope A2 – Other Terminal Equipment
  - 2 Radio Law (Radio Equipment):
    - All Scope B1 – Specified Radio Equipment specified in Article 38-2-2, paragraph 1, item 1 of the Radio Law
    - All Scope B2 – Specified Radio Equipment specified in Article 38-2-2, paragraph 1, item 2 of the Radio Law
    - All Scope B3 – Specified Radio Equipment specified in Article 38-2-2, paragraph 1, item 3 of the Radio Law

C- ***A Product Certification Body accredited to ISO/IEC 17065:2012 by A2LA (Product Certification Body Accreditation Certificate Number 3297.01)*** to certify Products to USA's Environmental Protection Agency (EPA) ENERGY STAR Product Specifications for:

2017 Electronics and Office Equipment:
- for Telephony (ver. 3.0)
- for Audio/Video (ver. 3.0)
- for Battery Charging Systems (ver. 1.1)
- for Set-top Boxes & Cable Boxes (ver. 4.1)
- for Televisions (ver. 6.1)
- for Computers (ver. 6.0)
- for Displays (ver. 6.0)
- for Imaging Equipment (ver. 2.0)
- for Computer Servers (ver. 2.0)

2017 Commercial Food Service Equipment
- for Commercial Dishwashers (ver. 2.0)
- for Commercial Ice Machines (ver. 2.0)
- for Commercial Ovens (ver. 2.1)
- for Commercial Refrigerators and Freezers

2017 Lighting Products
- For Decorative Light Strings (ver. 1.5)
- For Luminaires (including sub-components) and Lamps (ver. 1.2)
- For Compact Fluorescent Lamps (CFLs) (ver. 4.3)
- For Integral LED Lamps (ver. 1.4)

4 Heating, Ventilation, and AC Products
- for Residential Ceiling Fans (ver. 3.0)
- for Residential Ventilating Fans (ver. 3.2)

5 Other
- For Water Coolers (ver. 3.0)

***D. A NIST Designated Phase-I and Phase-II Conformity Assessment Body (CAB) for the following economies and regulatory authorities under the terms of the stated MRAs/Treaties:***

- Australia: ACMA (Australian Communication and Media Authority) – APEC Tel MRA –Phase I;
- Canada: (Industry Canada – IC) Foreign Certification Body – FCB – APEC Tel MRA –Phase I & Phase II;
- Chinese Taipei (Republic of China – Taiwan):
  - BSMI (Bureau of Standards, Metrology and Inspection) APEC Tel MRA –Phase I;
  - NCC (National Communications Commission) APEC Tel MRA –Phase I;
- European Union:
  - Radio & Teleterminal Equipment (R&TTE) Directive 1995/5/EC
    US –EU EMC & Telecom MRA CAB
- Hong Kong Special Administrative Region: (Office of the Telecommunications Authority – OFTA)
  APEC Tel MRA –Phase I & Phase II
- Israel – US-Israel MRA Phase I
- Republic of Korea (Ministry of Communications – Radio Research Laboratory) APEC Tel MRA –Phase I
- Singapore: (Infocomm Development Authority – IDA) APEC Tel MRA –Phase I & Phase II;
- Japan: VCCI – Voluntary Control Council for Interference US-Japan Telecom Treaty VCCI Side Letter-
- USA:
  - ENERGY STAR Recognized Test Laboratory – US EPA
  - Telecommunications Certification Body (TCB) – US FCC;
- Vietnam: APEC Tel MRA –Phase I;

# 2 Reference, Standards and Guidelines

**FCC:**

The Report and Order requires routine SAR evaluation prior to equipment authorization of portable transmitter devices, including portable telephones. For consumer products, the applicable limit is 1.6 Mw/g as recommended by the ANSI/IEEE standard C95.1-1992 [6] for an uncontrolled environment (Paragraph 65). According to the Supplement C of OET Bulletin 65 "Evaluating Compliance with FCC Guide-lines for Human Exposure to Radio frequency Electromagnetic Fields", released on Jun 29, 2001 by the FCC, the device should be evaluated at maximum output power (radiated from the antenna) under "worst-case" conditions for normal or intended use, incorporating normal antenna operating positions, device peak performance frequencies and positions for maximum RF energy coupling.

This report describes the methodology and results of experiments performed on wireless data terminal. The objective was to determine if there is RF radiation and if radiation is found, what is the extent of radiation with respect to safety limits. SAR (Specific Absorption Rate) is the measure of RF exposure determined by the amount of RF energy absorbed by human body (or its parts) – to determine how the RF energy couples to the body or head which is a primary health concern for body worn devices. The limit below which the exposure to RF is considered safe by regulatory bodies in North America is 1.6 Mw/g average over 1 gram of tissue mass.

**CE:**

The CE requires routine SAR evaluation prior to equipment authorization of portable transmitter devices, including portable telephones. For consumer products, the applicable limit is 2 Mw/g as recommended by the EN50360 for an uncontrolled environment. According to the Standard, the device should be evaluated at maximum output power (radiated from the antenna) under "worst-case" conditions for normal or intended use, incorporating normal antenna operating positions, device peak performance frequencies and positions for maximum RF energy coupling.

This report describes the methodology and results of experiments performed on wireless data terminal. The objective was to determine if there is RF radiation and if radiation is found, what is the extent of radiation with respect to safety limits? SAR (Specific Absorption Rate) is the measure of RF exposure determined by the amount of RF energy absorbed by human body (or its parts) – to determine how the RF energy couples to the body or head which is a primary health concern for body worn devices. The limit below which the exposure to RF is considered safe by regulatory bodies in Europe is 2 mW/g average over 10 gram of tissue mass.

The test configurations were laid out on a specially designed test fixture to ensure the reproducibility of measurements. Each configuration was scanned for SAR. Analysis of each scan was carried out to characterize the above effects in the device.

## 2.1 SAR Limits

FCC/IC Limit

| 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 1 g of tissue) | 1.60 | 8.0 |
| Spatial Peak (hands/wrists/feet/ankles averaged over 10 g) | 4.0 | 20.0 |

CE Limit

| 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 10 g of tissue) | 2.0 | 10 |
| Spatial Peak (hands/wrists/feet/ankles averaged over 10 g) | 4.0 | 20.0 |

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

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

General Population/Uncontrolled environments Spatial Peak limit 4.0 W/kg (FCC) & 4.0 W/kg (CE) applied to the EUT.

# 3 Equipment List and Calibration

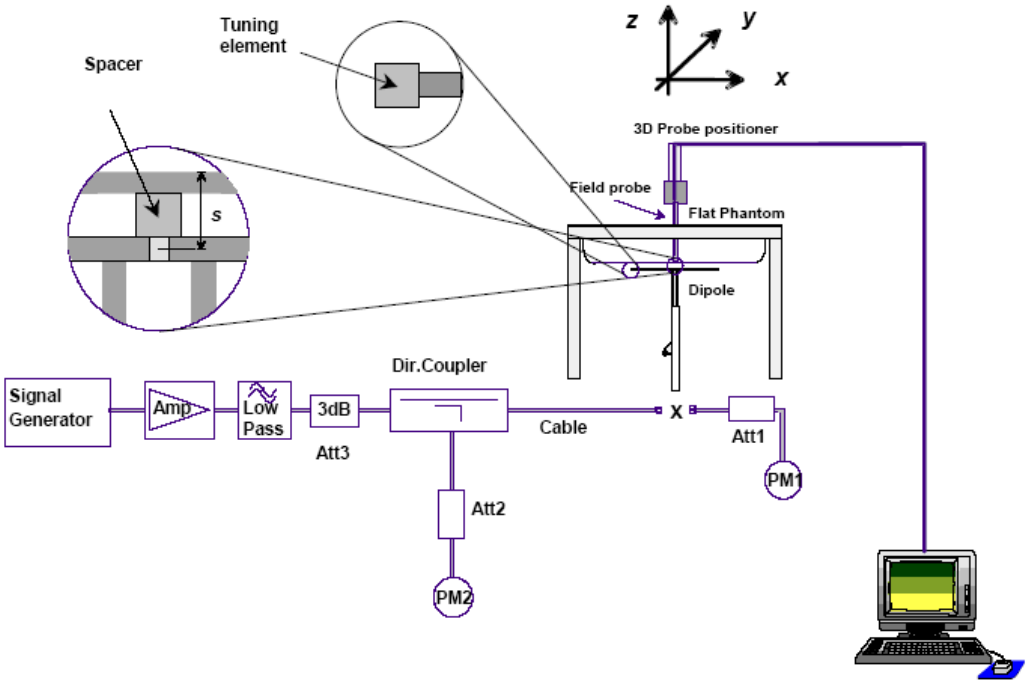
| Type/Model | Cal. Due Date | S/N |
|---|---|---|
| DASY4 Professional Dosimetric System | N/A | N/A |
| Robot RX60L | N/A | CS7MBSP / 467 |
| Robot Controller | N/A | F01/5J72A1/A/01 |
| Dell Computer Dimension 3000 | N/A | N/A |
| SPEAG EDC3 | N/A | N/A |
| SPEAG DAE4 | 2017-09-21 | 530 |
| DASY4 Measurement Server | N/A | 1176 |
| SPEAG E-Field Probe EX3DV4 | 2017-09-23 | 3619 |
| Antenna, Dipole, D-2450-S-1 | 2017-08-19 | BCL-141 |
| SPEAG Twin SAM Phantom | N/A | TP-1032 |
| Muscle Equivalent Matter (2450 MHz) | Each Time | N/A |
| Head Equivalent Matter (2450 MHz) | Each Time | N/A |
| Agilent, Spectrum Analyzer E4440A | 2017-01-19 | US45303156 |
| Mini Circuits, AMPLIFIER ZVA-183-S | 2017-11-08 | 460 |
| Power Sensor Agilent E9304A | 2017-08-31 | MY54280008 |
| Power Sensor Agilent E9304A | 2017-08-31 | MY54280006 |
| Power Meter Amplifier Research | 2017-09-01 | PM2002 |
| Dielectric Probe Kit HP85070A | N/A | US99360201 |
| HP, Signal Generator, 83650B | 2017-09-09 | 3614A00276 |
| Mini Circuits, AMPLIFIER ZVE-8G+ | 2016-11-05 | N605601404 |

# 4 SAR Measurement System Verification

## 4.1 System Accuracy Verification

SAR system verification is required to confirm measurement accuracy. The system verification must be performed for each frequency band. A system verification must be performed before each series of SAR measurements.

## 4.2 SAR System Verification Setup and procedure




**Procedure:**

1) The SAR system verification measurements were performed in the flat section of TWIN SAM or flat phantom with shell thickness of 2±0.2mm filled with head or body liquid.

2) The depth of liquid in phantom must be ≥15 cm for SAR measurement less than 3 GHz and ≥10 cm for SAR measurement above 3 GHz.

3) The dipole was mounted below the center of flat phantom, and oriented parallel to the Y-Axis. The standard measurement distance is 15mm (below 1 GHz) and 10mm (above 1 GHz) from dipole center to the liquid surface.

4) The dipole input power was 250 mW or 100 mW.

5) The SAR results are normalized to 1 Watt input power.

6) Compared the normalized the SAR results to the dipole calibration results.

## 4.3 Liquid and System Validation

| Date | Simulant | Freq. [MHz] | Parameters | Liquid Temp [ºC] | Target Value | Measured Value | Deviation [%] | Limits [%] |
|---|---|---|---|---|---|---|---|---|
| 2016-12-08 | Body | 2450 | εr | 23 | 52.7 | 51.6 | -2.09 | ± 5 |
| | | | σ | 23 | 1.95 | 1.97 | 1.03 | ± 5 |
| | | | 1g SAR | 23 | 56.519 | 55.2 | -2.33 | ± 10 |

| Date | Simulant | Freq. [MHz] | Parameters | Liquid Temp [ºC] | Target Value | Measured Value | Deviation [%] | Limits [%] |
|---|---|---|---|---|---|---|---|---|
| 2016-12-09 | Head | 2450 | εr | 23 | 39.2 | 38.9 | -0.77 | ± 5 |
| | | | σ | 23 | 1.8 | 1.81 | 0.56 | ± 5 |
| | | | 1g SAR | 23 | 52.985 | 54.5 | 2.86 | ± 10 |

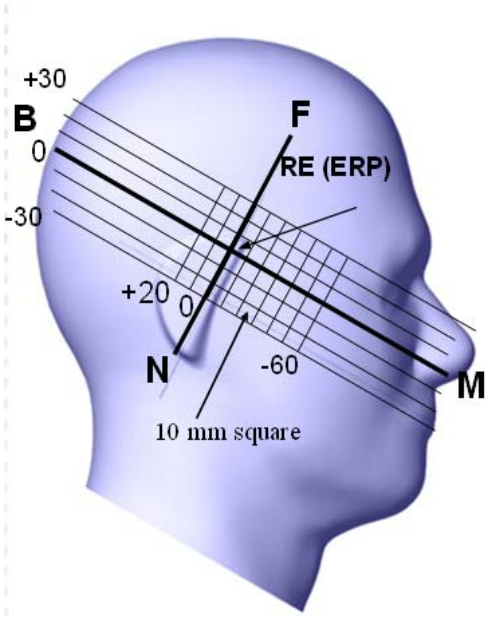
*$\varepsilon r$ = relative permittivity, $\sigma$ = conductivity and $\rho$=1000 kg/m$^3$*

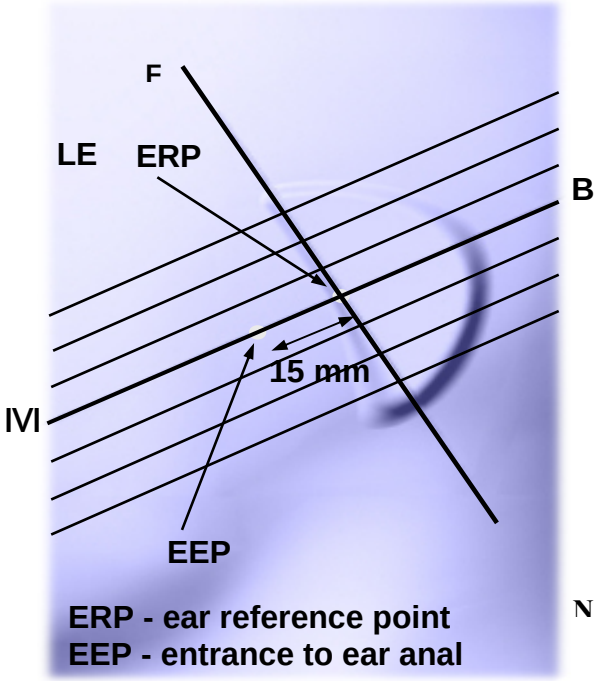
# 5 EUT Test Strategy and Methodology

## 5.1 Test Positions for Device Operating Next to a Person's Ear

This category includes most wireless handsets with fixed, retractable or internal antennas located toward the top half of the device, with or without a foldout, sliding or similar keypad cover. The handset should have its earpiece located within the upper ¼ of the device, either along the centerline or off-centered, as perceived by its users. This type of handset should be positioned 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" should be located at the same level as the center of the earpiece region. The "vertical centerline" should bisect the front surface of the handset at its top and bottom edges. An "ear reference point" is located on the outer surface of the head phantom on each ear spacer. It is located 1.5 cm above the center of the ear canal entrance in the "phantom reference plane" defined by the three lines joining the center of each "ear reference point" (left and right) and the tip of the mouth.

A handset should be initially positioned with the earpiece region pressed against the ear spacer of a head phantom. For the SCC-34/SC-2 head phantom, the device should be positioned parallel to the "N-F" line defined along the base of the ear spacer that contains the "ear reference point". For interim head phantoms, the device should be positioned parallel to the cheek for maximum RF energy coupling. The "test device reference point" is aligned to the "ear reference point" on the head phantom and the "vertical centerline" is aligned to the "phantom reference plane". This is called the "initial ear position". While maintaining these three alignments, the body of the handset is gradually adjusted to each of the following positions for evaluating SAR:



## 5.2 Cheek/Touch Position

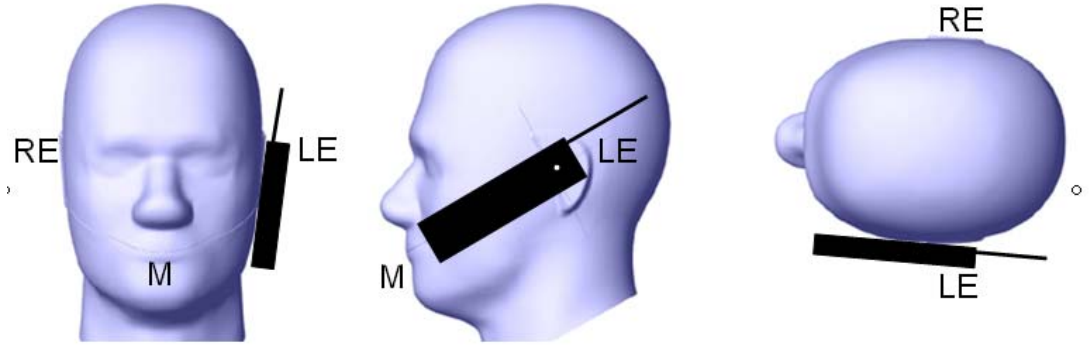
The device is brought toward the mouth of the head phantom by pivoting against the "ear reference point" or along the "N-F" line for the SCC-34/SC-2 head phantom.

This test position is established:

- When any point on the display, keypad or mouthpiece portions of the handset is in contact with the phantom.
- (or) When any portion of a foldout, sliding or similar keypad cover opened to its intended self-adjusting normal use position is in contact with the cheek or mouth of the phantom.

For existing head phantoms – when the handset loses contact with the phantom at the pivoting point, rotation should continue until the device touches the cheek of the phantom or breaks its last contact from the ear spacer.

**Cheek /Touch Position**




## 5.3 Ear/Tilt Position

With the handset aligned in the "Cheek/Touch Position":

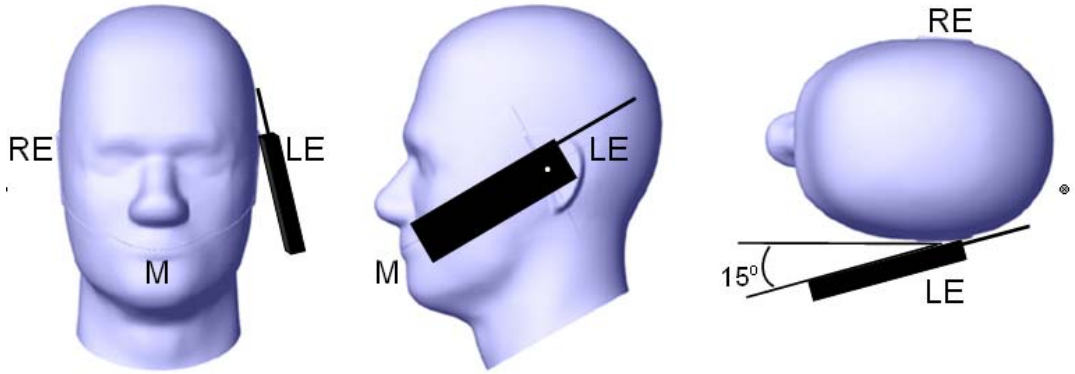
1) If the earpiece of the handset is not in full contact with the phantom's ear spacer (in the "Cheek/Touch position") and the peak SAR location for the "Cheek/Touch" position is located at the ear spacer region or corresponds to the earpiece region of the handset, the device should be returned to the "initial ear position" by rotating it away from the mouth until the earpiece is in full contact with the ear spacer.

2) (otherwise) The handset should be moved (translated) away from the cheek perpendicular to the line passes through both "ear reference points" (note: one of these ear reference points may not physically exist on a split head model) for approximate 2-3 cm. While it is in this position, the device handset is tilted away from the mouth with respect to the "test device reference point" until the inside angle between the vertical centerline on the front surface of the phone and the horizontal line passing through the ear reference point is by 15 80°. After the tilt, it is then moved (translated) back toward the head perpendicular to the line passes through both "ear reference points" until the device touches the phantom or the ear spacer. If the antenna touches the head first, the positioning process should be repeated with a tilt angle less than 15 80° so that the device and its antenna would touch the phantom simultaneously. This test position may require a device holder or positioner to achieve the translation and tilting with acceptable positioning repeatability.

If a device is also designed to transmit with its keypad cover closed for operating in the head position, such positions should also be considered in the SAR evaluation. The device should be tested on the left and right side of the head phantom in the "Cheek/Touch" and "Ear/Tilt" positions. When applicable, each configuration should be tested with the antenna in its fully extended and fully retracted positions. These test configurations

should be tested at the high, middle and low frequency channels of each operating mode; for example, AMPS, CDMA, and TDMA. If the SAR measured at the middle channel for each test configuration (left, right, Cheek/Touch, Tile/Ear, extended and retracted) is at least 2.0 dB lower than the SAR limit, testing at the high and low channels is optional for such test configuration(s). If the transmission band of the test device is less than 10 MHz, testing at the high and low frequency channels is optional.

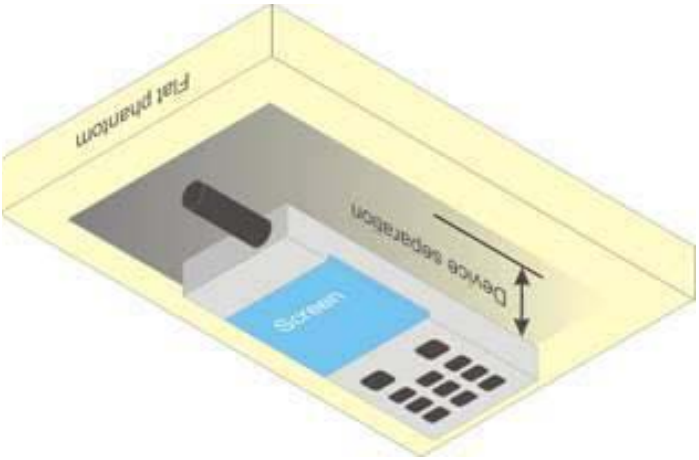
**Ear /Tilt 15$^{o}$ Position**



## 5.4 Test positions for body-worn and other configurations

Body-worn operating configurations should be tested with the belt-clips and holsters attached to the device and positioned against a flat phantom in normal use configurations. Devices with a headset output should be tested with a headset connected to the device. When multiple accessories that do not contain metallic components are supplied with the device, the device may be tested with only the accessory that dictates the closest spacing to the body. When multiple accessories that contain metallic components are supplied with the device, the device must be tested with each accessory that contains a unique metallic component. If multiple accessories share an identical metallic component (e.g., the same metallic belt-clip used with different holsters with no other metallic components), only the accessory that dictates the closest spacing to the body must be tested.

Body-worn accessories may not always be supplied or available as options for some devices that are intended to be authorized for body-worn use. A separation distance of 1.5 cm between the back of the device and a flat phantom is recommended for testing body-worn SAR compliance under such circumstances. Other separation distances may be used, but they should not exceed 2.5 cm. In these cases, the device may use body-worn accessories that provide a separation distance greater than that tested for the device provided however that the accessory contains no metallic components.




## 5.5 SAR Evaluation Procedure

The evaluation was performed with the following procedure:

**Step 1:** Measurement of the SAR value at a fixed location above the ear point or central position was used as a reference value for assessing the power drop. The SAR at this point is measured at the start of the test and then again at the end of the testing.

**Step 2:** The SAR distribution at the exposed side of the head was measured at a distance of 4 mm from the inner surface of the shell. The area covered the entire dimension of the head or EUT and the horizontal grid spacing was 15 mm x 15 mm. Based on these data, the area of the maximum absorption was determined by line interpolation. The first Area Scan covers the entire dimension of the EUT to ensure that the hotspot was correctly identified.

**Step 3**: Around this point, a volume of 30 mm x 30 mm x 21 mm was assessed by measuring 5 x 5 x 7 points. On the basis of this data set, the spatial peak SAR value was evaluated under the following procedure:

1. The data at the surface were extrapolated, since the center of the dipoles is 1.2 mm away from the tip of the probe and the distance between the surface and the lowest measuring point is 1.3 mm. The extrapolation was based on a least square algorithm. A polynomial of the fourth order was calculated through the points in z-axes. This polynomial was then used to evaluate the points between the surface and the probe tip.

2. The maximum interpolated value was searched with a straightforward algorithm. Around this maximum the SAR values averaged over the spatial volumes (1 g or 10 g) were computed by the 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 integrated with the trapezoidal-algorithm. One thousand points (10 x 10 x 10) were interpolated to calculate the averages.

3. All neighboring volumes were evaluated until no neighboring volume with a higher average value was found.

**Step 4**: Re-measurement of the SAR value at the same location as in Step 1. If the value changed by more than 5%, the evaluation was repeated.

## 5.6 Test Methodology

- KDB 447498 D01 (General SAR Guidance)
- KDB 648474 D01 (SAR Handsets Multi Xmitter and Ant)
- KDB 248227 D01 (SAR Consideration for 802.11 Devices)
- KDB 865664 D01 (SAR Measurements up to 6 GHz)

# 6 DASY4 SAR Evaluation Procedure

## 6.1 Power Reference Measurement

The Power Reference Measurement and Power Drift Measurement jobs are useful jobs for monitoring the power drift of the device under test in the batch process. Both jobs measure the field at a specified reference position, at a selectable distance from the phantom surface. The reference position can be either the selected section's grid reference point or a user point in this section. The reference job projects the selected point onto the phantom surface, orients the probe perpendicularly to the surface, and approaches the surface using the selected detection method. The Minimum distance of probe sensors to surface determines the closest measurement point to phantom surface. By default, the Minimum distance of probe sensors to surface is 4mm. This distance can be modified by the user, but cannot be smaller than the Distance of sensor calibration points to probe tip as defined in the probe properties (for example, 2.7mm for an ET3DV6 probe type).

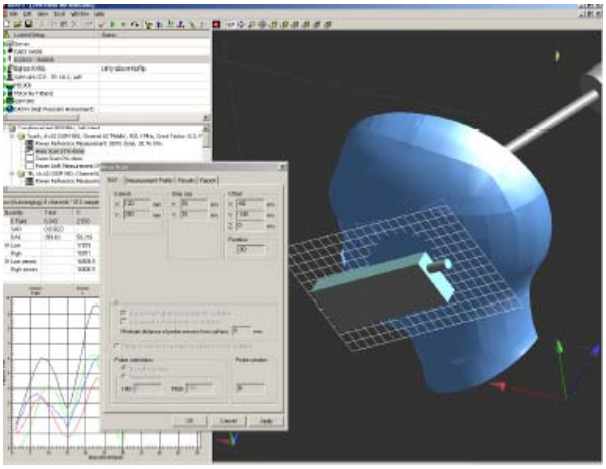
## 6.2 Area Scan

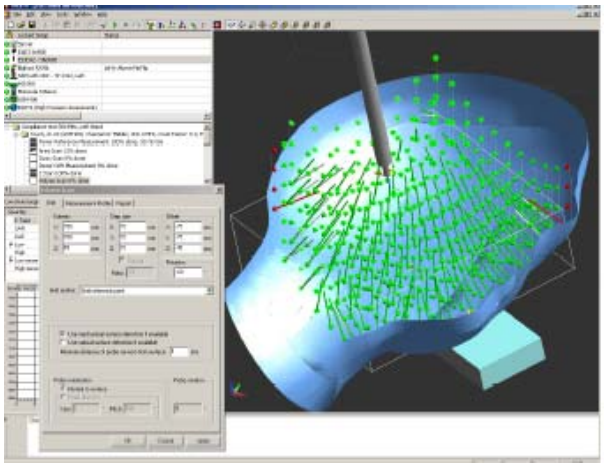
The Area Scan is used as a fast scan in two dimensions to find the area of high field values, before doing a finer measurement around the hot spot. The sophisticated interpolation routines implemented in DASY4 software can find the maximum locations even in relatively coarse grids.

The scanning area is defined by an editable grid. This grid is anchored at the grid reference point of the selected section in the phantom. When the Area Scan's property sheet is brought-up, grid settings can be edited by a user.

When an Area Scan has measured all reachable points, it computes the field maxima found in the scanned area, within a range of the global maximum. The range (in dB) is specified in the standards for compliance testing. For example, a 2 dB range is required in IEEE 1528-2003, EN 50361 and IEC 62209 standards, whereby 3 dB is a requirement when compliance is assessed in accordance with the ARIB standard (Japan). If only one Zoom Scan follows the Area Scan, then only the absolute maximum will be taken as reference. For cases where multiple maximums are detected, the number of Zoom Scans has to be increased accordingly.

After measurement is completed, all maxima and their coordinates are listed in the Results property page. The maximum selected in the list is highlighted in the 3-D view. For the secondary maxima returned from an Area Scan, the user can specify a lower limit (peak SAR value), in addition to the Find secondary maxima within x dB condition. Only the primary maximum and any secondary maxima within x dB from the primary maximum and above this limit will be measured.





## 6.3 Zoom Scan

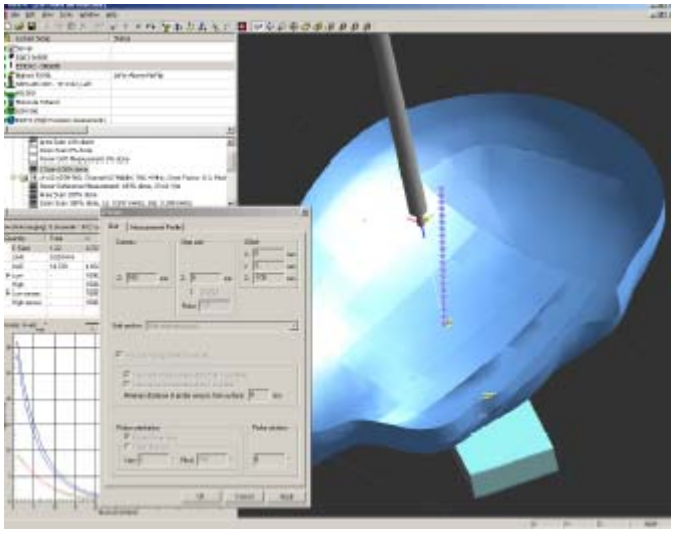
Zoom Scans are used to assess the peak spatial SAR values within a cubic averaging volume containing 1 g and 10 g of simulated tissue. The default Zoom Scan measures 5 x 5 x 7 points within a cube whose base faces are centered around the maxima found in a preceding area scan job within the same procedure. When the measurement is done, the Zoom Scan evaluates the averaged SAR for 1 g and 10 g and displays these values next to the job's label.

## 6.4 Power drift measurement

The Power Drift Measurement job measures the field at the same location as the most recent power reference measurement job within the same procedure, and with the same settings. The Power Drift Measurement gives the field difference in dB from the reading conducted within the last Power Reference Measurement. Several drift measurements are possible for one reference measurement. This allows a user to monitor the power drift of the device under test within a batch process. The measurement procedure is the same as Step 1.

## 6.5 Z-Scan

The Z Scan job measures points along a vertical straight line. The line runs along the Z axis of a one-dimensional grid. A user can anchor the grid to the section reference point, to any defined user point or to the current probe location. As with any other grids, the local Z axis of the anchor location establishes the Z axis of the grid.



# 7 Description of Test System

These measurements were performed with the automated near-field scanning system DASY4 from Schmid & Partner Engineering AG (SPEAG) which is the fourth generation of the system shown in the figure hereinafter:

The system is based on a high precision robot (working range greater than 0.9m), which positions the probes with a positional repeatability of better than ±0.02mm. Special E- and H-field probes have been developed for measurements close to material discontinuity, the sensors of which are directly loaded with a Schottky diode and connected via highly resistive lines to the data acquisition unit.

The SAR measurements were conducted with the dosimetric probe ET3DV6 SN: 1604 (manufactured by SPEAG), designed in the classical triangular configuration and optimized for dosimetric evaluation. The probe has been calibrated according to the procedure with accuracy of better than ±10%. The spherical isotropy was evaluated with the procedure and found to be better than ±0.25dB.

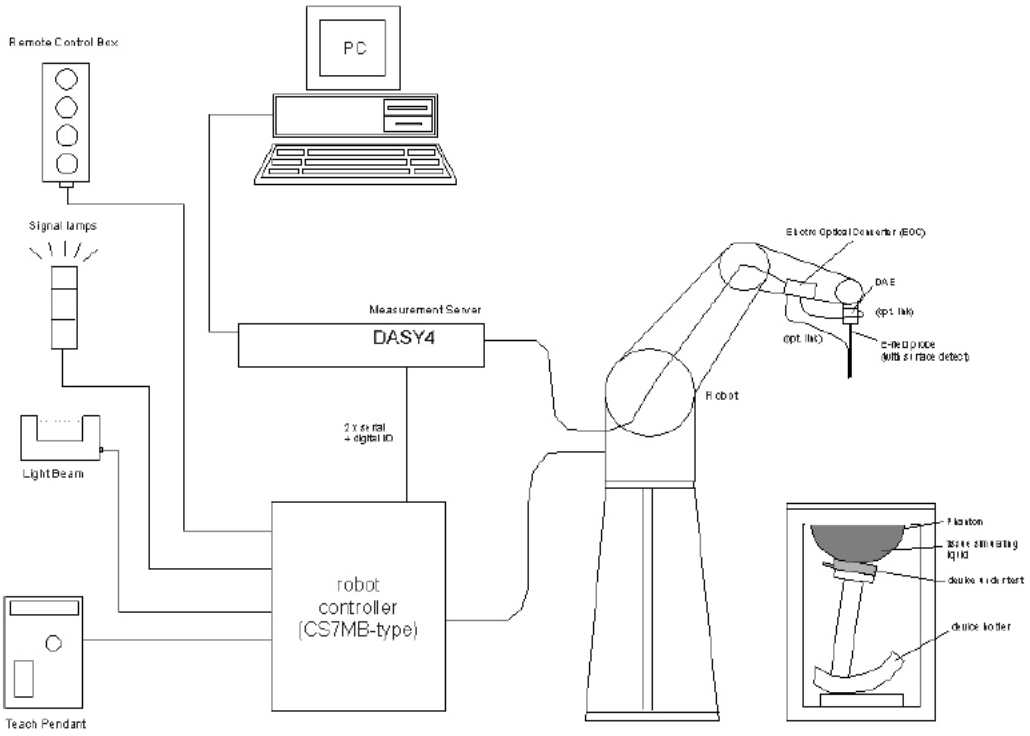
## 7.1 IEEE SCC-34/SC-2 P1528 Recommended Tissue Dielectric Parameters

| Frequency (MHz) | Head Tissue | | Body Tissue | |
|---|---|---|---|---|
| | εr | σ (S/m) | εr | σ (S/m) |
| 150 | 52.3 | 0.76 | 61.9 | 0.80 |
| 300 | 45.3 | 0.87 | 58.2 | 0.92 |
| 450 | 43.5 | 0.87 | 56.7 | 0.94 |
| 835 | 41.5 | 0.90 | 55.2 | 0.97 |
| 900 | 41.5 | 0.97 | 55.0 | 1.05 |
| 915 | 41.5 | 0.98 | 55.0 | 1.06 |
| 1450 | 40.5 | 1.20 | 54.0 | 1.30 |
| 1610 | 40.3 | 1.29 | 53.8 | 1.40 |
| 1800-2000 | 40.0 | 1.40 | 53.3 | 1.52 |
| 2450 | 39.2 | 1.80 | 52.7 | 1.95 |
| 3000 | 38.5 | 2.40 | 52.0 | 2.73 |
| 5800 | 35.3 | 5.27 | 48.2 | 6.00 |

## 7.2 DASY4 user's Manual Recommended Tissue Dielectric Parameters

| Frequency (MHz) | Head Tissue | | Body Tissue | |
|---|---|---|---|---|
| | εr | σ (S/m) | εr | σ (S/m) |
| 2450 | 39.2 | 1.8 | 52.7 | 1.95 |
| 5200 | 36.0 | 4.66 | 49.0 | 5.30 |
| 5500 | 35.6 | 4.96 | 48.6 | 5.65 |
| 5800 | 35.3 | 5.27 | 48.2 | 6.00 |

## 7.3 Measurement System Diagram




The DASY4 system for performing compliance tests consists of the following items:

- A standard high precision 6-axis robot (Stäubli RX family) with controller, teach pendant and software. An arm extension for accommodating the data acquisition electronics (DAE).

- A dosimetric probe, i.e., an isotropic E-field probe optimized and calibrated for usage in tissue simulating liquid. The probe is equipped with an optical surface detector system.

- A data acquisition electronics (DAE) which performs the signal amplification, signal multiplexing, AD-conversion, offset measurements, mechanical surface detection, collision detection, etc. The unit is battery powered with standard or rechargeable batteries. The signal is optically transmitted to the EOC.

- The Electro-optical converter (EOC) performs the conversion between 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 is connected to the measurement server.

- The function of the measurement server is to perform the time critical tasks such as signal filtering, control of the robot operation and fast movement interrupts.

- A probe alignment unit which improves the (absolute) accuracy of the probe positioning.

- A computer operating Windows 2000 or Windows XP.

- DASY4 software.

• Remote control with teach pendant and additional circuitry for robot safety such as warning lamps, etc.

• The SAM twin phantom enabling testing left-hand and right-hand usage.

• The device holder for handheld mobile phones.

• Tissue simulating liquid mixed according to the given recipes.

• Validation dipole kits allowing system validation.

## 7.4 System Components

• DASY4 Measurement Server
• Data Acquisition Electronics
• Probes
• Light Beam Unit
• Medium
• SAM Twin Phantom
• Device Holder for SAM Twin Phantom
• System Validation Kits
• Robot

**DASY4 Measurement Server**

The DASY4 measurement server is based on a PC/104 CPU board with a 166MHz low-power Pentium, 32MB chip disk and 64MB RAM. The necessary circuits for communication with either the DAE4 (or DAE3) electronic box as well as the 16-bit AD-converter system for optical detection and digital I/O interface are contained on the DASY4 I/O-board, which is directly connected to the PC/104 bus of the CPU board.

The measurement server performs 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. All connections are supervised by a watchdog, and disconnection of any of the cables to the measurement server will automatically disarm the robot and disable all program-controlled robot movements. Furthermore, the measurement server is equipped with two expansion slots which are reserved for future applications. Please note that the expansion slots do not have a standardized pin out and therefore only the expansion cards provided by SPEAG can be inserted. Expansion cards from any other supplier could seriously damage the measurement server.

**Data Acquisition Electronics**

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

**Probes**

The DASY system can support many different probe types.

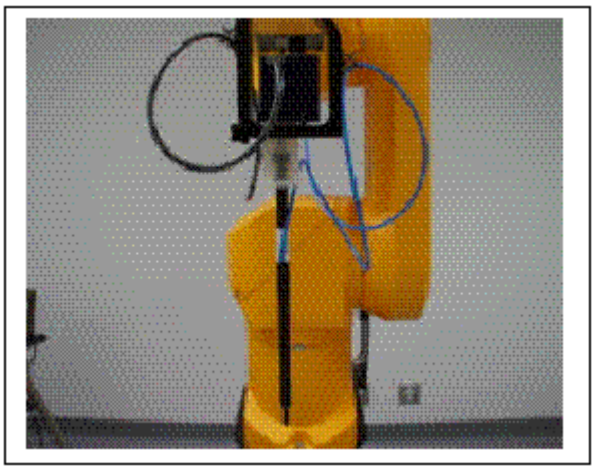
**Dosimetric Probes:** These probes are specially designed and calibrated for use in liquids with high permittivities. They should not be used in air, since the spherical isotropy in air is poor (±2 dB). The dosimetric probes have special calibrations in various liquids at different frequencies.

**Free Space Probes:** These are electric and magnetic field probes specially designed for measurements in free space. The z-sensor is aligned to the probe axis and the rotation angle of the x-sensor is specified. This allows the DASY system to automatically align the probe to the measurement grid for field component measurement. The free space probes are generally not calibrated in liquid. (The H-field probes can be used in liquids without any change of parameters.)

**Temperature Probes:** Small and sensitive temperature probes for general use. They use a completely different parameter set and different evaluation procedures. Temperature rise features allow direct SAR evaluations with these probes.

**ET3DV6 Probe Specification**

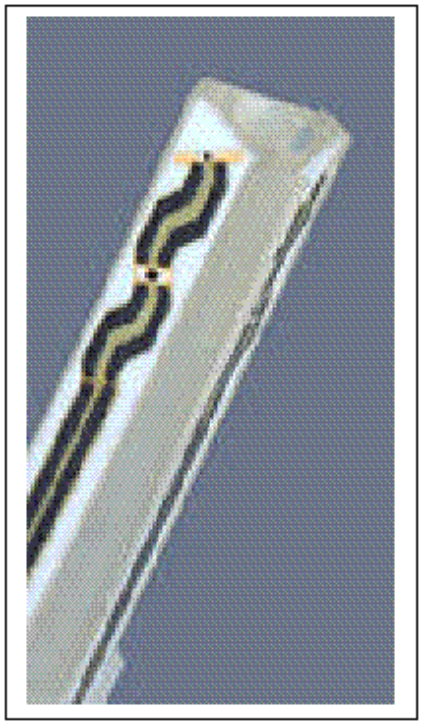
Construction Symmetrical design with triangular core
Built-in optical fiber for surface detection System
Built-in shielding against static charges
Calibration In air from 10 MHz to 2.5 GHz
In brain and muscle simulating tissue at
Frequencies of 450 MHz, 900 MHz and
1.8 GHz (accuracy ± 8%)
Frequency 10 MHz to > 6 GHz; Linearity: ± 0.2 dB
(30 MHz to 3 GHz)
Directivity ± 0.2 dB in brain tissue (rotation around
probe axis)
± 0.4 dB in brain tissue (rotation normal probe axis)
Dynamic 5 mW/g to > 100 mW/g;
Range Linearity: ± 0.2 dB
Surface ± 0.2 mm repeatability in air and clear liquids
Detection over diffuse reflecting surfaces.
Dimensions Overall length: 330 mm
Tip length: 16 mm



**Photograph of the probe**

Body diameter: 12 mm
Tip diameter: 6.8 mm
Distance from probe tip to dipole centers: 2.7 mm
Application General dosimetric up to 3 GHz
Compliance tests of mobile phones
Fast automatic scanning in arbitrary phantoms

The SAR measurements were conducted with the dosimetric probe ET3DV6 designed in the classical triangular configuration 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 multi-fiber 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 DASY3 software reads the reflection during a software approach and looks for the maximum using a 2nd order fitting. The approach is stopped when reaching the maximum.



**Inside view of ET3DV6 E-field Probe**

**E-Field Probe Calibration Process**

Each probe is calibrated according to a dosimetric assessment procedure described in [6] with accuracy better than +/- 10%. The spherical isotropy was evaluated with the procedure described in [7] 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 are tested.

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

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 dielectric medium. For temperature correlation calibration a RF transparent thermistor-based temperature probe is used in conjunction with the E-field probe.

**Data Evaluation**

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 | Normi, ai0, ai1, ai2 |
| | - Conversion factor | ConvFi |
| | - Diode compression point | dcpi |
| 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 they 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 Vi = compensated signal of channel i (i =x, y, z)
Ui = 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:

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

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

With Vi = compensated signal of channel i (i =x, y, z)
$Norm_i$ = sensor sensitivity of channel i (i =x, y, z)
μV/ $(V/m)^2$ for E-field probes
ConF = sensitivity enhancement in solution
$a_{ij}$ = sensor sensitivity factors for H-field probes
f = carrier frequency [GHz]
Ei = electric field strenggy of channel i in V/m
$H_i$ = diode compression point (DASY parameter)

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/meter] or [Siemens/meter]
ρ = equivalent tissue density in g/cm$^3$

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

**Light Beam Unit**

The light beam switch 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.

**Medium**

Parameters

The parameters of the tissue simulating liquid strongly influence the SAR in the liquid. The parameters for the different frequencies are defined in the corresponding compliance standards (e.g., EN 50361, IEEE 1528-2003).

Parameter measurements

Several measurement systems are available for measuring the dielectric parameters of liquids:

- The open coax test method (e.g., HP85070 dielectric probe kit) is easy to use, but has only moderate acuracy. It is calibrated with open, short, and deionized water and the calibrations a critical process.

- The transmission line method (e.g., model 1500T from DAMASKOS, INC.) measures the transmission and reflection in a liquid filled high precision line. It needs standard two port calibration and is probably more accurate than the open coax method.

- The reflection line method measures the reflection in a liquid filled shorted precision lined.The method is not suitable for these liquids because of its low sensitivity.

- The slotted line method scans the field magnitude and phase along a liquid filled line. The evaluation is straight forward and only needs a simple response calibration. The method is very accurate, but can only be used in high loss liquids and at frequencies above 100 to 200MHz. Cleaning the line can be tedious.

**SAM Twin Phantom**

The SAM twin phantom is a fiberglass shell phantom with 2mm shell thickness (except the ear region where shell thickness increases to 6mm). It has three measurement areas:

- Left hand
- Right hand
- Flat phantom

The phantom table comes in two sizes: A 100 x 50 x 85 cm (L x W x H) table for use with free standing robots (DASY4 professional system option) or as a second phantom and a 100 x 75 x 85 cm(L x W x H) table with reinforcements for table mounted robots (DASY4 compact system option) .
The bottom plate contains three pair of bolts for locking the device holder. The device holder positions are adjusted to the standard measurement positions in the three sections. Only one device holder is necessary if two phantoms are used (e.g., for different liquids) A white cover is provided to tap the phantom during o_-periods to prevent water evaporation and changes in the liquid parameters. Free space scans of devices on the cover are possible. On the phantom top, three reference markers are provided to identify the phantom position with respect to the robot.

The phantom can be used with the following tissue simulating liquids:

- Water-sugar based liquids can be left permanently in the phantom. Always cover the liquid if the system is not used, otherwise the parameters will change due to water evaporation.

- Glycol based liquids should be used with care. As glycol is a softener for most plastics, the liquid should be taken out of the phantom and the phantom should be dried when the system is not used (desirable at least once a week).

- Do not use other organic solvents without previously testing the phantom's compatibility.

**Device Holder for SAM Twin Phantom**

The SAR in the phantom is approximately inversely proportional to the square of the distance between the source and the liquid surface. For a source in 5mm distance, a positioning uncertainty of ±0.5mm would produce a SAR uncertainty of ±20%. An accurate device positioning is therefore crucial for accurate and repeatable measurements. The positions, in which the devices must be measured, are defined by the standards.

The DASY device holder is designed to cope with different positions given in the standard. It has two scales for the device rotation (with respect to the body axis) and the device inclination (with respect to the line between the

ear reference points). The rotation center for both scales is the ear reference point ERP). Thus the device needs no repositioning when changing the angles.

The DASY device holder has been made out of low-loss POM material having the following dielectric parameters: relative permittivity "=3 and loss tangent _=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.

**System Validation Kits**

Each DASY system is equipped with one or more system validation kits. These units, together with the predefined measurement procedures within the DASY software, enable the user to conduct the system performance check and system validation. For that purpose a well defined SAR distribution in the flat section of the SAM twin phantom is produced.

System validation kit includes a dipole, tripod holder to fix it underneath the flat phantom and a corresponding distance holder. Dipoles are available for the variety of frequencies between 300MHz and 6 GHz (dipoles for other frequencies or media and other calibration conditions are available upon request).

The dipoles are highly symmetric and matched at the center frequency for the specified liquid and distance to the flat phantom (or flat section of the SAM-twin phantom). The accurate distance between the liquid surface and the dipole center is achieved with a distance holder that snaps on the dipole.

**Robot**

The DASY4 system uses the high precision industrial robots RX60L, RX90 and RX90L, as well as the RX60BL and RX90BL types out of the newer series from Stäubli SA (France). The RX robot series offers many features that are important for our application:

• High precision (repeatability 0.02mm)
• High reliability (industrial design)
• Low maintenance costs (virtually maintenance-free due to direct drive gears; no belt drives)
• Jerk-free straight movements (brushless synchronous motors; no stepper motors)
• Low ELF interference (the closed metallic construction shields against motor control fields)

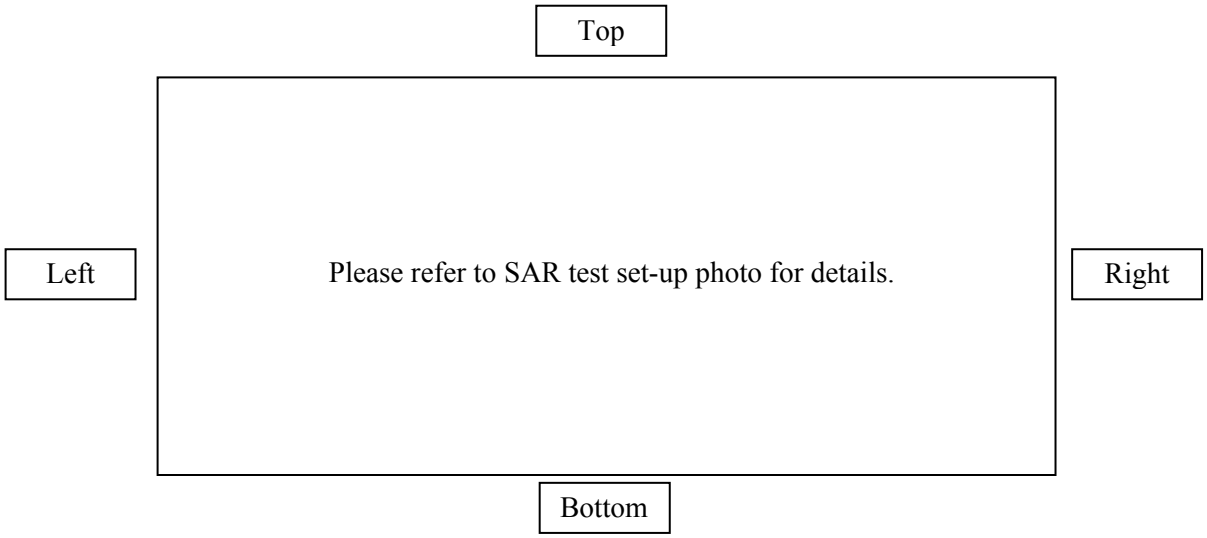
For the newly delivered DASY4 systems as well as for the older DASY3 systems delivered since 1999, the CS7MB robot controller version from Stäubli is used. Previously delivered systems have either a CS7 or CS7M controller; the differences to the CS7MB are mainly in the hardware, but some procedures in the robot software from Stäubli are also not completely the same. The following descriptions about robot hard- and software correspond to CS7MB controller with software version 13.1 (edit S5). The actual commands, procedures and configurations, also including details in hardware, might differ if an older robot controller is in use. In this case please also refer to the Stäubli manuals for further information.

# 8 SAR Measurement Consideration and Reduction

## 8.1 SAR Reductions

**EUT Antennas Location**

(Front Side View)




Note1: two positions were chosen for SAR testing, rear side wrist-worn extremity and front side 10mm next to mouth for normal operation.

Note2: According to KDB 248227 Section 1, while 1-g SAR thresholds are specified in the procedure for SAR test reduction and exclusion, these thresholds should be multiplied by 2.5 when 10-g extremity SAR is considered.

**Reduced[1]**

According to KDB 248227 Section 5.2.1, when the reported SAR of the highest measured maximum output power channel for the exposure configuration is ≤ 0.8 W/kg, no further SAR testing is required for 802.11b DSSS in that exposure configuration. When the reported SAR is > 0.8 W/kg, SAR is required for that exposure configuration using the next highest measured output power channel. When any reported SAR is > 1.2 W/kg, SAR is required for the third channel; i.e., all channels require testing.

**Reduced[2]**

According to KDB 248227 Section 5.2.2 (b), when the highest reported SAR for DSSS is adjusted by the ratio of OFDM to DSSS specified maximum output power and the adjusted SAR is ≤ 1.2 W/kg.

**Reduced[3]**

According to KDB 447498 Section 4.4.1, testing of other required channels within the operating mode of a frequency band is not required when the reported 1-g or 10-g SAR for the mid-band or highest output power channel is: (a) ≤ 0.8 W/kg or 2.0 W/kg, for 1-g or 10-g respectively, when the transmission band is ≤ 100 MHz

## 8.2 SAR Consideration

| Mode | Side | Channel | Result |
|---|---|---|---|
| 2.4 GHz 802.11b | Front Side | Low Channel-2412 | Reduced[1] |
| | | Mid Channel-2437 | Tested |
| | | High Channel-2462 | Reduced[1] |
| | Rear Side 10mm | Low Channel-2412 | Tested |
| | | Mid Channel-2437 | Tested |
| | | High Channel-2462 | Tested |
| 2.4 GHz 802.11g | Front Side | Low Channel-2412 | Reduced[2] |
| | | Mid Channel-2437 | Reduced[2] |
| | | High Channel-2462 | Reduced[2] |
| | Rear Side 10mm | Low Channel-2412 | Reduced[2] |
| | | Mid Channel-2437 | Reduced[2] |
| | | High Channel-2462 | Reduced[2] |
| 2.4 GHz 802.11n20 | Front Side | Low Channel-2412 | Reduced[2] |
| | | Mid Channel-2437 | Reduced[2] |
| | | High Channel-2462 | Reduced[2] |
| | Rear Side 10mm | Low Channel-2412 | Reduced[2] |
| | | Mid Channel-2437 | Reduced[2] |
| | | High Channel-2462 | Reduced[2] |
| 2.4 GHz BT/BLE | Front Side | Low Channel-2402 | Reduced[3] |
| | | Mid Channel-2441 | Tested[1] |
| | | High Channel-2480 | Reduced[3] |
| | Rear Side 10mm | Low Channel-2402 | Tested |
| | | Mid Channel-2441 | Tested |
| | | High Channel-2480 | Tested |

*Note[1]: according to RSS-102, §2.5.1, the exemption limit (mW) for 2450MHz at separation distance10mm is 7mW, the conducted maximum power of the device is 10mW, therefore we tested.*

# 9 SAR Measurement Results

This page summarizes the results of the performed SAR evaluation. The plots with the corresponding SAR distributions, which reveal information about the location of the maximum SAR with respect to the device, could be found in Appendix E.

## 9.1 Test Environmental Conditions

| | |
|---|---|
| **Temperature:** | 24° C |
| **Relative Humidity:** | 46 % |
| **ATM Pressure:** | 102 kPa |

*Testing was performed by Jin Yang in SAR chamber from 12-08-2016 to 12-09-2016.*

## 9.2 Standalone SAR Results

Please refer to the following tables.

| 2.4 GHz Band | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Radio Mode** | **EUT Position** | **Frequency (MHz)** | **Test Type** | **Output Power (dBm)** | | **Scale Factor** | **Measured (W/kg)** | **Scaled (W/kg)** | **Limit (W/kg)** | **Plot #** |
| | | | | **Measured** | **Target** | | | | | |
| 802.11b | Rear Side Touch (Middle CH) | 2437 | Body | 15.11 | 15.5 | 1.09 | 0.262 | 0.2866 | 4 | - |
| | Rear Side Touch (Low CH) | 2412 | Body | 15.04 | 15.5 | 1.11 | 0.246 | 0.2735 | 4 | - |
| | Rear Side Touch (High CH) | 2462 | Body | 15.06 | 15.5 | 1.11 | **0.279** | 0.3087 | 4 | 1 |
| | Front side 10mm (Middle CH) | 2437 | Head | 15.11 | 15.5 | 1.09 | **0.0581** | 0.0636 | 1.6 | 2 |
| BT (GFSK) | Rear Side Touch (Middle CH) | 2441 | Body | 9.17 | 9.5 | 1.08 | 0.0269 | 0.0290 | 4 | - |
| | Rear Side Touch (Low CH) | 2402 | Body | 9.22 | 9.5 | 1.07 | 0.0226 | 0.0241 | 4 | - |
| | Rear Side Touch (High CH) | 2480 | Body | 9.00 | 9.5 | 1.12 | 0.0275 | 0.0309 | 4 | 3 |
| | Front side 10mm (Middle CH) | 2441 | Head | 9.17 | 9.5 | 1.08 | 0.0121 | 0.0131 | 1.6 | 4 |

*Note[1]: NOTICE 2012-DRS1203: Based on the IEEE 1528 and IEC 62209 requirements, the high, mid and low channels for the configuration with the highest SAR value must be tested regardless of the SAR value measured.*

*Note[2]: for rear side touch position, the measured SAR value and limit are in 10 g SAR (W/kg); for front side 10mm position, the measured SAR value and limit are in 1 g SAR (W/kg)*

**Corrected SAR Evaluation Table**

| Frequency (MHz) | Liquid Type | $C_\varepsilon$ | $\triangle\varepsilon_r$ | $C_\delta$ | $\triangle_\delta$ | △SAR |
|---|---|---|---|---|---|---|
| 2412 | Body | -0.225 | -2.028 | 0.489 | 1.571 | 1.224 |
| 2437 | Body | -0.225 | -2.143 | 0.483 | 1.031 | 0.980 |
| 2462 | Body | -0.225 | -2.278 | 0.478 | 1.015 | 0.997 |
| 2480 | Body | -0.225 | -2.317 | 0.474 | 1.005 | 0.997 |

| Frequency (MHz) | Liquid Type | $C_\varepsilon$ | $\triangle\varepsilon_r$ | $C_\delta$ | $\triangle_\delta$ | △SAR |
|---|---|---|---|---|---|---|
| 2412 | Head | -0.225 | -0.662 | 0.489 | 0.565 | 0.425 |
| 2437 | Head | -0.225 | -0.739 | 0.483 | 0.559 | 0.436 |
| 2462 | Head | -0.225 | -0.715 | 0.478 | 0.552 | 0.425 |
| 2480 | Head | -0.225 | -0.894 | 0.474 | 0.546 | 0.460 |

$$\Delta SAR = c_\varepsilon \, \Delta\varepsilon_r + c_\sigma \, \Delta\sigma$$

$$c_\varepsilon = -7{,}854 \times 10^{-4} f^3 + 9{,}402 \times 10^{-3} f^2 - 2{,}742 \times 10^{-2} f - 0{,}202\,6$$

$$c_\sigma = 9{,}804 \times 10^{-3} f^3 - 8{,}661 \times 10^{-2} f^2 + 2{,}981 \times 10^{-2} f + 0{,}782\,9$$

where

$f$ is the frequency in GHz.

*Note 1: According NOTICE 2012-DRS0529, if the correction △SAR has a negative sign, the measured SAR result should be corrected, and has a positive sign, the measured SAR result shall not be corrected.*

# 10 Appendix A – Measurement Uncertainty

The uncertainty budget has been determined for the DASY4 measurement system and is given in the following Table.

**Below 3 GHz**

| DASY4 Uncertainty Budget According to IEC 62209-2 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Error Description | Uncertainty Value | Prob. Dist. | Div. | (c i) 1g | (c i) 10g | Std. Unc. (1g) | Std. Unc. (10g) | (v i) veff |
| **Measurement System** | | | | | | | | |
| Probe Calibration (2450 MHz) | ± 6.00 % | N | 1 | 1 | 1 | ± 6.00 % | ± 6.00 % | ∞ |
| Isotropy | ± 0.94 % | R | $\sqrt{3}$ | 1 | 1 | ± 0.54 % | ± 0.54 % | ∞ |
| Linearity | ± 0.3 % | R | $\sqrt{3}$ | 1 | 1 | ± 0.17 % | ± 0.17 % | ∞ |
| Modulation Response | ± 1.65 % | R | $\sqrt{3}$ | 1 | 1 | ± 0.95 % | ± 0.95 % | ∞ |
| System Detection Limits | ± 1.0 % | R | $\sqrt{3}$ | 1 | 1 | ± 0.6 % | ± 0.6 % | ∞ |
| Boundary Effects | ± 0.5 % | R | $\sqrt{3}$ | 1 | 1 | ± 0.29 % | ± 0.29 % | ∞ |
| Readout Electronics | ± 0.3 % | N | 1 | 1 | 1 | ± 0.3 % | ± 0.3 % | ∞ |
| Response Time | ± 0.8 % | R | $\sqrt{3}$ | 1 | 1 | ± 0.5 % | ± 0.5 % | ∞ |
| Integration Time | ± 2.6 % | R | $\sqrt{3}$ | 1 | 1 | ± 1.5 % | ± 1.5 % | ∞ |
| RF Ambient Noise | ± 0.0 % | R | $\sqrt{3}$ | 1 | 1 | ± 0.0 % | ± 0.0 % | ∞ |
| RF Ambient Reflections | ± 3.0 % | R | $\sqrt{3}$ | 1 | 1 | ± 1.7 % | ± 1.7 % | ∞ |
| Probe Positioner | ± 0.4 % | R | $\sqrt{3}$ | 1 | 1 | ± 0.2 % | ± 0.2 % | ∞ |
| Probe Positioning | ± 2.9 % | R | $\sqrt{3}$ | 1 | 1 | ± 1.7 % | ± 1.7 % | ∞ |
| Post-processing | ± 1.0 % | R | $\sqrt{3}$ | 1 | 1 | ± 0.6 % | ± 0.6 % | ∞ |
| **Test Sample Related** | | | | | | | | |
| Device Holder | ± 3.6 % | N | 1 | 1 | 1 | ± 3.6 % | ± 2.6 % | 5 |
| Device Positioning | ± 2.9 % | N | 1 | 1 | 1 | ± 2.9 % | ± 2.9 % | 145 |
| SAR Scaling | ± 0.0 % | R | $\sqrt{3}$ | 1 | 1 | ± 0.0 % | ± 0.0 % | ∞ |
| Power Drift | ± 5.0 % | R | $\sqrt{3}$ | 1 | 1 | ± 2.9 % | ± 2.9 % | ∞ |
| **Phantom and Setup** | | | | | | | | |
| Phantom Uncertainty | ± 4.0 % | R | $\sqrt{3}$ | 1 | 1 | ± 2.3 % | ± 2.3 % | ∞ |
| SAR Correction | ± 0.0 % | N | 1 | 1 | 1 | ± 0.0 % | ± 0.0 % | ∞ |
| Liquid Conductivity (Target) | ± 5.0 % | R | $\sqrt{3}$ | 0.64 | 0.43 | ± 1.8 % | ± 1.2 % | ∞ |
| Liquid Conductivity (meas.) | ± 2.5 % | N | 1 | 0.64 | 0.43 | ± 1.6 % | ± 1.1 % | ∞ |
| Liquid Permittivity (Target) | ± 5.0 % | R | $\sqrt{3}$ | 0.6 | 0.49 | ± 1.7 % | ± 1.4 % | ∞ |
| Liquid Permittivity (meas.) | ± 2.5 % | N | 1 | 0.6 | 0.49 | ± 1.5 % | ± 1.2 % | ∞ |
| Combined Std. Uncertainty | - | RSS | - | - | - | ± 9.32 % | ± 9.23 % | 330 |
| Expanded STD Uncertainty | - | 2 | - | - | - | ± 18.6 % | ± 18.5 % | - |

# 11 Appendix B - Probe Calibration Certificates

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

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

Accredited by the Swiss Accreditation Service (SAS)
**The Swiss Accreditation Service is one of the signatories to the EA Multilateral Agreement for the recognition of calibration certificates**

**Accreditation No.: SCS 0108**

**Client** BACL

**Certificate No: EX3-3619_Sep16**

## CALIBRATION CERTIFICATE

| | |
|---|---|
| Object | EX3DV4 - SN:3619 |
| Calibration procedure(s) | QA CAL-01.v9, QA CAL-12.v9, QA CAL-14.v4, QA CAL-23.v5, QA CAL-25.v6<br>Calibration procedure for dosimetric E-field probes |
| Calibration date: | September 23, 2016 |

This calibration certificate documents the traceability to national standards, which realize the physical units of measurements (SI).
The measurements and the uncertainties with confidence probability are given on the following pages and are part of the certificate.

All calibrations have been conducted in the closed laboratory facility: environment temperature (22 ± 3)°C and humidity < 70%.

Calibration Equipment used (M&TE critical for calibration)

| Primary Standards | ID | Cal Date (Certificate No.) | Scheduled Calibration |
|---|---|---|---|
| Power meter NRP | SN: 104778 | 06-Apr-16 (No. 217-02288/02289) | Apr-17 |
| Power sensor NRP-Z91 | SN: 103244 | 06-Apr-16 (No. 217-02288) | Apr-17 |
| Power sensor NRP-Z91 | SN: 103245 | 06-Apr-16 (No. 217-02289) | Apr-17 |
| Reference 20 dB Attenuator | SN: S5277 (20x) | 05-Apr-16 (No. 217-02293) | Apr-17 |
| Reference Probe ES3DV2 | SN: 3013 | 31-Dec-15 (No. ES3-3013_Dec15) | Dec-16 |
| DAE4 | SN: 660 | 23-Dec-15 (No. DAE4-660_Dec15) | Dec-16 |
| | | | |
| Secondary Standards | ID | Check Date (in house) | Scheduled Check |
| Power meter E4419B | SN: GB41293874 | 06-Apr-16 (in house check Jun-16) | In house check: Jun-18 |
| Power sensor E4412A | SN: MY41498087 | 06-Apr-16 (in house check Jun-16) | In house check: Jun-18 |
| Power sensor E4412A | SN: 000110210 | 06-Apr-16 (in house check Jun-16) | In house check: Jun-18 |
| RF generator HP 8648C | SN: US3642U01700 | 04-Aug-99 (in house check Jun-16) | In house check: Jun-18 |
| Network Analyzer HP 8753E | SN: US37390585 | 18-Oct-01 (in house check Oct-15) | In house check: Oct-16 |

| | Name | Function | Signature |
|---|---|---|---|
| Calibrated by: | Michael Weber | Laboratory Technician | M.Weber |
| Approved by: | Katja Pokovic | Technical Manager | |

Issued: September 28, 2016

This calibration certificate shall not be reproduced except in full without written approval of the laboratory.

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**Calibration Laboratory of**
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**Zeughausstrasse 43, 8004 Zurich, Switzerland**

**S** Schweizerischer Kalibrierdienst
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**The Swiss Accreditation Service is one of the signatories to the EA Multilateral Agreement for the recognition of calibration certificates**

**Accreditation No.: SCS 0108**

## Glossary:

| | |
|---|---|
| TSL | tissue simulating liquid |
| NORMx,y,z | sensitivity in free space |
| ConvF | sensitivity in TSL / NORMx,y,z |
| DCP | diode compression point |
| CF | crest factor (1/duty_cycle) of the RF signal |
| A, B, C, D | modulation dependent linearization parameters |
| Polarization φ | φ rotation around probe axis |
| Polarization ϑ | ϑ rotation around an axis that is in the plane normal to probe axis (at measurement center), i.e., ϑ = 0 is normal to probe axis |
| Connector Angle | information used in DASY system to align probe sensor X to the robot coordinate system |

## Calibration is Performed According to the Following Standards:

a) IEEE Std 1528-2013, "IEEE Recommended Practice for Determining the Peak Spatial-Averaged Specific Absorption Rate (SAR) in the Human Head from Wireless Communications Devices: Measurement Techniques", June 2013
b) IEC 62209-1, "Procedure to measure the Specific Absorption Rate (SAR) for hand-held devices used in close proximity to the ear (frequency range of 300 MHz to 3 GHz)", February 2005
c) IEC 62209-2, "Procedure to determine the Specific Absorption Rate (SAR) for wireless communication devices used in close proximity to the human body (frequency range of 30 MHz to 6 GHz)", March 2010
d) KDB 865664, "SAR Measurement Requirements for 100 MHz to 6 GHz"

## Methods Applied and Interpretation of Parameters:

- *NORMx,y,z:* Assessed for E-field polarization ϑ = 0 (f ≤ 900 MHz in TEM-cell; f > 1800 MHz: R22 waveguide). NORMx,y,z are only intermediate values, i.e., the uncertainties of NORMx,y,z does not affect the $E^2$-field uncertainty inside TSL (see below *ConvF*).
- *NORM(f)x,y,z = NORMx,y,z * frequency_response* (see Frequency Response Chart). This linearization is implemented in DASY4 software versions later than 4.2. The uncertainty of the frequency response is included in the stated uncertainty of *ConvF*.
- *DCPx,y,z:* DCP are numerical linearization parameters assessed based on the data of power sweep with CW signal (no uncertainty required). DCP does not depend on frequency nor media.
- *PAR:* PAR is the Peak to Average Ratio that is not calibrated but determined based on the signal characteristics
- *Ax,y,z; Bx,y,z; Cx,y,z; Dx,y,z; VRx,y,z: A, B, C, D* are numerical linearization parameters assessed based on the data of power sweep for specific modulation signal. The parameters do not depend on frequency nor media. *VR* is the maximum calibration range expressed in RMS voltage across the diode.
- *ConvF and Boundary Effect Parameters:* Assessed in flat phantom using E-field (or Temperature Transfer Standard for f ≤ 800 MHz) and inside waveguide using analytical field distributions based on power measurements for f > 800 MHz. The same setups are used for assessment of the parameters applied for boundary compensation (alpha, depth) of which typical uncertainty values are given. These parameters are used in DASY4 software to improve probe accuracy close to the boundary. The sensitivity in TSL corresponds to *NORMx,y,z * ConvF* whereby the uncertainty corresponds to that given for *ConvF*. A frequency dependent *ConvF* is used in DASY version 4.4 and higher which allows extending the validity from ± 50 MHz to ± 100 MHz.
- *Spherical isotropy (3D deviation from isotropy)*: in a field of low gradients realized using a flat phantom exposed by a patch antenna.
- *Sensor Offset*: The sensor offset corresponds to the offset of virtual measurement center from the probe tip (on probe axis). No tolerance required.
- *Connector Angle*: The angle is assessed using the information gained by determining the *NORMx* (no uncertainty required).

# Probe EX3DV4

## SN:3619

Manufactured: July 3, 2007
Calibrated: September 23, 2016

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

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# DASY/EASY - Parameters of Probe: EX3DV4 - SN:3619

## Basic Calibration Parameters

| | Sensor X | Sensor Y | Sensor Z | Unc (k=2) |
|---|---|---|---|---|
| Norm (μV/(V/m)$^2$)[A] | 0.44 | 0.36 | 0.39 | ± 10.1 % |
| DCP (mV)[B] | 101.0 | 98.1 | 99.9 | |

## Modulation Calibration Parameters

| UID | Communication System Name | | A dB | B dB√μV | C | D dB | VR mV | Unc[E] (k=2) |
|---|---|---|---|---|---|---|---|---|
| 0 | CW | X | 0.0 | 0.0 | 1.0 | 0.00 | 176.2 | ±3.3 % |
| | | Y | 0.0 | 0.0 | 1.0 | | 178.2 | |
| | | Z | 0.0 | 0.0 | 1.0 | | 177.1 | |

The reported uncertainty of measurement is stated as the standard uncertainty of measurement multiplied by the coverage factor k=2, which for a normal distribution corresponds to a coverage probability of approximately 95%.

[A] The uncertainties of Norm X,Y,Z do not affect the $E^2$-field uncertainty inside TSL (see Pages 5 and 6).
[B] Numerical linearization parameter: uncertainty not required.
[E] Uncertainty is determined using the max. deviation from linear response applying rectangular distribution and is expressed for the square of the field value.

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# DASY/EASY - Parameters of Probe: EX3DV4 - SN:3619

## Calibration Parameter Determined in Head Tissue Simulating Media

| f (MHz) [C] | Relative Permittivity [F] | Conductivity (S/m) [F] | ConvF X | ConvF Y | ConvF Z | Alpha [G] | Depth [G] (mm) | Unc (k=2) |
|---|---|---|---|---|---|---|---|---|
| 450 | 43.5 | 0.87 | 9.60 | 9.60 | 9.60 | 0.17 | 1.15 | ± 13.3 % |
| 600 | 42.7 | 0.88 | 8.83 | 8.83 | 8.83 | 0.14 | 1.15 | ± 13.3 % |
| 750 | 41.9 | 0.89 | 9.88 | 9.88 | 9.88 | 0.64 | 0.80 | ± 12.0 % |
| 835 | 41.5 | 0.90 | 9.28 | 9.28 | 9.28 | 0.54 | 0.80 | ± 12.0 % |
| 1750 | 40.1 | 1.37 | 7.56 | 7.56 | 7.56 | 0.30 | 0.80 | ± 12.0 % |
| 1900 | 40.0 | 1.40 | 7.21 | 7.21 | 7.21 | 0.34 | 0.87 | ± 12.0 % |
| 2450 | 39.2 | 1.80 | 6.64 | 6.64 | 6.64 | 0.34 | 0.85 | ± 12.0 % |
| 2600 | 39.0 | 1.96 | 6.59 | 6.59 | 6.59 | 0.32 | 0.97 | ± 12.0 % |
| 5250 | 35.9 | 4.71 | 4.52 | 4.52 | 4.52 | 0.40 | 1.80 | ± 13.1 % |
| 5600 | 35.5 | 5.07 | 4.00 | 4.00 | 4.00 | 0.50 | 1.80 | ± 13.1 % |
| 5800 | 35.3 | 5.27 | 4.05 | 4.05 | 4.05 | 0.50 | 1.80 | ± 13.1 % |

[C] Frequency validity above 300 MHz of ± 100 MHz only applies for DASY v4.4 and higher (see Page 2), else it is restricted to ± 50 MHz. The uncertainty is the RSS of the ConvF uncertainty at calibration frequency and the uncertainty for the indicated frequency band. Frequency validity below 300 MHz is ± 10, 25, 40, 50 and 70 MHz for ConvF assessments at 30, 64, 128, 150 and 220 MHz respectively. Above 5 GHz frequency validity can be extended to ± 110 MHz.

[F] At frequencies below 3 GHz, the validity of tissue parameters (ε and σ) can be relaxed to ± 10% if liquid compensation formula is applied to measured SAR values. At frequencies above 3 GHz, the validity of tissue parameters (ε and σ) is restricted to ± 5%. The uncertainty is the RSS of the ConvF uncertainty for indicated target tissue parameters.

[G] Alpha/Depth are determined during calibration. SPEAG warrants that the remaining deviation due to the boundary effect after compensation is always less than ± 1% for frequencies below 3 GHz and below ± 2% for frequencies between 3-6 GHz at any distance larger than half the probe tip diameter from the boundary.

# DASY/EASY - Parameters of Probe: EX3DV4 - SN:3619

## Calibration Parameter Determined in Body Tissue Simulating Media

| f (MHz) [C] | Relative Permittivity [F] | Conductivity (S/m) [F] | ConvF X | ConvF Y | ConvF Z | Alpha [G] | Depth [G] (mm) | Unc (k=2) |
|---|---|---|---|---|---|---|---|---|
| 450 | 56.7 | 0.94 | 10.05 | 10.05 | 10.05 | 0.08 | 1.15 | ± 13.3 % |
| 600 | 56.1 | 0.95 | 9.19 | 9.19 | 9.19 | 0.12 | 1.15 | ± 13.3 % |
| 750 | 55.5 | 0.96 | 8.36 | 8.36 | 8.36 | 0.45 | 0.80 | ± 12.0 % |
| 835 | 55.2 | 0.97 | 8.20 | 8.20 | 8.20 | 0.44 | 0.80 | ± 12.0 % |
| 1750 | 53.4 | 1.49 | 7.26 | 7.26 | 7.26 | 0.27 | 1.05 | ± 12.0 % |
| 1900 | 53.3 | 1.52 | 7.00 | 7.00 | 7.00 | 0.39 | 0.84 | ± 12.0 % |
| 2450 | 52.7 | 1.95 | 6.69 | 6.69 | 6.69 | 0.35 | 0.85 | ± 12.0 % |
| 2600 | 52.5 | 2.16 | 6.54 | 6.54 | 6.54 | 0.26 | 0.95 | ± 12.0 % |
| 5250 | 48.9 | 5.36 | 4.05 | 4.05 | 4.05 | 0.50 | 1.90 | ± 13.1 % |
| 5600 | 48.5 | 5.77 | 3.39 | 3.39 | 3.39 | 0.60 | 1.90 | ± 13.1 % |
| 5800 | 48.2 | 6.00 | 3.68 | 3.68 | 3.68 | 0.60 | 1.90 | ± 13.1 % |

[C] Frequency validity above 300 MHz of ± 100 MHz only applies for DASY v4.4 and higher (see Page 2), else it is restricted to ± 50 MHz. The uncertainty is the RSS of the ConvF uncertainty at calibration frequency and the uncertainty for the indicated frequency band. Frequency validity below 300 MHz is ± 10, 25, 40, 50 and 70 MHz for ConvF assessments at 30, 64, 128, 150 and 220 MHz respectively. Above 5 GHz frequency validity can be extended to ± 110 MHz.

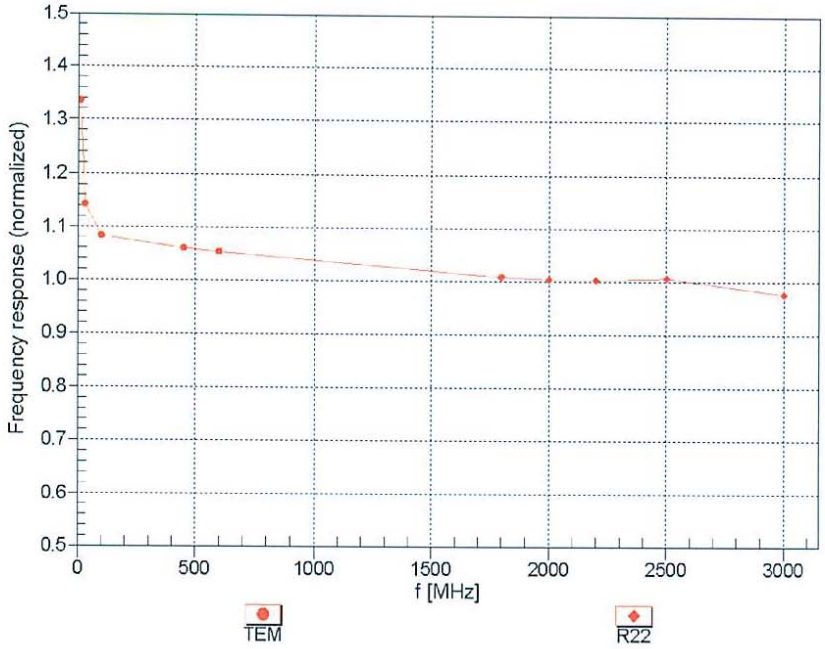
[F] At frequencies below 3 GHz, the validity of tissue parameters (ε and σ) can be relaxed to ± 10% if liquid compensation formula is applied to measured SAR values. At frequencies above 3 GHz, the validity of tissue parameters (ε and σ) is restricted to ± 5%. The uncertainty is the RSS of the ConvF uncertainty for indicated target tissue parameters.

[G] Alpha/Depth are determined during calibration. SPEAG warrants that the remaining deviation due to the boundary effect after compensation is always less than ± 1% for frequencies below 3 GHz and below ± 2% for frequencies between 3-6 GHz at any distance larger than half the probe tip diameter from the boundary.

EX3DV4– SN:3619

September 23, 2016

## Frequency Response of E-Field
(TEM-Cell:ifi110 EXX, Waveguide: R22)




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

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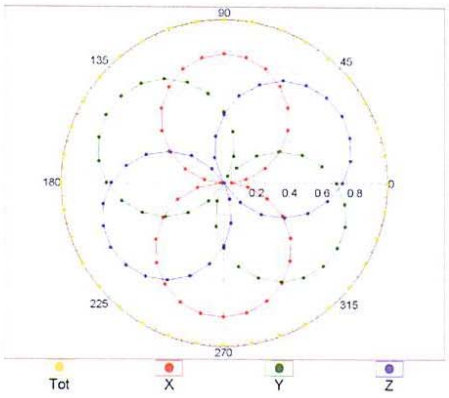
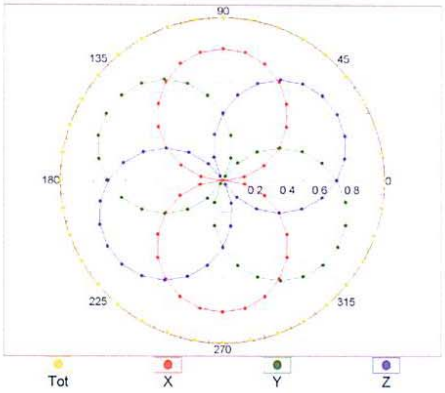
September 23, 2016

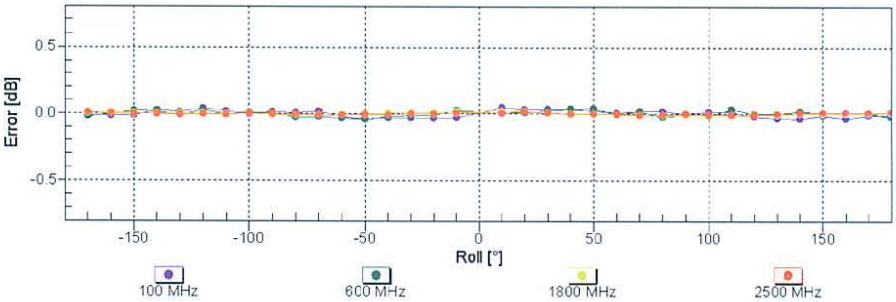
## Receiving Pattern (ϕ), ϑ = 0°

f=600 MHz,TEM




f=1800 MHz,R22




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

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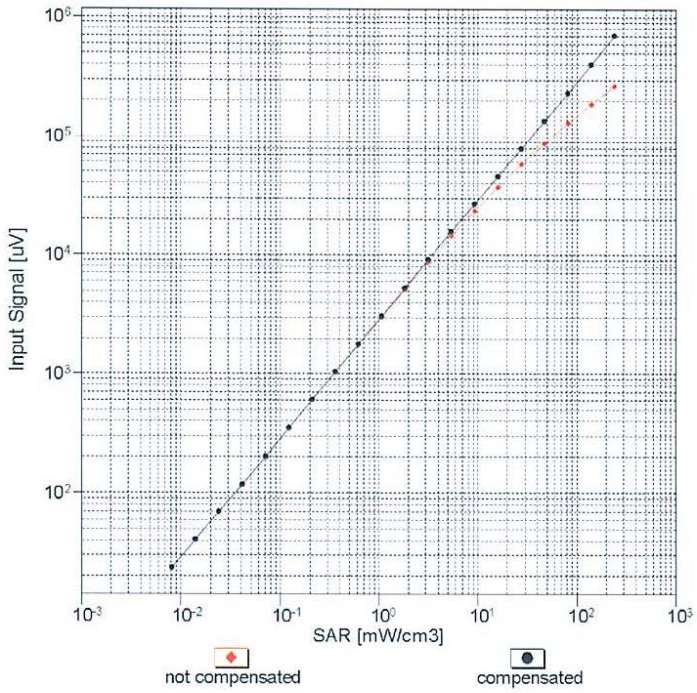
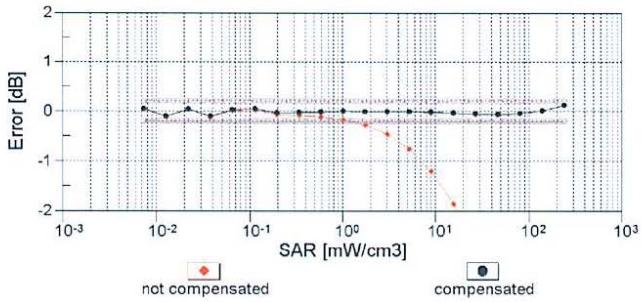
## Dynamic Range f(SAR$_{head}$)
(TEM cell , $f_{eval}$= 1900 MHz)



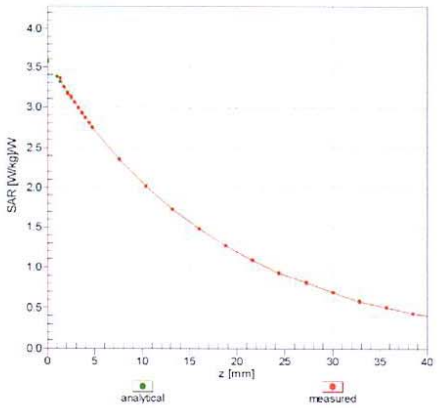

**Uncertainty of Linearity Assessment: ± 0.6% (k=2)**

Certificate No: EX3-3619_Sep16 Page 9 of 11

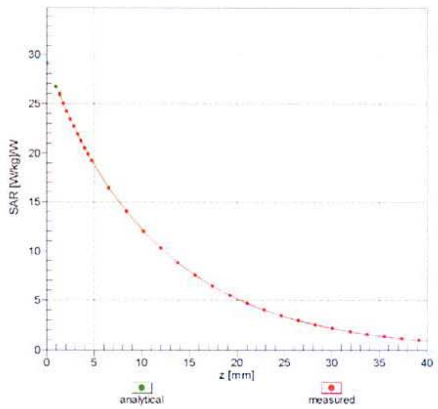
EX3DV4– SN:3619 September 23, 2016

## Conversion Factor Assessment

f = 835 MHz,WGLS R9 (H_convF)

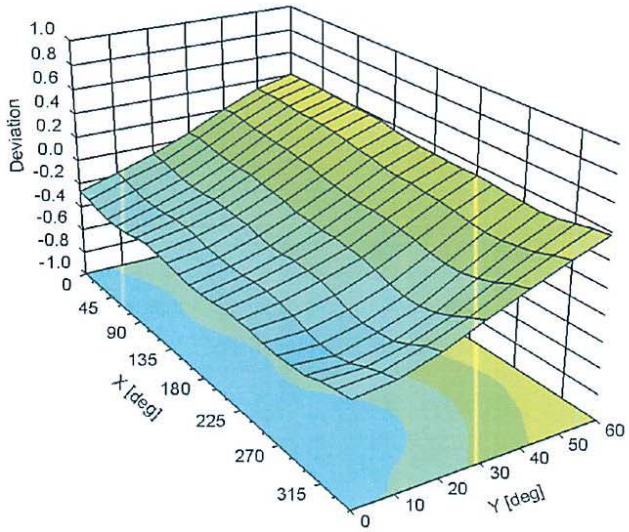


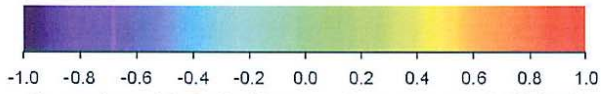

f = 1900 MHz,WGLS R22 (H_convF)




## Deviation from Isotropy in Liquid

**Error (ϕ, ϑ), f = 900 MHz**




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

Certificate No: EX3-3619_Sep16 Page 10 of 11

# DASY/EASY - Parameters of Probe: EX3DV4 - SN:3619

## Other Probe Parameters

| | |
|---|---|
| Sensor Arrangement | Triangular |
| Connector Angle (°) | 30 |
| Mechanical Surface Detection Mode | enabled |
| Optical Surface Detection Mode | disabled |
| Probe Overall Length | 337 mm |
| Probe Body Diameter | 10 mm |
| Tip Length | 9 mm |
| Tip Diameter | 2.5 mm |
| Probe Tip to Sensor X Calibration Point | 1 mm |
| Probe Tip to Sensor Y Calibration Point | 1 mm |
| Probe Tip to Sensor Z Calibration Point | 1 mm |
| Recommended Measurement Distance from Surface | 1.4 mm |

# 12 Appendix C – Dipole Calibration Certificates

**NCL CALIBRATION LABORATORIES**

Calibration File No: DC-1578
Project Number: BACL-dipole-cal-5774

**CERTIFICATE OF CALIBRATION**

It is certified that the equipment identified below has been calibrated in the **NCL CALIBRATION LABORATORIES** by qualified personnel following recognized procedures and using transfer standards traceable to NRC/NIST.

BACL Validation Dipole (Head & Body)

Manufacturer: APREL Laboratories
Part number: D-2450-S-1
Frequency: 2450 MHz
Serial No: BCL-141

Customer: Bay Area Compliance Laboratory

Calibrated: 19th August 2014
Released on: 20th August 2014

This Calibration Certificate is Incomplete Unless Accompanied with the Calibration Results Summary

Released By: _____
Art Brennan, Quality Manager

**NCL** CALIBRATION LABORATORIES

Suite 102, 303 Terry Fox Dr.
Kanata, ONTARIO
CANADA K2K 3J1

Division of APREL Lab.
TEL: (613) 435-8300
FAX: (613) 432-8306

**NCL Calibration Laboratories**
Division of APREL Laboratories.

## Conditions

Dipole BCL-141 was received from customer in good condition for re-calibration, SMA connector required cleaning prior to calibration.

**Ambient Temperature of the Laboratory:** 22 °C ± 0.5°C
**Temperature of the Tissue:** 21 °C ± 0.5°C

**Attestation**

The below named signatories have conducted the calibration and review of the data which is presented in this calibration report.

**We the undersigned attest that to the best of our knowledge the calibration of this subject has been accurately conducted and that all information contained within the results pages have been reviewed for accuracy.**

**Art Brennan, Quality Manager**

**Maryna Nesterova Calibration Engineer**

This page has been reviewed for content and attested to by signature within this document.

**NCL Calibration Laboratories**
Division of APREL Laboratories.

## Calibration Results Summary

The following results relate the Calibrated Dipole and should be used as a quick reference for the user.

**Mechanical Dimensions**

**Length:** 49.8 mm
**Height:** 29.9 mm

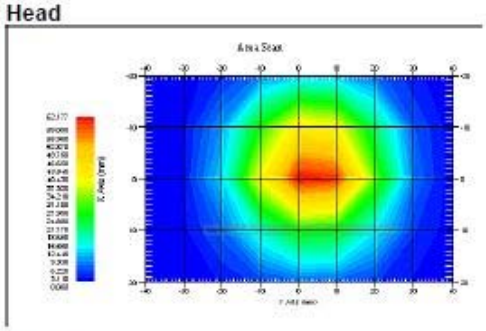
**Electrical Calibration**

| Test | Result Head | Result Body |
|---|---|---|
| S11 R/L | -28.771 dB | -24.946 dB |
| SWR | 1.075 U | 1.120 U |
| Impedance | 53.072 Ω | 55.701 Ω |

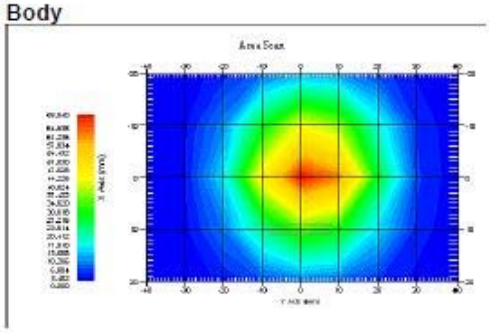
**System Validation Results**

| Frequency 2450 MHz | 1 Gram | 10 Gram |
|---|---|---|
| Head | 52.985 | 24.065 |
| Body | 56.519 | 24.855 |

**Head**



**Body**



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## Introduction

This Calibration Report has been produced in line with the SSI Dipole Calibration Procedure SSI-TP-018-ALSAS. The results contained within this report are for Validation Dipole BCL-141. The calibration routine consisted of a three-step process. Step 1 was a mechanical verification of the dipole to ensure that it meets the mechanical specifications. Step 2 was an Electrical Calibration for the Validation Dipole, where the SWR, Impedance, and the Return loss were assessed. Step 3 involved a System Validation using the ALSAS-10U, along with APREL E-020 30 MHz to 6 GHz E-Field Probe Serial Number 225.

## References

- SSI-TP-018-ALSAS Dipole Calibration Procedure
- SSI-TP-016 Tissue Calibration Procedure
- IEEE 1528 "Recommended Practice for Determining the Peak Spatial-Average Specific Absorption Rate (SAR) in the Human Body Due to Wireless Communications Devices: Experimental Techniques"
- IEC-62209 "Human exposure to radio frequency fields from hand-held and body-mounted wireless communication devices – Human models, instrumentation, and procedures"
- Part 1: "Procedure to determine the Specific Absorption Rate (SAR) for hand-held devices used in close proximity of the ear (frequency range of 300 MHz to 3 GHz)"
- IEC-62209 "Human exposure to radio frequency fields from hand-held and body-mounted wireless communication devices – Human models, instrumentation, and procedures"
- Part 2: "Procedure to determine the Specific Absorption Rate (SAR) for hand-held devices used in close proximity of the ear (frequency range of 30 MHz to 6 GHz)"
- TP-D01-032-E020-V2 E-Field probe calibration procedure
- D22-012-Tissue dielectric tissue calibration procedure
- D28-002-Dipole procedure for validation of SAR system using a dipole
- IEEE 1309 Draft Standard for Calibration of Electromagnetic Field Sensors and Probes, Excluding Antennas, from 9 kHz to 40 GHz

## Conditions

Dipole BCL-141 was received from customer in good condition for re-calibration, SMA connector required cleaning prior to calibration.

**Ambient Temperature of the Laboratory:** 21 °C ± 0.5°C
**Temperature of the Tissue:** 20 °C ± 0.5°C



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## Dipole Calibration Results

### Mechanical Verification

| APREL Length | APREL Height | Measured Length | Measured Height |
|---|---|---|---|
| 51.0 mm | 30.0 mm | 49.8 mm | 29.9 mm |

### Tissue Validation

| Tissue 2450MHz | Measured Head | Measured Body |
|---|---|---|
| Dielectric constant, $\varepsilon_r$ | 37.61 | 53.69 |
| Conductivity, $\sigma$ [S/m] | 1.86 | 1.96 |

### Dipole Calibration uncertainty

The calibration uncertainty for the dipole is made up of various parameters presented below.

| | |
|---|---|
| **Mechanical** | 1% |
| **Positioning Error** | 1.22% |
| **Electrical** | 1.7% |
| **Tissue** | 2.2% |
| **Dipole Validation** | 2.2% |
| **TOTAL** | **8.32% (16.64% K=2)** |

### Primary Measurement Standards

| Instrument | Serial Number | Cal due date |
|---|---|---|
| Tektronix USB Power Meter | 11C940 | May 14, 2015 |
| Network Analyzer Anritsu 37347C | 002106 | Feb. 20, 2015 |
| Agilent Signal Generator | MY45094463 | Dec. 2015 |

We have a two year calibration interval.

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Division of APREL Laboratories.

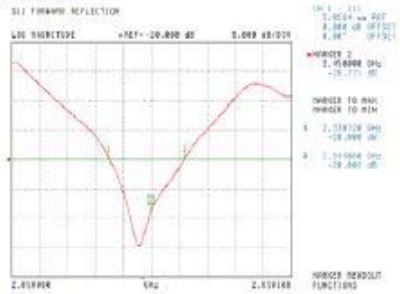
## Electrical Calibration

| Test | Result Head | Result Body |
|---|---|---|
| S11 R/L | -28.771 dB | -24.946 dB |
| SWR | 1.075 U | 1.120 U |
| Impedance | 53.072 Ω | 55.701 Ω |

The Following Graphs are the results as displayed on the Vector Network Analyzer.

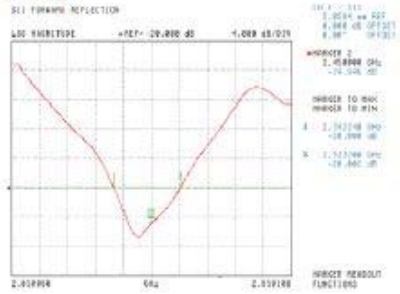
### S11 Parameter Return Loss

**HEAD**



Frequency Range 2330 MHz to 2544 MHz

**BODY**



Frequency Range 2342 MHz to 2532 MHz

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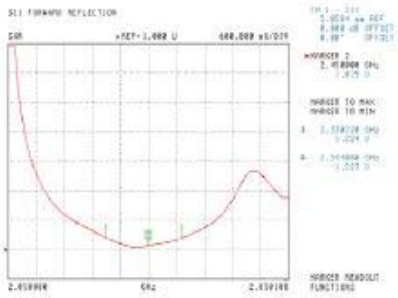
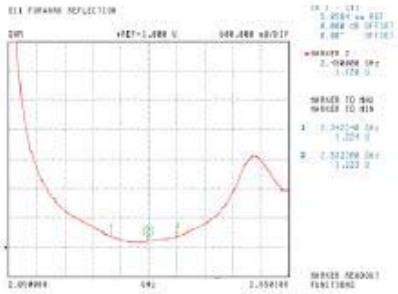
## SWR

### Head



### Body



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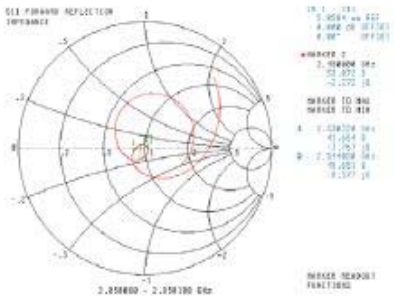
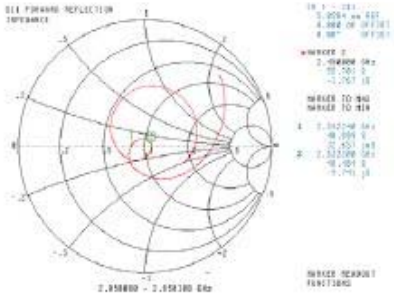
## Smith Chart Dipole Impedance

### Head



### Body



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Division of APREL Laboratories.

## Test Equipment

The test equipment used during Probe Calibration, manufacturer, model number and, current calibration status are listed and located on the main APREL server R:\NCL\Calibration Equipment\Instrument List May 2014.



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# 13 Appendix D - Test System Verifications Scans

Test Laboratory: Bay Area Compliance Lab Corp. (BACL)

**2450 MHz Body System Validation**

**DUT: Dipole 2450 MHz; Type: D-2450-S-1; S/N: BCL-141**

Communication System: CW; Frequency: 2450 MHz;Duty Cycle: 1:1
Medium parameters used: f = 2450 MHz; $\sigma$ = 1.97 mho/m; $\varepsilon_r$ = 51.6; $\rho$ = 1000 kg/m$^3$
Phantom section: Flat Section
Measurement Standard: DASY4 (High Precision Assessment)

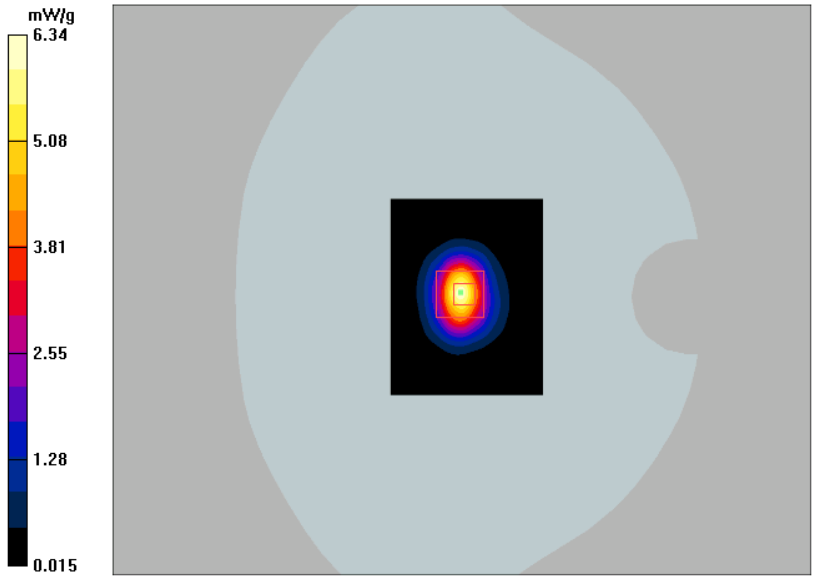
DASY4 Configuration:

- Probe: EX3DV4 - SN3619; ConvF(6.69, 6.69, 6.69); Calibrated: 9/23/2016
- Sensor-Surface: 4mm (Mechanical Surface Detection)
- Electronics: DAE4 Sn530; Calibrated: 9/21/2016
- Phantom: SAM with CRP; Type: SAM; Serial: TP-1032
- Measurement SW: DASY4, V4.7 Build 80; Postprocessing SW: SEMCAD, V1.8 Build 186

**d=10 mm, Pin = 0.1 W/Area Scan (71x91x1):** Measurement grid: dx=10mm, dy=10mm
Maximum value of SAR (interpolated) = 6.20 mW/g

**d=10mm, Pin = 0.1 W/Zoom Scan (7x7x7)/Cube 0:** Measurement grid: dx=5mm, dy=5mm, dz=5mm
Reference Value = 55.6 V/m; Power Drift = 0.069 dB
Peak SAR (extrapolated) = 12.8 W/kg

**SAR (1 g) = 5.52 mW/g; SAR (10 g) = 2.37 mW/g**
Maximum value of SAR (measured) = 6.34 mW/g



Test Laboratory: Bay Area Compliance Lab Corp. (BACL)

**2450 MHz Head System Validation**

**DUT: Dipole 2450 MHz; Type: D-2450-S-1; S/N: BCL-141**

Communication System: CW; Frequency: 2450 MHz;Duty Cycle: 1:1
Medium parameters used: f = 2450 MHz; $\sigma$ = 1.81 mho/m; $\varepsilon_r$ = 38.9; $\rho$ = 1000 kg/m$^3$
Phantom section: Flat Section
Measurement Standard: DASY4 (High Precision Assessment)

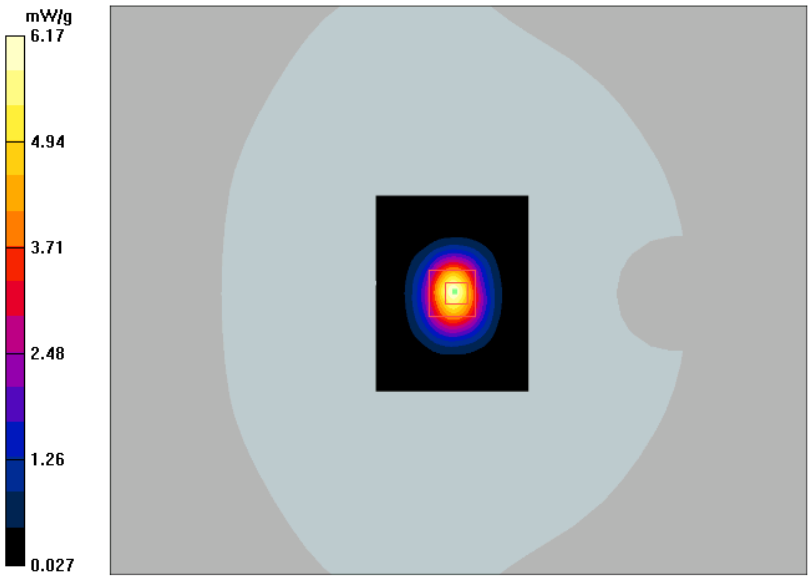
DASY4 Configuration:

- Probe: EX3DV4 - SN3619; ConvF(6.64, 6.64, 6.64); Calibrated: 9/23/2016
- Sensor-Surface: 4mm (Mechanical Surface Detection)
- Electronics: DAE4 Sn530; Calibrated: 9/21/2016
- Phantom: SAM with CRP; Type: SAM; Serial: TP-1032
- Measurement SW: DASY4, V4.7 Build 80; Postprocessing SW: SEMCAD, V1.8 Build 186

**d=10mm, Pin = 0.1 W/Area Scan (71x91x1):** Measurement grid: dx=10mm, dy=10mm
Maximum value of SAR (interpolated) = 6.03 mW/g

**d=10mm, Pin = 0.1 W/Zoom Scan (7x7x7)/Cube 0:** Measurement grid: dx=5mm, dy=5mm, dz=5mm
Reference Value = 58.1 V/m; Power Drift = 0.101 dB
Peak SAR (extrapolated) = 12.4 W/kg

**SAR (1 g) = 5.45 mW/g; SAR (10 g) = 2.44 mW/g**
Maximum value of SAR (measured) = 6.17 mW/g



# 14 Appendix E - EUT Scan Results (Maximum)

Test Laboratory: Bay Area Compliance Lab Corp. (BACL)

**Body Rear Touch Phantom 802.11b mode, High CH, 2462 MHz**

**DUT: Intel; Type: Watch; Serial: BID301EQ645002Q**

Communication System: 802.11b; Frequency: 2462 MHz; Duty Cycle: 1:1
Medium parameters used: f = 2462 MHz; $\sigma$ = 1.99 mho/m; $\varepsilon_r$ = 51.5; $\rho$ = 1000 kg/m$^3$
Phantom section: Flat Section
Measurement Standard: DASY4 (High Precision Assessment)

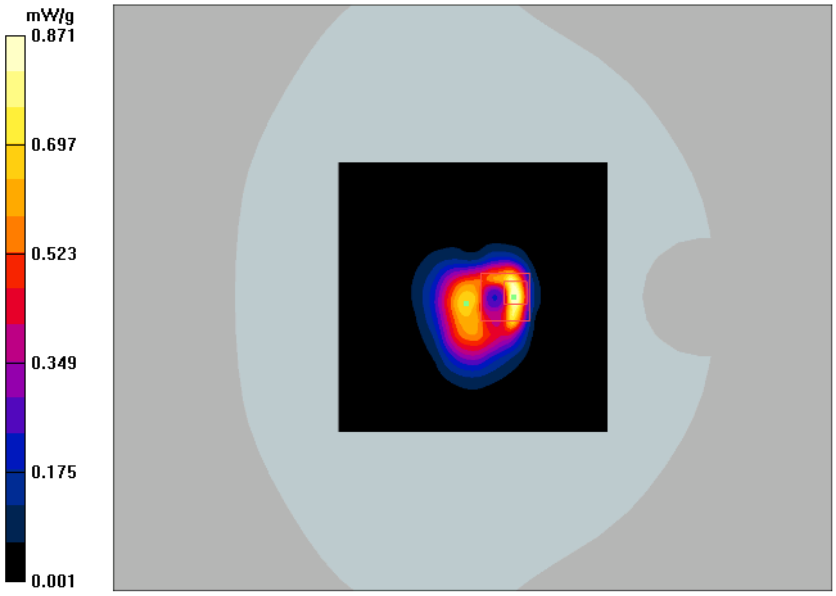
DASY4 Configuration:

- Probe: EX3DV4 - SN3619; ConvF(6.69, 6.69, 6.69); Calibrated: 9/23/2016
- Sensor-Surface: 4mm (Mechanical Surface Detection)
- Electronics: DAE4 Sn530; Calibrated: 9/21/2016
- Phantom: SAM with CRP; Type: Twin SAM; Serial: TP-1032
- Measurement SW: DASY4, V4.7 Build 80; Postprocessing SW: SEMCAD, V1.8 Build 186

**Rear Touch to Phantom High Channel/Area Scan (121x121x1):** Measurement grid: dx=10mm, dy=10mm
Maximum value of SAR (interpolated) = 0.931 mW/g

**Rear Touch to Phantom High Channel/Zoom Scan (7x7x7)/Cube 0:** Measurement grid: dx=5mm, dy=5mm, dz=5mm
Reference Value = 18.5 V/m; Power Drift = -0.204 dB
Peak SAR (extrapolated) = 2.51 W/kg

**SAR (1 g) = 0.727 mW/g; SAR (10 g) = 0.279 mW/g**
Maximum value of SAR (measured) = 0.871 mW/g




**#1**

Test Laboratory: Bay Area Compliance Lab Corp. (BACL)

**Head Speaker on, Front 10mm to Phantom, 802.11b mode, Mid CH, 2437 MHz**

**DUT: Intel; Type: Watch; Serial: BID301EQ645002Q**

Communication System: 802.11b; Frequency: 2437 MHz; Duty Cycle: 1:1
Medium parameters used: f = 2437 MHz; $\sigma$ = 1.8 mho/m; $\varepsilon_r$ = 38.9; $\rho$ = 1000 kg/m$^3$
Phantom section: Flat Section
Measurement Standard: DASY4 (High Precision Assessment)

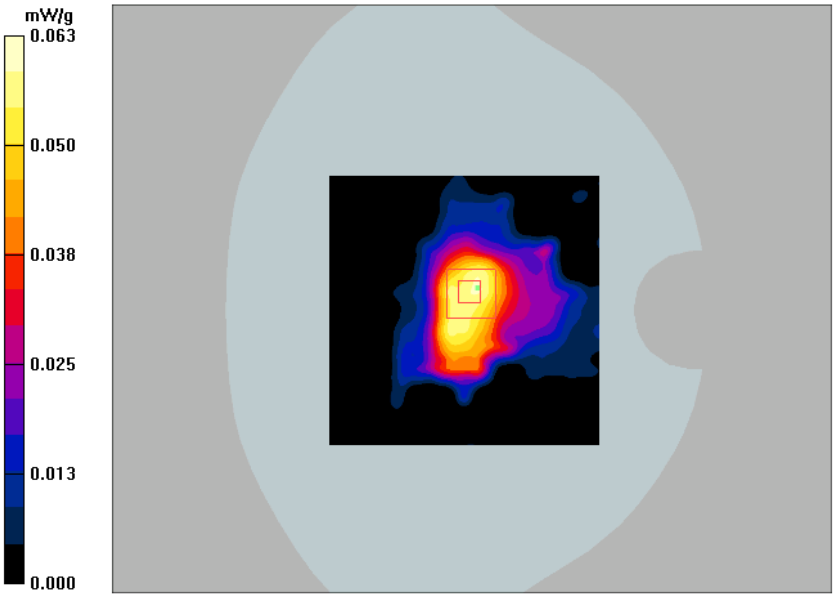
DASY4 Configuration:

- Probe: EX3DV4 - SN3619; ConvF(6.64, 6.64, 6.64); Calibrated: 9/23/2016
- Sensor-Surface: 4mm (Mechanical Surface Detection)
- Electronics: DAE4 Sn530; Calibrated: 9/21/2016
- Phantom: SAM with CRP; Type: Twin SAM; Serial: TP-1032
- Measurement SW: DASY4, V4.7 Build 80; Postprocessing SW: SEMCAD, V1.8 Build 186

**Front 10mm to Phantom Mid Channel/Area Scan (121x121x1):** Measurement grid: dx=10mm, dy=10mm
Maximum value of SAR (interpolated) = 0.060 mW/g

**Front 10mm to Phantom Mid Channel/Zoom Scan (7x7x7)/Cube 0:** Measurement grid: dx=5mm, dy=5mm, dz=5mm
Reference Value = 5.33 V/m; Power Drift = 0.742 dB
Peak SAR (extrapolated) = 0.116 W/kg

**SAR (1 g) = 0.058 mW/g; SAR (10 g) = 0.031 mW/g**
Maximum value of SAR (measured) = 0.063 mW/g




**#2**

Test Laboratory: Bay Area Compliance Lab Corp. (BACL)

**Body Rear Touch Phantom, BT GFSK, High CH, 2480 MHz**

**DUT: Intel; Type: Watch; Serial: BID301EQ645002Q**

Communication System: Bluetooth; Frequency: 2480 MHz;Duty Cycle: 1:1
Medium parameters used: f = 2480 MHz; $\sigma$ = 2.01 mho/m; $\varepsilon_r$ = 51.4; $\rho$ = 1000 kg/m$^3$
Phantom section: Flat Section
Measurement Standard: DASY4 (High Precision Assessment)

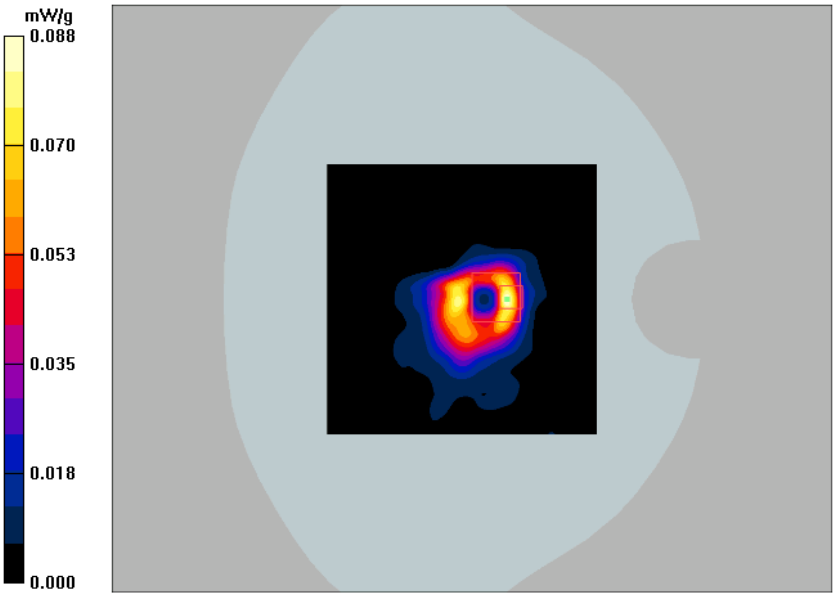
DASY4 Configuration:

- Probe: EX3DV4 - SN3619; ConvF(6.69, 6.69, 6.69); Calibrated: 9/23/2016
- Sensor-Surface: 4mm (Mechanical Surface Detection)
- Electronics: DAE4 Sn530; Calibrated: 9/21/2016
- Phantom: SAM with CRP; Type: Twin SAM; Serial: TP-1032
- Measurement SW: DASY4, V4.7 Build 80; Postprocessing SW: SEMCAD, V1.8 Build 186

**Rear Touch to Phantom High Channel/Area Scan (121x121x1):** Measurement grid: dx=10mm, dy=10mm
Maximum value of SAR (interpolated) = 0.087 mW/g

**Rear Touch to Phantom High Channel/Zoom Scan (7x7x7)/Cube 0:** Measurement grid: dx=5mm, dy=5mm, dz=5mm
Reference Value = 5.88 V/m; Power Drift = -0.238 dB
Peak SAR (extrapolated) = 0.172 W/kg

**SAR (1 g) = 0.070 mW/g; SAR (10 g) = 0.028 mW/g**
Maximum value of SAR (measured) = 0.088 mW/g




**#3**

Test Laboratory: Bay Area Compliance Lab Corp. (BACL)

**Head Speaker on, Front 10mm Phantom, BT GFSK, Mid CH, 2441MHz**

**DUT: Intel; Type: Watch; Serial: BID301EQ645002Q**

Communication System: Bluetooth; Frequency: 2441 MHz;Duty Cycle: 1:1
Medium parameters used: f = 2441 MHz; $\sigma$ = 1.8 mho/m; $\varepsilon_r$ = 38.9; $\rho$ = 1000 kg/m$^3$
Phantom section: Flat Section
Measurement Standard: DASY4 (High Precision Assessment)

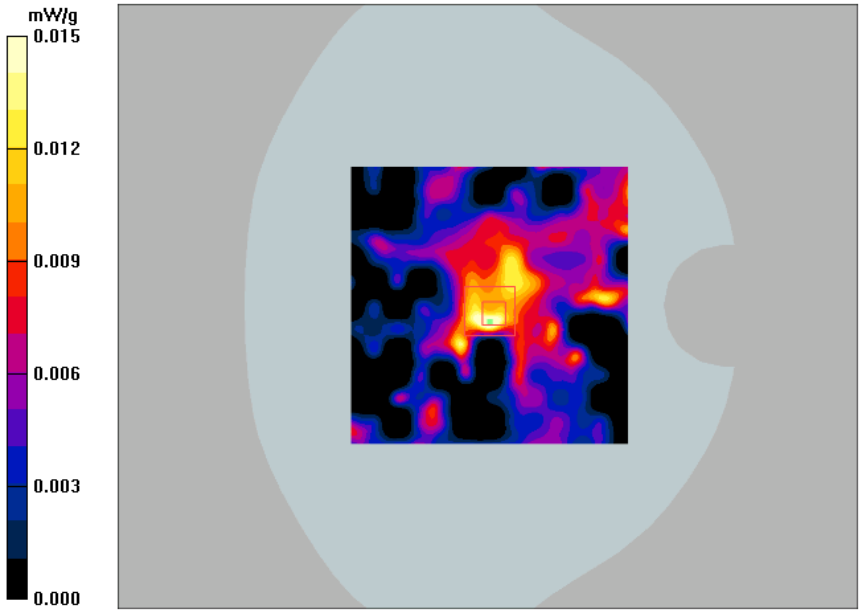
DASY4 Configuration:

- Probe: EX3DV4 - SN3619; ConvF(6.64, 6.64, 6.64); Calibrated: 9/23/2016
- Sensor-Surface: 4mm (Mechanical Surface Detection)
- Electronics: DAE4 Sn530; Calibrated: 9/21/2016
- Phantom: SAM with CRP; Type: Twin SAM; Serial: TP-1032
- Measurement SW: DASY4, V4.7 Build 80; Postprocessing SW: SEMCAD, V1.8 Build 186

**Front 10mm to Phantom Mid Channel/Area Scan (121x121x1):** Measurement grid: dx=10mm, dy=10mm
Maximum value of SAR (interpolated) = 0.018 mW/g

**Front 10mm to Phantom Mid Channel/Zoom Scan (7x7x7)/Cube 0:** Measurement grid: dx=5mm, dy=5mm, dz=5mm
Reference Value = 2.07 V/m; Power Drift = 0.086 dB
Peak SAR (extrapolated) = 0.063 W/kg

**SAR (1 g) = 0.012 mW/g; SAR (10 g) = 0.00477 mW/g**
Maximum value of SAR (measured) = 0.015 mW/g




**#4**

# 15 Appendix F- RF Output Power Measurement

**RF Output Power Measurement Results**

2.4 GHz WLAN:

| Modulation | Frequency (MHz) | Output Average Power Conducted (dBm) | |
|---|---|---|---|
| | | Measured | Target |
| 2.4 GHz 802.11b | 2412 | 15.04 | 15.5 |
| | 2437 | 15.11 | 15.5 |
| | 2462 | 15.06 | 15.5 |
| 2.4 GHz 802.11g | 2412 | 15.43 | 15.5 |
| | 2437 | 15.46 | 15.5 |
| | 2462 | 15.41 | 15.5 |
| 2.4 GHz 802.11n HT20 | 2412 | 15.34 | 15.5 |
| | 2437 | 15.35 | 15.5 |
| | 2462 | 15.34 | 15.5 |

2.4 GHz Bluetooth:

| Modulation | Frequency (MHz) | Output Peak Power Conducted (dBm) | |
|---|---|---|---|
| | | Measured | Target |
| BT-GFSK | 2402 | 9.22 | 9.5 |
| | 2441 | 9.17 | 9.5 |
| | 2480 | 9.00 | 9.5 |
| BT-DQPSK | 2402 | 6.95 | 7.5 |
| | 2441 | 7.02 | 7.5 |
| | 2480 | 6.73 | 7.5 |
| BT-8DPSK | 2402 | 7.34 | 7.5 |
| | 2441 | 7.38 | 7.5 |
| | 2480 | 7.09 | 7.5 |
| BT-BLE | 2402 | 8.21 | 8.5 |
| | 2440 | 8.39 | 8.5 |
| | 2480 | 8.14 | 8.5 |