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Rev : 01
Page : 1 of 38

FCC SAR TEST REPORT

Application No: SZEM180600 5189RG

Applicant: BrainCo Inc.

Manufacturer: BrainCo Inc.

Factory: Huizhou BYD ELECTRONIC CO., LTD

Product Name: Wearable BCI Device

Model No.(EUT): FE-01

Trade Mark: BrainCo

FCC ID: 2AQA9BCFE01

Standards: FCC 47CFR §2.1093

Date of Receipt: 2018-06-15

Date of Test: 2018-06-21 to 2018-06-21

Date of Issue: 2018-07-17

Test Result: **PASS ***

* In the configuration tested, the EUT detailed in this report complied with the standards specified above.

Authorized Signature:

Derek Yang

Wireless Laboratory Manager

The manufacturer should ensure that all products in series production are in conformity with the product sample detailed in this report. If the product in this report is used in any configuration other than that detailed in the report, the manufacturer must ensure the new system complies with all relevant standards. Any mention of SGS International Electrical Approvals or testing done by SGS International Electrical Approvals in connection with, distribution or use of the product described in this report must be approved by SGS International Electrical Approvals in writing.

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REVISION HISTORY

| Revision Record | | | | |
|-----------------|---------|------------|----------|----------|
| Version | Chapter | Date | Modifier | Remark |
| 01 | | 2018-07-17 | | Original |
| | | | | |
| | | | | |

TEST SUMMARY

| Frequency Band | Maximum Reported SAR(W/kg) |
|-----------------------|-----------------------------------|
| | Head |
| WI-FI (2.4GHz) | 0.16 |
| SAR Limited(W/kg) | 1.6 |

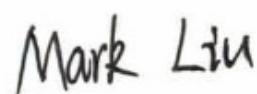
Approved & Released by



Simon Ling

SAR Manager

Tested by



Mark Liu

SAR Engineer

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1 General Information

1.1 Details of Client

| | |
|---------------|--|
| Applicant: | BrainCo Inc. |
| Address: | 120 Beacon St. STE 201, Somerville, MA, 02143 Boston Massachusetts United States |
| Manufacturer: | BrainCo Inc. |
| Address: | 120 Beacon St. STE 201, Somerville, MA, 02143 Boston Massachusetts United States |
| Factory: | Huizhou BYD ELECTRONIC CO.,LTD |
| Address: | Xiangshui River,Economic Development Zone,Daya Bay, Huizhou, Guangdong, 516083,P.R.China |

1.2 Test Location

Company: SGS-CSTC Standards Technical Services Co., Ltd. Shenzhen Branch
Address: No. 1 Workshop, M-10, Middle section, Science & Technology Park, Shenzhen, Guangdong, China
Post code: 518057
Telephone: +86 (0) 755 2601 2053
Fax: +86 (0) 755 2671 0594
E-mail: ee.shenzhen@sgs.com

1.3 Test Facility

The test facility is recognized, certified, or accredited by the following organizations:

- **CNAS (No. CNAS L2929)**

CNAS has accredited SGS-CSTC Standards Technical Services Co., Ltd. Shenzhen Branch EMC Lab to ISO/IEC 17025:2005 General Requirements for the Competence of Testing and Calibration Laboratories (CNAS-CL01 Accreditation Criteria for the Competence of Testing and Calibration Laboratories) for the competence in the field of testing.

- **A2LA (Certificate No. 3816.01)**

SGS-CSTC Standards Technical Services Co., Ltd., Shenzhen EMC Laboratory is accredited by the American Association for Laboratory Accreditation(A2LA). Certificate No. 3816.01.

- **VCCI**

The 10m Semi-anechoic chamber and Shielded Room of SGS-CSTC Standards Technical Services Co., Ltd. have been registered in accordance with the Regulations for Voluntary Control Measures with Registration No.: G-823, R-4188, T-1153 and C-2383 respectively.

- **FCC –Designation Number: CN1178**

SGS-CSTC Standards Technical Services Co., Ltd., Shenzhen EMC Laboratory has been recognized as an accredited testing laboratory.

Designation Number: CN1178. Test Firm Registration Number: 406779.

- **Industry Canada (IC)**

Two 3m Semi-anechoic chambers and the 10m Semi-anechoic chamber of SGS-CSTC Standards Technical Services Co., Ltd. Shenzhen Branch EMC Lab have been registered by Certification and Engineering Bureau of Industry Canada for radio equipment testing with Registration No.: 4620C-1, 4620C-2, 4620C-3.

1.4 General Description of EUT

| | |
|--------------------|---|
| Product Name: | Wearable BCI Device |
| Model No.(EUT): | FE-01 |
| Trade Mark: | BrainCo |
| Product Phase: | production unit |
| Device Type : | portable device |
| Exposure Category: | uncontrolled environment / general population |
| SN: | BCFE0142170218F828 |
| FCC ID: | 2AQA9BCFE01 |
| Hardware Version: | Focus1-EDU-xBeta V1.0.10 |
| Software Version: | V1.0.15.C |
| Antenna Type: | Inner antenna |

Device Operating Configurations :

| | | | |
|----------------------|------------------|-------------------------------------|-----------|
| Modulation Mode: | WIFI: DSSS, OFDM | | |
| Frequency Bands: | Band | Tx (MHz) | Rx (MHz) |
| | WIFI | 2412-2462 | 2412-2462 |
| Battery Information: | Model: | GSP581933 | |
| | Normal Voltage : | 3.7Vdc | |
| | Rated capacity : | 400mAh | |
| | Manufacturer | ZHUHAI GREAT POWER ENERGY CO., LTD. | |

1.5 Test Specification

| Identity | Document Title |
|--|---|
| FCC 47CFR §2.1093 | Radiofrequency Radiation Exposure Evaluation: Portable Devices |
| ANSI/IEEE Std C95.1 – 1992 | IEEE Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz – 300 GHz. |
| IEEE 1528-2013 | Recommended Practice for Determining the Peak Spatial-Average Specific Absorption Rate (SAR) in the Human Head from Wireless Communications Devices: Measurement Techniques |
| KDB 248227 D01 802.11 Wi-Fi SAR v02r02 | SAR GUIDANCE FOR IEEE 802.11 (Wi-Fi) TRANSMITTERS |
| KDB447498 D01 General RF Exposure Guidance v06 | Mobile and Portable Devices RF Exposure Procedures and Equipment Authorization Policies |
| KDB447498 D03 Supplement C Cross-Reference v01 | OET Bulletin 65, Supplement C Cross-Reference |
| KDB 865664 D01 SAR Measurement 100 MHz to 6 GHz v01r04 | SAR Measurement Requirements for 100 MHz to 6 GHz |
| KDB 865664 D02 RF Exposure Reporting v01r02 | RF Exposure Compliance Reporting and Documentation Considerations |

1.6 RF exposure limits

| Human Exposure | Uncontrolled Environment General Population | Controlled Environment Occupational |
|--|--|--|
| Spatial Peak SAR* (Brain) | 1.60 W/kg | 8.00 W/kg |
| Spatial Average SAR** (Whole Body) | 0.08 W/kg | 0.40 W/kg |
| Spatial Peak SAR*** (Hands/Feet/Ankle/Wrist) | 4.00 W/kg | 20.00 W/kg |

Notes:

* The Spatial Peak value of the SAR averaged over any 1 gram of tissue (defined as a tissue volume in the shape of a cube) and over the appropriate averaging time

** The Spatial Average value of the SAR averaged over the whole body.

*** The Spatial Peak value of the SAR averaged over any 10 grams of tissue (defined as a tissue volume in the shape of a cube) and over the appropriate averaging time.

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

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

2 SAR Measurements System Configuration

2.1 The SAR Measurement System

This SAR Measurement System uses a Computer-controlled 3-D stepper motor system (SPEAG DASY5 professional system). A E-field probe is used to determine the internal electric fields. The SAR can be obtained from the equation $SAR = \sigma (|E|)^2 / \rho$ where σ and ρ are the conductivity and mass density of the tissue-Simulate.

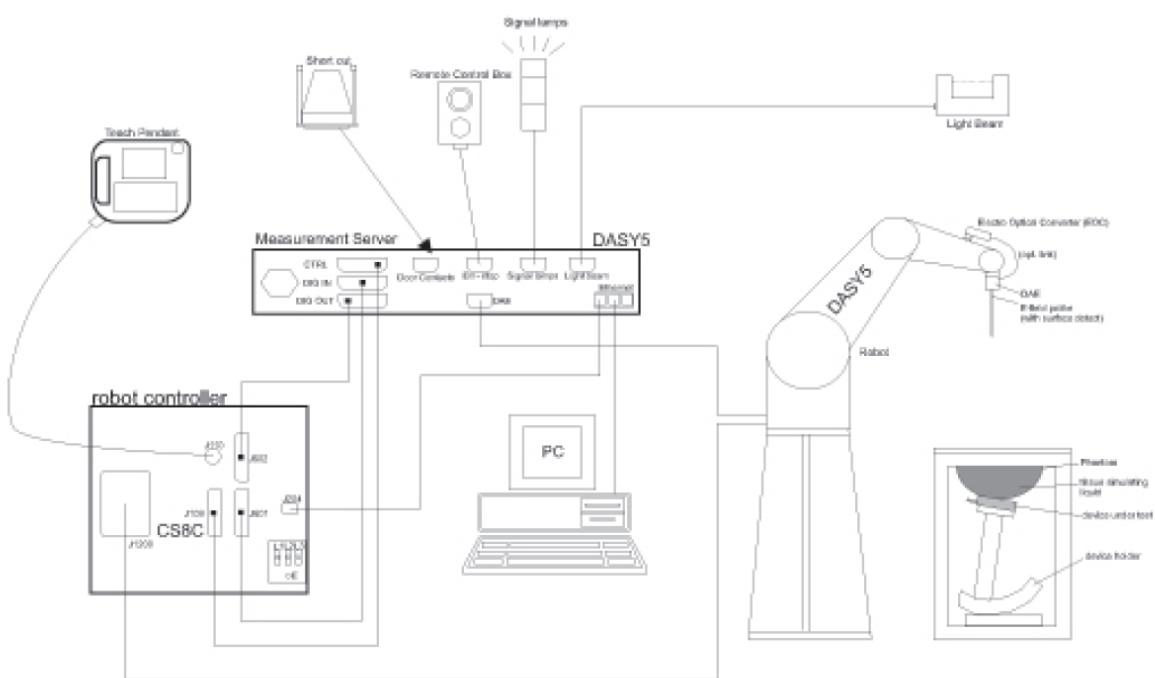
The DASY5 system for performing compliance tests consists of the following items:

A standard high precision 6-axis robot (Stabile RX family) with controller, teach pendant and software .An arm extension for accommodation 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 DAE and for the analog signal from the optical surface detection. The EOC is connected to the measurement server.



F-1. SAR Measurement System Configuration

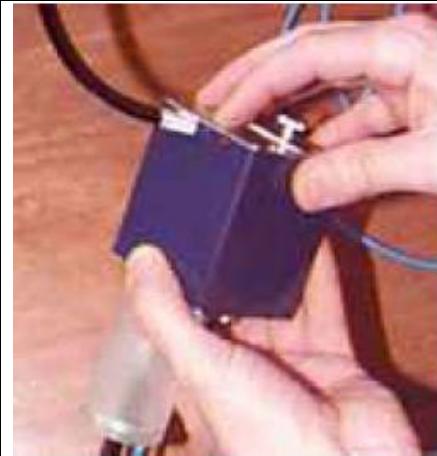
- The function of the measurement server is to perform the time critical tasks such as signal filtering, control of the robot operation and fast movement interrupts.
- A probe alignment unit which improves the (absolute) accuracy of the probe positioning.
- A computer operating Windows 7.
- DASY5 software.
- Remote control with teach pendant and additional circuitry for robot safety such as warning lamps, etc.
- The SAM twin phantom enabling testing left-hand, right-hand and Body Worn usage.
- The device holder for handheld mobile phones.
- Tissue simulating liquid mixed according to the given recipes.
- Validation dipole kits allowing to validating the proper functioning of the system.

2.2 Isotropic E-field Probe EX3DV4

| | |
|--|---|
|  | Symmetrical design with triangular core Built-in shielding against static charges PEEK enclosure material (resistant to organic solvents, e.g., DGBE) |
| Calibration | ISO/IEC 17025 calibration service available. |
| Frequency | 10 MHz to > 6 GHz Linearity: ± 0.2 dB (30 MHz to 6 GHz) |
| Directivity | ± 0.3 dB in TSL (rotation around probe axis) ± 0.5 dB in TSL (rotation normal to probe axis) |
| Dynamic Range | 10 μ W/g to > 100 mW/g Linearity: ± 0.2 dB (noise: typically < 1 μ W/g) |
| Dimensions | Overall length: 337 mm (Tip: 20 mm) Tip diameter: 2.5 mm (Body: 12 mm) Typical distance from probe tip to dipole centers: 1 mm |
| Application | High precision dosimetric measurements in any exposure scenario (e.g., very strong gradient fields); the only probe that enables compliance testing for frequencies up to 6 GHz with precision of better 30%. |
| Compatibility | DASY3, DASY4, DASY52 SAR and higher, EASY4/MRI |

2.3 Data Acquisition Electronics (DAE)

| | |
|-----------------------------|--|
| Model | DAE4 |
| Construction | Signal amplifier, multiplexer, A/D converter and control logic. Serial optical link for communication with DASY4/5 embedded system (fully remote controlled). Two step probe touch detector for mechanical surface detection and emergency robot stop. |
| Measurement Range | -100 to +300 mV (16 bit resolution and two range settings: 4mV,400mV) |
| Input Offset Voltage | < 5µV (with auto zero) |
| Input Bias Current | < 50 f A |
| Dimensions | 60 x 60 x 68 mm |



2.4 SAM Twin Phantom

| | |
|--|---|
| Material | Vinylester, glass fiber reinforced (VE-GF) |
| Liquid Compatibility | Compatible with all SPEAG tissue simulating liquids (incl. DGBE type) |
| Shell Thickness | 2 ± 0.2 mm (6 ± 0.2 mm at ear point) |
| Dimensions (incl. Wooden Support) | Length: 1000 mm Width: 500 mm Height: adjustable feet |
| Filling Volume | approx. 25 liters |
| Wooden Support | SPEAG standard phantom table |



The shell corresponds to the specifications of the Specific Anthropomorphic Mannequin (SAM) phantom defined in IEEE 1528 and IEC 62209-1. It enables the dosimetric evaluation of left and right hand phone usage as well as body mounted usage at the flat phantom region. A cover prevents evaporation of the liquid. Reference markings on the phantom allow the complete setup of all predefined phantom positions and measurement grids by teaching three points with the robot.

Twin SAM V5.0 has the same shell geometry and is manufactured from the same material as Twin SAM V4.0, but has reinforced top structure.

2.5 ELI Phantom

| | | | |
|---|---|--|--|
| Material | Vinylester, glass fiber reinforced (VE-GF) |  | |
| Liquid Compatibility | Compatible with all SPEAG tissue simulating liquids (incl. DGBE type) | | |
| Shell Thickness | 2.0 ± 0.2 mm (bottom plate) | | |
| Dimensions | Major axis: 600 mm Minor axis: 400 mm | | |
| Filling Volume | approx. 30 liters | | |
| Wooden Support | SPEAG standard phantom table | | |
| Phantom for compliance testing of handheld and body-mounted wireless devices in the frequency range of 30 MHz to 6 GHz. ELI is fully compatible with the IEC 62209-2 standard and all known tissue simulating liquids. ELI has been optimized regarding its performance and can be integrated into our standard phantom tables. A cover prevents evaporation of the liquid. Reference markings on the phantom allow installation of the complete setup, including all predefined phantom positions and measurement grids, by teaching three points. The phantom is compatible with all SPEAG dosimetric probes and dipoles. | | | |
| ELI V5.0 has the same shell geometry and is manufactured from the same material as ELI4, but has reinforced top structure. | | | |

2.6 Device Holder for Transmitters



F-2. Device Holder for Transmitters

- 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 centres for both scales are 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 $\epsilon=3$ and loss tangent $\delta=0.02$. The amount of dielectric material has been reduced in the closest vicinity of the device, since measurements have suggested that the influence of the clamp on the test results could thus be lowered.

2.7 Measurement procedure

2.7.1 Scanning procedure

Step 1: Power reference measurement

The “reference” and “drift” measurements are located at the beginning and end of the batch process. They measure the field drift at one single point in the liquid over the complete procedure.

Step 2: Area scan

The SAR distribution at the exposed side of the head was measured at a distance of 4mm from the inner surface of the shell. The area covered the entire dimension of the head and the horizontal grid spacing was 15mm*15mm or 12mm*12mm or 10mm*10mm. Based on the area scan data, the area of the maximum absorption was determined by spline interpolation.

Step 3: Zoom scan

Around this point, a volume of 30mm*30mm*30mm (fine resolution volume scan, zoom scan) was assessed by measuring 5x5x7 points (\leq 2GHz) and 7x7x7 points (\geq 2GHz). On this basis of this data set, the spatial peak SAR value was evaluated with the following procedure:

The data at the surface was extrapolated, since the centre of the dipoles is 2.0mm away from the tip of the probe and the distance between the surface and the lowest measuring point is 1.2mm. (This can be variable. Refer to the probe specification). 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. The maximum interpolated value was searched with a straight-forward algorithm. Around this maximum the SAR values averaged over the spatial volumes (1g or 10g) were computed using the 3D-Spline interpolation algorithm. The volume was integrated with the trapezoidal algorithm. One thousand points were interpolated to calculate the average. All neighbouring volumes were evaluated until no neighboring volume with a higher average value was found.

The area and zoom scan resolutions specified in the table below must be applied to the SAR measurements. Probe boundary effect error compensation is required for measurements with the probe tip closer than half a probe tip diameter to the phantom surface. Both the probe tip diameter and sensor offset distance must satisfy measurement protocols; to ensure probe boundary effect errors are minimized and the higher fields closest to the phantom surface can be correctly measured and extrapolated to the phantom surface for computing 1-g SAR. Tolerances of the post-processing algorithms must be verified by the test laboratory for the scan resolutions used in the SAR measurements, according to the reference distribution functions specified in IEEE Std. 1528-2003.

| | | ≤ 3 GHz | > 3 GHz |
|---|---|--|--|
| Maximum distance from closest measurement point (geometric center of probe sensors) to phantom surface | | 5 ± 1 mm | $\frac{1}{2} \cdot \delta \cdot \ln(2) \pm 0.5$ mm |
| Maximum probe angle from probe axis to phantom surface normal at the measurement location | | $30^\circ \pm 1^\circ$ | $20^\circ \pm 1^\circ$ |
| | | ≤ 2 GHz: ≤ 15 mm $2 - 3$ GHz: ≤ 12 mm | $3 - 4$ GHz: ≤ 12 mm $4 - 6$ GHz: ≤ 10 mm |
| Maximum area scan spatial resolution: Δx_{Area} , Δy_{Area} | | When the x or y dimension of the test device, in the measurement plane orientation, is smaller than the above, the measurement resolution must be \leq the corresponding x or y dimension of the test device with at least one measurement point on the test device. | |
| Maximum zoom scan spatial resolution: Δx_{Zoom} , Δy_{Zoom} | | ≤ 2 GHz: ≤ 8 mm $2 - 3$ GHz: ≤ 5 mm* | $3 - 4$ GHz: ≤ 5 mm* $4 - 6$ GHz: ≤ 4 mm* |
| Maximum zoom scan spatial resolution, normal to phantom surface | uniform grid: $\Delta z_{\text{Zoom}}(n)$ | | $3 - 4$ GHz: ≤ 4 mm $4 - 5$ GHz: ≤ 3 mm $5 - 6$ GHz: ≤ 2 mm |
| | graded grid | $\Delta z_{\text{Zoom}}(1)$: between 1 st two points closest to phantom surface | ≤ 4 mm |
| Minimum zoom scan volume | $\Delta z_{\text{Zoom}}(n > 1)$: between subsequent points | | $3 - 4$ GHz: ≤ 3 mm $4 - 5$ GHz: ≤ 2.5 mm $5 - 6$ GHz: ≤ 2 mm |
| | x, y, z | $\leq 1.5 \cdot \Delta z_{\text{Zoom}}(n-1)$ | ≥ 30 mm |
| Note: δ is the penetration depth of a plane-wave at normal incidence to the tissue medium; see draft standard IEEE P1528-2011 for details. | | | |
| * When zoom scan is required and the <u>reported</u> SAR from the <i>area scan based 1-g SAR estimation</i> procedures of KDB 447498 is ≤ 1.4 W/kg, ≤ 8 mm, ≤ 7 mm and ≤ 5 mm zoom scan resolution may be applied, respectively, for 2 GHz to 3 GHz, 3 GHz to 4 GHz and 4 GHz to 6 GHz. | | | |

Step 4: Power reference measurement (drift)

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 indicated drift is mainly the variation of the DUT's output power and should vary max. $\pm 5\%$

2.7.2 Data Storage

The DASY software stores the acquired data from the data acquisition electronics as raw data (in microvolt readings from the probe sensors), together with all necessary software parameters for the data evaluation (probe calibration data, liquid parameters and device frequency and modulation data) in measurement files with the extension ".DAE". The software evaluates the desired unit and format for output each time the data is visualized or exported. This allows verification of the complete software setup even after the measurement and allows correction of incorrect parameter settings. For example, if a measurement has been performed with a wrong crest factor parameter in the device setup, the parameter can be corrected afterwards and the data can be re-evaluated. The measured data can be visualized or exported in different units or formats, depending on the selected probe type ([V/m], [A/m], [°C], [m W/g], [m W/cm²], [dBrel], etc.). Some of these units are not available in certain situations or show meaningless results, e.g., a SAR output in a lossless media will always be zero. Raw data can also be exported to perform the evaluation with other software packages.

2.7.3 Data Evaluation by SEMCAD

The SEMCAD software 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 | Dcp <i>i</i> | |
| Device parameters: | - Frequency | f |
| - Crest factor | cf | |
| Media parameters: | - Conductivity | ε |
| - 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:

$$V_i = U_i + U_i^2 \cdot c f / d c p_i$$

With V_i = compensated signal of channel i ($i = x, y, z$)

U_i = input signal of channel i ($i = x, y, z$)

cf = crest factor of exciting field (DASY parameter)

dcp_i = diode compression point (DASY parameter)

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

E-field probes:

$$E_i = (V_i / Norm_i \cdot ConvF)^{1/2}$$

H-field probes:

$$H_i = (V_i)^{1/2} \cdot (a_{i0} + a_{i1}f + a_{i2}f^2) / f$$

With V_i = compensated signal of channel i $(i = x, y, z)$

Norm i = sensor sensitivity of channel i $(i = x, y, z)$

[mV/(V/m)2] for E-field Probes

ConvF = sensitivity enhancement in solution

aij = sensor sensitivity factors for H-field probes

f = carrier frequency [GHz]

Ei = electric field strength of channel i in V/m

Hi = magnetic field strength of channel i in A/m

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

$$E_{tot} = (E_x^2 + E_y^2 + E_z^2)^{1/2}$$

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

$$SAR = (E_{tot}^2 \cdot \sigma) / (\epsilon \cdot 1000)$$

with SAR = local specific absorption rate in mW/g

Etot = total field strength in V/m

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

ϵ = equivalent tissue density in g/cm3

Note that the density is normally set to 1 (or 1.06), to account for actual brain density rather than the density of the simulation liquid. The power flow density is calculated assuming the excitation field to be a free space field.

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

with Ppwe = equivalent power density of a plane wave in mW/cm2

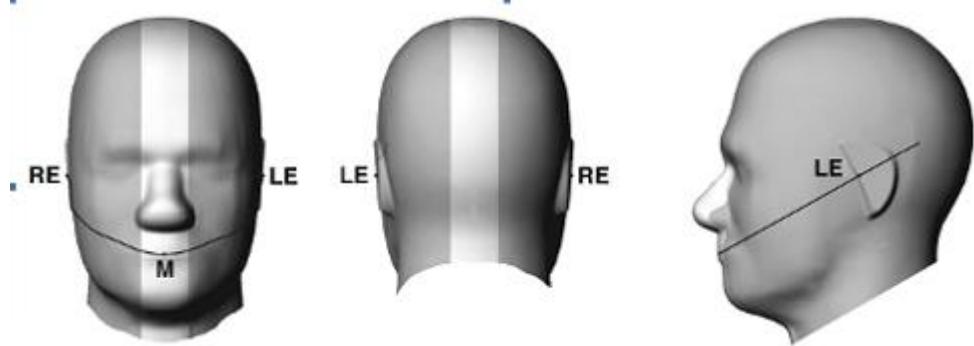
Etot = total electric field strength in V/m

Htot = total magnetic field strength in A/m

3 Description of Test Position

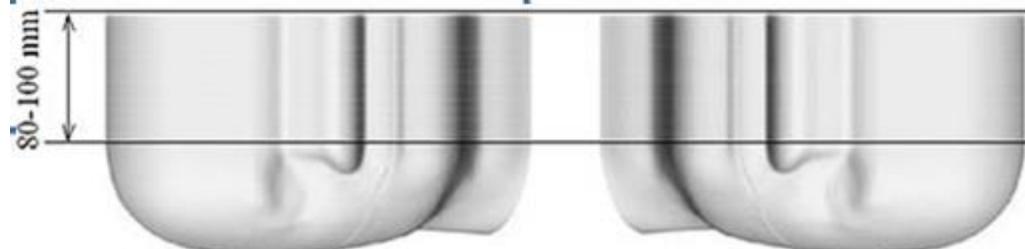
3.1 The Head Test Position

3.1.1 SAM Phantom Shape

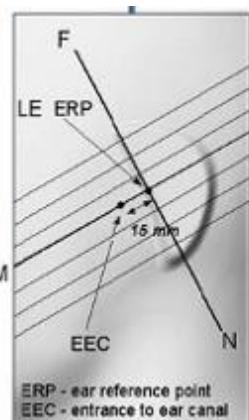


F-3. Front, back, and side views of SAM (model for the phantom shell). Full-head model is for illustration purposes only-procedures in this recommended practice are intended primarily for the phantom setup.

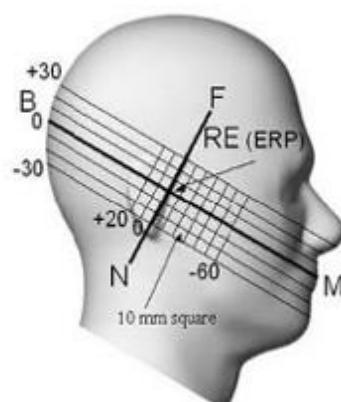
Note: The centre strip including the nose region has a different thickness tolerance.



F-4. Sagittally bisected phantom with extended perimeter (shown placed on its side as used for SAR measurements)

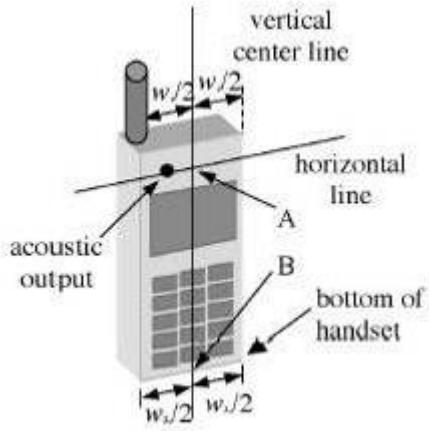


F-5. Close-up side view of phantom, showing the ear region, N-F and B-M lines, and seven cross-sectional plane locations

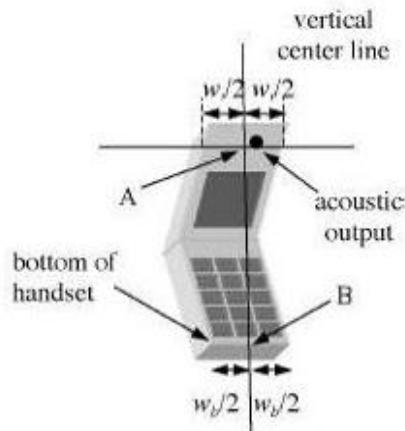


F-6. Side view of the phantom showing relevant markings and seven cross-sectional plane locations

3.1.2 EUT constructions



F-7. Handset vertical and horizontal reference lines-“fixed case”



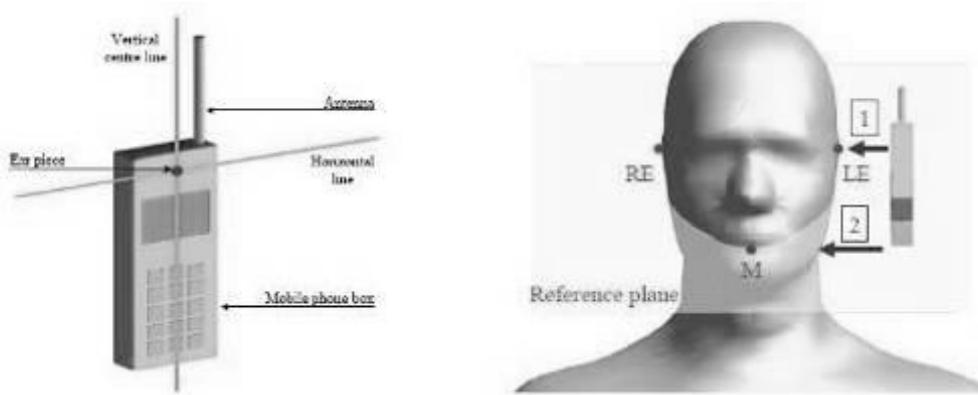
F-8. Handset vertical and horizontal reference lines-“clam-shell case”

3.1.3 Definition of the “cheek” position

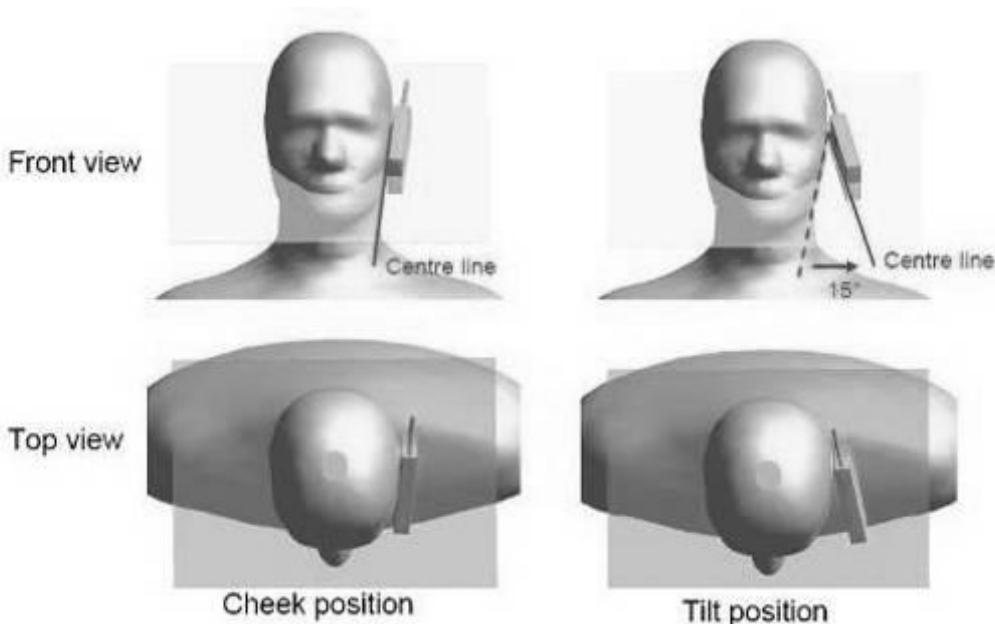
- Position the device with the vertical centre line of the body of the device and the horizontal line crossing the centre of the ear piece in a plane parallel to the sagittal plane of the phantom ("initial position"). While maintaining the device in this plane, align the vertical centre line with the reference plane containing the three ear and mouth reference points (M, RE and LE) and align the centre of the ear piece with the line RE-LE.
- Translate the mobile phone box towards the phantom with the ear piece aligned with the line LE-RE until telephone touches the ear. While maintaining the device in the reference plane and maintaining the phone contact with the ear, move the bottom of the box until any point on the front side is in contact with the cheek of the phantom or until contact with the ear is lost.

3.1.4 Definition of the “tilted” position

- Position the device in the “cheek” position described above;
- While maintaining the device in the reference plane described above and pivoting against the ear, move it outward away from the mouth by an angle of 15 degrees or until contact with the ear is lost.



F-9. Definition of the reference lines and points, on the phone and on the phantom and initial position



F-10. “Cheek” and “tilt” positions of the mobile phone on the left side

3.2 The Body Test Position

Per KDB inquiry, SAR can test the sides near the antenna, the surface of the device should be tested for SAR compliance with the device touching the phantom. The SAR Exclusion Threshold in KDB 447498 D01 can be applied to determine SAR test exclusion for adjacent edge configurations. The closest distance from the antenna to an adjacent device surface is used to determine if SAR testing is required for the adjacent surfaces, with the adjacent surface positioned against the phantom and the surface containing the antenna positioned perpendicular to the phantom.

4 SAR System Verification Procedure

4.1 Tissue Simulate Liquid

4.1.1 Recipes for Tissue Simulate Liquid

The following tables give the recipes for tissue simulating liquids to be used in different frequency bands:

| Ingredients (% by weight) | Frequency (MHz) |
|---|-----------------------------|
| | 2450 |
| Tissue Type | Head |
| Water | 55.00 |
| Salt (NaCl) | 0.2 |
| Sucrose | 0 |
| HEC | 0 |
| Bactericide | 0 |
| Tween | 44.80 |
| Salt: 99+% Pure Sodium Chloride | Sucrose: 98+% Pure Sucrose |
| Water: De-ionized, 16 MΩ ⁺ resistivity | HEC: Hydroxyethyl Cellulose |
| Tween: Polyoxyethylene (20) sorbitan monolaurate | |

Table 1 : Recipe of Tissue Simulate Liquid

4.1.2 Measurement for Tissue Simulate Liquid

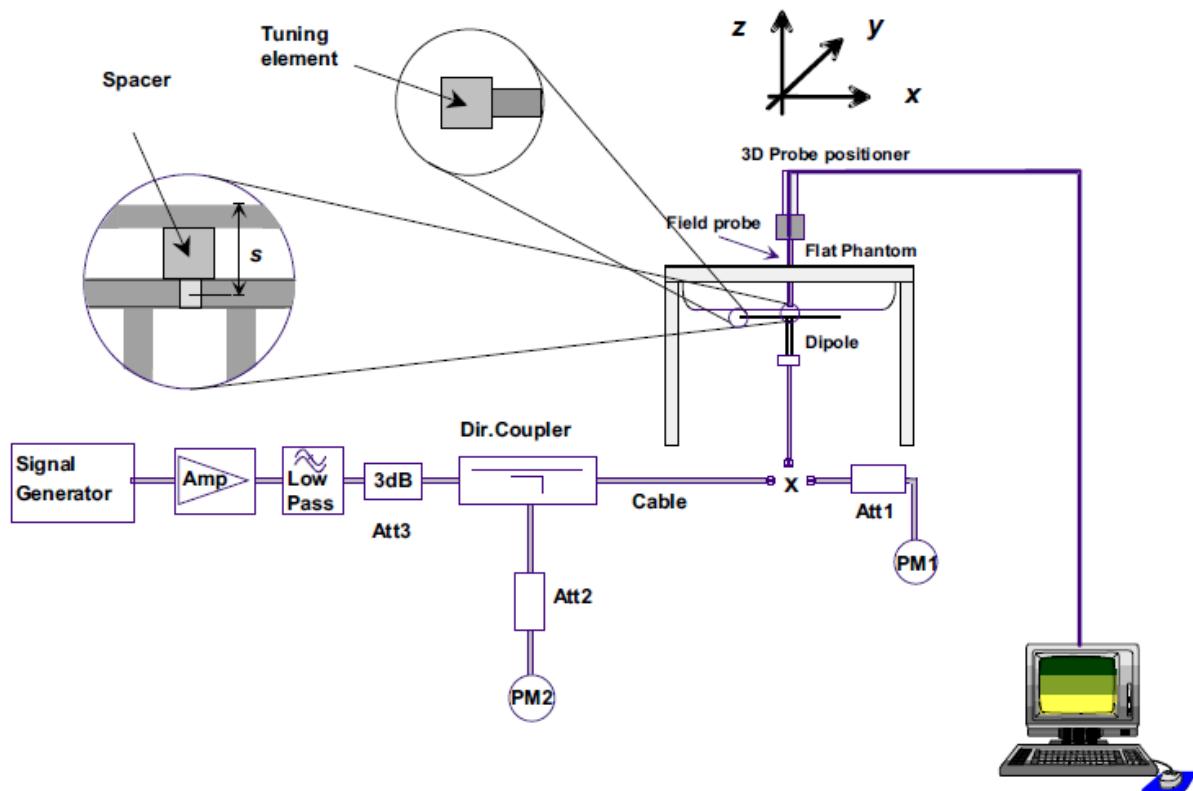
The dielectric properties for this Tissue Simulate Liquids were measured by using the Agilent Model 85070E Dielectric Probe in conjunction with Agilent E5071C Network Analyzer (300 KHz-8500 MHz). The Conductivity (σ) and Permittivity (ϵ_r) are listed in Table 2. For the SAR measurement given in this report. The temperature variation of the Tissue Simulate Liquids was $22\pm2^{\circ}\text{C}$.

| Tissue Type | Measured Frequency (MHz) | Target Tissue ($\pm 5\%$) | | Measured Tissue | | Liquid Temp. (°C) | Measured Date |
|-------------|--------------------------|-----------------------------|----------------------|-----------------|----------------------|-------------------|---------------|
| | | ϵ_r | $\sigma(\text{S/m})$ | ϵ_r | $\sigma(\text{S/m})$ | | |
| 2450 Head | 2450 | 39.20 (37.24~41.16) | 1.80 (1.71~1.89) | 39.903 | 1.825 | 22 | 2018/6/21 |

Table 2 : Measurement result of Tissue electric parameters

4.2 SAR System Validation

The microwave circuit arrangement for system verification is sketched in F-12. The daily system accuracy verification occurs within the flat section of the SAM phantom. A SAR measurement was performed to see if the measured SAR was within $\pm 10\%$ from the target SAR values. The tests were conducted on the same days as the measurement of the EUT. The obtained results from the system accuracy verification are displayed in the table 3(A power level of 250mw was input to the dipole antenna for below 3G, a power level of 100mw was input to the dipole antenna for 3G~6G). During the tests, the ambient temperature of the laboratory was in the range $22 \pm 2^\circ\text{C}$, the relative humidity was in the range 60% and the liquid depth above the ear reference points was above 15 cm in all the cases. It is seen that the system is operating within its specification, as the results are within acceptable tolerance of the reference values.



F-11. the microwave circuit arrangement used for SAR system verification

4.2.1 Justification for Extended SAR Dipole Calibrations

- 1) Referring to KDB865664 D01 requirements for dipole calibration, instead of the typical annual calibration recommended by measurement standards, longer calibration intervals of up to three years may be considered when it is demonstrated that the SAR target, impedance and return loss of a dipole have remain stable according to the following requirements. Each measured dipole is expected to evaluate with the following criteria at least on annual interval in Appendix C.
 - a) There is no physical damage on the dipole;
 - b) System check with specific dipole is within 10% of calibrated value;
 - c) Return-loss is within 10% of calibrated measurement;
 - d) Impedance is within 5Ω from the previous measurement.
- 2) Network analyzer probe calibration against air, distilled water and a shorting block performed before measuring liquid parameters.

4.2.2 Summary System Validation Result(s)

| Validation Kit | | Measured SAR 250mW | Measured SAR 250mW | Measured SAR (normalized to 1w) | Measured SAR (normalized to 1w) | Target SAR (normalized to 1w) (±10%) | Target SAR (normalized to 1w) (±10%) | Liquid Temp. (°C) | Measured Date |
|----------------|------|--------------------|--------------------|---------------------------------|---------------------------------|--------------------------------------|--------------------------------------|-------------------|---------------|
| | | 1g (W/kg) | 10g (W/kg) | 1g (W/kg) | 10g (W/kg) | 1-g(W/kg) | 10-g(W/kg) | | |
| D2450V2 | Head | 12.9 | 5.99 | 51.6 | 23.96 | 53.1 (47.79~58.41) | 24.9 (22.41~27.39) | 22 | 2018/6/21 |

Table 3 : SAR System Validation Result

4.2.3 Detailed System Validation Results

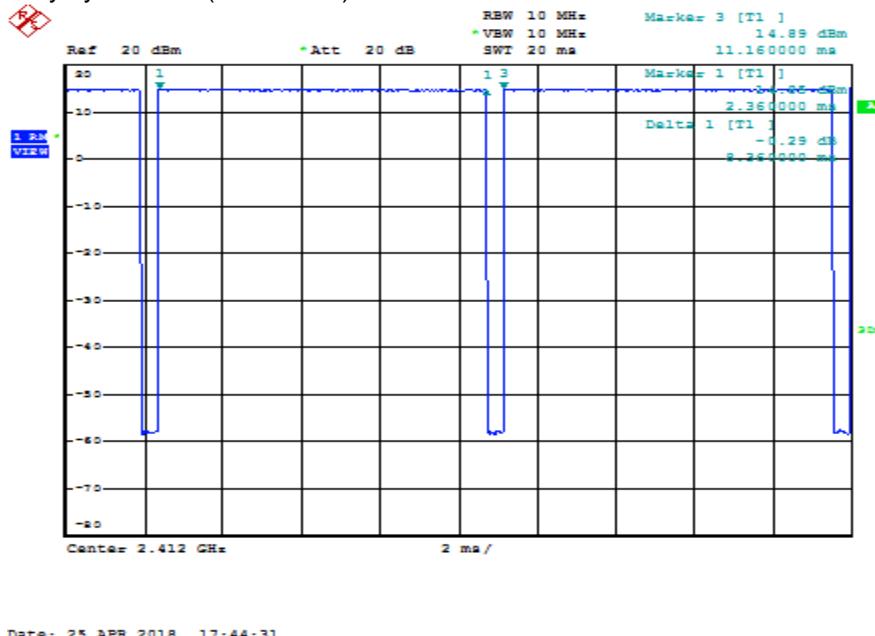
Please see the Appendix A

5 Test results and Measurement Data

5.1 WiFi Test Configuration

A Wi-Fi device must be configured to transmit continuously at the required data rate, channel bandwidth and signal modulation, using the highest transmission duty factor supported by the test mode tools for SAR measurement.

Duty cycle=8.36/(11.16-2.36) =95%



5.1.1 Initial Test Position SAR Test Reduction Procedure

DSSS and OFDM configurations are considered separately according to the required SAR procedures. SAR is measured in the initial test position using the 802.11 transmission mode configuration required by the DSSS procedure or initial test configuration and subsequent test configuration(s) according to the OFDM procedures. The initial test position procedure is described in the following:

- 1) . When the reported SAR of the initial test position is ≤ 0.4 W/kg, further SAR measurement is not required for the other (remaining) test positions in that exposure configuration and 802.11 transmission mode combinations within the frequency band or aggregated band. SAR is also not required for that exposure configuration in the subsequent test configuration(s).
- 2) . When the reported SAR of the initial test position is > 0.4 W/kg, SAR is repeated for the 802.11 transmission mode configuration tested in the initial test position using subsequent highest extrapolated or estimated 1-g SAR conditions determined by area scans or next closest/smallest test separation distance and maximum RF coupling test positions based on manufacturer justification, on the highest maximum output power channel, until the reported SAR is ≤ 0.8 W/kg or all required test positions (left, right, touch, tilt or subsequent surfaces and edges) are tested.
- 3) . For all positions/configurations tested using the initial test position and subsequent test positions, when the reported SAR is > 0.8 W/kg, SAR is measured for these test positions/configurations on the subsequent next highest measured output power channel(s) until the reported SAR is ≤ 1.2 W/kg or all required channels are tested. a) Additional power measurements may be required for this step, which should be limited to those necessary for identifying the subsequent highest output power channels.

5.1.1.1 Initial Test Configuration Procedures

An initial test configuration is determined for OFDM transmission modes according to the channel bandwidth, modulation and data rate combination(s) with the highest maximum output power specified for production units in each standalone and aggregated frequency band. SAR is measured using the highest measured maximum output power channel. For configurations with the same specified or measured maximum output power, additional transmission mode and test channel selection procedures are required. SAR test reduction for subsequent highest output test channels is determined according to *reported* SAR of the initial test configuration.

For next to the ear, hotspot mode and UMC mini-tablet exposure configurations where multiple test positions are required, the initial test position procedure is applied to minimize the number of test positions required for SAR measurement using the initial test configuration transmission mode. For fixed exposure conditions that do not have multiple SAR test positions, SAR is measured in the transmission mode determined by the initial test configuration.

When the *reported* SAR of the initial test configuration is $> 0.8 \text{ W/kg}$, SAR measurement is required for subsequent next highest measured output power channel(s) in the initial test configuration until *reported* SAR is $\leq 1.2 \text{ W/kg}$ or all required channels are tested.

5.1.1.2 Subsequent Test Configuration Procedures

SAR measurement requirements for the remaining 802.11 transmission mode configurations that have not been tested in the initial test configuration are determined separately for each standalone and aggregated frequency band, in each exposure condition, according to the maximum output power specified for production units. The initial test position procedure is applied to next to the ear, UMPC mini-tablet and hotspot mode configurations. When the same maximum output power is specified for multiple transmission modes, additional power measurements may be required to determine if SAR measurements are required for subsequent highest output power channels in a subsequent test configuration. The subsequent test configuration and SAR measurement procedures are described in the following.

- 1) . When SAR test exclusion provisions of KDB Publication 447498 are applicable and SAR measurement is not required for the initial test configuration, SAR is also not required for the next highest maximum output power transmission mode subsequent test configuration(s) in that frequency band or aggregated band and exposure configuration.
- 2) . When the highest *reported* SAR for the initial test configuration (when applicable, include subsequent highest output channels), according to the initial test position or fixed exposure position requirements, is adjusted by the ratio of the subsequent test configuration to initial test configuration specified maximum output power and the adjusted SAR is $\leq 1.2 \text{ W/kg}$, SAR is not required for that subsequent test configuration.
- 3) . The number of channels in the initial test configuration and subsequent test configuration can be different due to differences in channel bandwidth. When SAR measurement is required for a subsequent test configuration and the channel bandwidth is smaller than that in the initial test configuration, all channels in the subsequent test configuration that overlap with the larger bandwidth channel tested in the initial test configuration should be used to determine the highest maximum output power channel. This step requires additional power measurement to identify the highest maximum output power channel in the subsequent test configuration to determine SAR test reduction.
 - a) SAR should first be measured for the channel with highest measured output power in the subsequent test configuration.
 - b) SAR for subsequent highest measured maximum output power channels in the subsequent test configuration is required only when the *reported* SAR of the preceding higher maximum output power channel(s) in the subsequent test configuration is $> 1.2 \text{ W/kg}$ or until all required channels are tested. i) For channels with the same measured maximum output power, SAR should be measured using the channel closest to the center frequency of the larger channel bandwidth channel in the initial test configuration.
- 4) . SAR measurements for the remaining highest specified maximum output power OFDM transmission mode configurations that have not been tested in the initial test configuration (highest maximum output) or subsequent test configuration(s) (subsequent next highest maximum output power) is determined by recursively applying the subsequent test configuration procedures in this section to the remaining configurations according to the following:
 - a) replace "subsequent test configuration" with "next subsequent test configuration" (i.e., subsequent next highest specified maximum output power configuration)
 - b) replace "initial test configuration" with "all tested higher output power configurations"

5.1.1.3 2.4 GHz SAR Procedures

Separate SAR procedures are applied to DSSS and OFDM configurations in the 2.4 GHz band to simplify DSSS test requirements. For 802.11b DSSS SAR measurements, DSSS SAR procedure applies to fixed exposure test position and initial test position procedure applies to multiple exposure test positions. When SAR measurement is required for an OFDM configuration, the initial test configuration, subsequent test configuration and initial test position procedures are applied. The SAR test exclusion requirements for 802.11g/n OFDM configurations are described in following.

- 802.11b DSSS SAR Test Requirements**

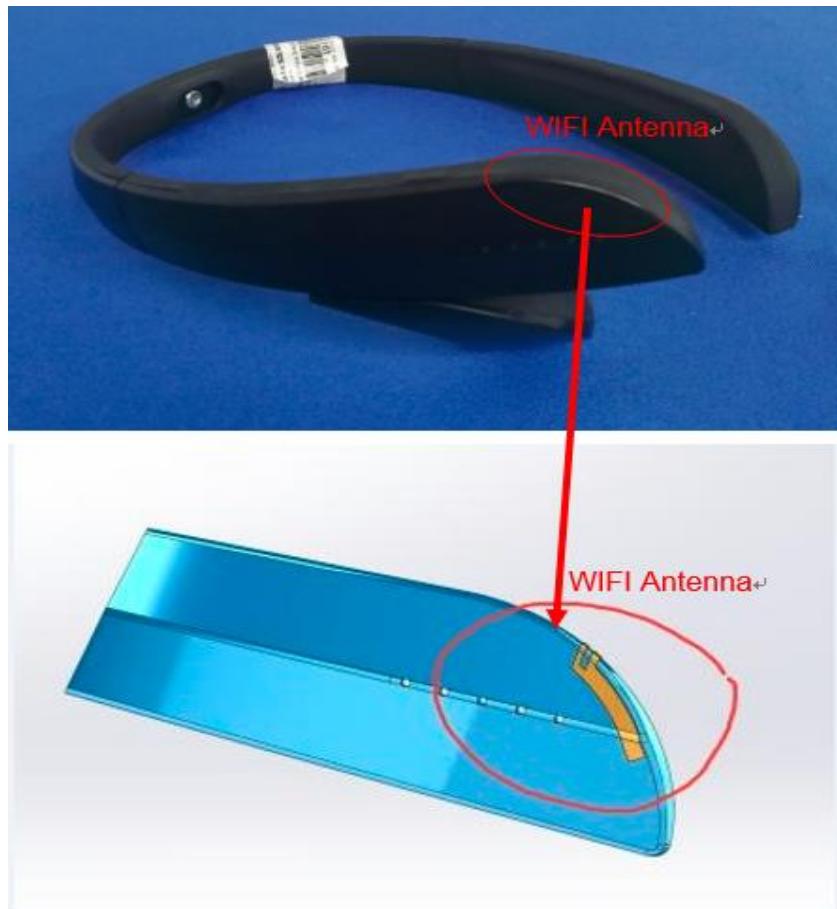
SAR is measured for 2.4 GHz 802.11b DSSS using either a fixed test position or, when applicable, the initial test position procedure. SAR test reduction is determined according to the following:

- 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.
- 2) . 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.

- 2.4 GHz 802.11g/n OFDM SAR Test Exclusion Requirements**

When SAR measurement is required for 2.4 GHz 802.11g/n OFDM configurations, the measurement and test reduction procedures for OFDM are applied (section 5.3, including sub-sections). SAR is not required for the following 2.4 GHz OFDM conditions.

- 1) . When KDB Publication 447498 SAR test exclusion applies to the OFDM configuration.
- 2) . 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.

5.1.2 DUT Antenna Locations

5.1.3 EUT side for SAR Testing

| Freq. Band | Frequency (GHz) | Position | Average Power | | Test Separation (mm) | Calculate Value | Exclusion Threshold | Exclusion (Y/N) |
|------------|-----------------|----------|---------------|------|----------------------|-----------------|---------------------|-----------------|
| | | | dBm | mW | | | | |
| Wi-Fi | 2462 | Head | 17 | 50.1 | 0 | 15.785 | 3 | N |

1) The SAR exclusion threshold for distances <50mm is defined by the following equation:
$$\frac{(\text{max. power of channel, including tune-up tolerance, mW})}{(\text{min. test separation distance, mm})} * \sqrt{\text{Frequency (GHz)}} \leq 3.0$$

2) The SAR exclusion threshold for distances >50mm is defined by the following equation, as illustrated in KDB 447498 D01 Appendix B:

a) at 100 MHz to 1500 MHz

[Power allowed at numeric threshold for 50 mm in step 1) + (test separation distance - 50 mm)·(f(MHz)/150)] mW

b) at > 1500 MHz and \leq 6 GHz

[Power allowed at numeric Threshold at 50 mm in step 1) + (test separation distance - 50 mm)·10] mW

5.2 Measurement of RF Conducted Power

5.2.1 Conducted Power of WIFI2.4GHz

| Mode | Channel | Frequency(MHz) | Data Rate(Mbps) | Tune up | Average Power (dBm) | SAR Test |
|----------------------|---------|----------------|-----------------|---------|---------------------|----------|
| 802.11b | 1 | 2412 | 1 | 17 | 16.64 | Yes |
| | 6 | 2437 | | 17 | 16.07 | NO |
| | 11 | 2462 | | 17 | 16.31 | NO |
| 802.11g | 1 | 2412 | 6 | 8 | 7.38 | NO |
| | 6 | 2437 | | 8 | 7.44 | NO |
| | 11 | 2462 | | 8 | 7.49 | NO |
| 802.11n HT20 SISO | 1 | 2412 | 6.5 | 13 | 12.62 | NO |
| | 6 | 2437 | | 13 | 12.73 | NO |
| | 11 | 2462 | | 13 | 12.66 | NO |
| 802.11n HT40 SISO | 3 | 2422 | 13.5 | 5.5 | 5.08 | NO |
| | 6 | 2437 | | 5.5 | 4.97 | NO |
| | 9 | 2452 | | 5.5 | 5.21 | NO |

Table 4 : Conducted Power of WIFI2.4GHz

5.3 Measurement of SAR Data

5.3.1 SAR Result Of WIFI2.4GHz

| Test position | Test mode | Test Ch./Freq. | Duty Cycle | Duty Cycle Scaled factor | SAR (W/kg)1-g | Power drift(dB) | Conducted power (dBm) | Tune up Limit (dBm) | Scaled factor | Scaled SAR (W/kg) | Liquid Temp. |
|----------------|-----------|----------------|------------|--------------------------|---------------|-----------------|-----------------------|---------------------|---------------|-------------------|--------------|
| Head Test data | | | | | | | | | | | |
| Left cheek | 802.11b | 1/2412 | 95.00% | 1.053 | 0.138 | -0.09 | 16.64 | 17 | 1.086 | 0.158 | 22 |
| Outside-0mm | 802.11b | 1/2412 | 95.00% | 1.053 | 0.0126 | 0 | 16.64 | 17 | 1.086 | 0.014 | 22 |
| Profile-0mm | 802.11b | 1/2412 | 95.00% | 1.053 | 0.00628 | 0.02 | 16.64 | 17 | 1.086 | 0.007 | 22 |

Table 5 : SAR of WIFI2.4GHz for Body

Note:

1) The maximum Scaled SAR value is marked in bold. Graph results refer to Appendix B

| Mode | tune up (dBm) | tune up (mW) | Max report SAR(W/Kg) | Adjusted SAR(W/Kg) | SAR Test (Yes/No) |
|--------------|---------------|--------------|----------------------|--------------------|-------------------|
| 802.11b | 17 | 50.12 | 0.158 | / | Yes |
| 802.11g | 8 | 6.31 | / | 0.020 | No |
| 802.11n-HT20 | 13 | 19.95 | / | 0.063 | No |
| 802.11n-HT40 | 5.5 | 3.55 | / | 0.011 | No |

Note: Per KDB248227D01, for Body SAR test of WiFi 2.4G,

- 1) SAR is measured for 2.4 GHz 802.11b DSSS using the initial test position procedure.
- 2) As the highest reported SAR for DSSS is adjusted by the ratio of OFDM 802.11g/n to DSSS specified maximum output power and the adjusted SAR is < 1.2 W/kg, so SAR for 802.11g/n is not required.

6 Equipment list

| Test Platform | SPEAG DASY5 Professional | | | | |
|--|---|-------------|----------------|------------------|-------------------------|
| Location | SGS-CSTC Standards Technical Services Co., Ltd. Shenzhen Branch | | | | |
| Description | SAR Test System (Frequency range 300MHz-6GHz) | | | | |
| Software Reference | DASY52 52.8.8(1222); SEMCAD X 14.6.10(7331) | | | | |
| Hardware Reference | | | | | |
| Equipment | Manufacturer | Model | Serial Number | Calibration Date | Due date of calibration |
| <input checked="" type="checkbox"/> Robot | Staubli | RX90L | F03/5V32A1/A01 | NCR | NCR |
| <input checked="" type="checkbox"/> Twin Phantom | SPEAG | SAM2 | 1913 | NCR | NCR |
| <input checked="" type="checkbox"/> DAE | SPEAG | DAE4 | 896 | 2017-09-27 | 2018-09-26 |
| <input checked="" type="checkbox"/> E-Field Probe | SPEAG | EX3DV4 | 3789 | 2018-02-08 | 2019-02-07 |
| <input checked="" type="checkbox"/> Validation Kits | SPEAG | D2450V2 | 733 | 2016-12-07 | 2019-12-06 |
| <input checked="" type="checkbox"/> Agilent Network Analyzer | Agilent | E5071C | MY46523590 | 2018-03-13 | 2019-03-12 |
| <input checked="" type="checkbox"/> Dielectric Probe Kit | Agilent | 85070E | US01440210 | NCR | NCR |
| <input checked="" type="checkbox"/> RF Bi-Directional Coupler | Agilent | 86205-60001 | MY31400031 | NCR | NCR |
| <input checked="" type="checkbox"/> Signal Generator | Agilent | N5171B | MY53050736 | 2018-03-13 | 2019-03-12 |
| <input checked="" type="checkbox"/> Preamplifier | Mini-Circuits | ZHL-42W | 15542 | NCR | NCR |
| <input type="checkbox"/> Preamplifier | Compliance Directions Systems Inc. | AMP28-3W | 073501433 | NCR | NCR |
| <input checked="" type="checkbox"/> Power Meter | Agilent | E4416A | GB41292095 | 2018-03-13 | 2019-03-12 |
| <input checked="" type="checkbox"/> Power Sensor | Agilent | 8481H | MY41091234 | 2018-03-13 | 2019-03-12 |
| <input checked="" type="checkbox"/> Power Sensor | R&S | NRP-Z92 | 100025 | 2018-03-13 | 2019-03-12 |
| <input checked="" type="checkbox"/> Attenuator | SHX | TS2-3dB | 30704 | NCR | NCR |
| <input checked="" type="checkbox"/> Coaxial low pass filter | Mini-Circuits | VLF-2500(+) | NA | NCR | NCR |
| <input checked="" type="checkbox"/> Coaxial low pass filter | Microlab Fxr | LA-F13 | NA | NCR | NCR |
| <input checked="" type="checkbox"/> 50 Ω coaxial load | Mini-Circuits | KARN-50+ | 00850 | NCR | NCR |
| <input checked="" type="checkbox"/> DC POWER SUPPLY | SAKO | SK1730SL5A | NA | NCR | NCR |
| <input checked="" type="checkbox"/> Speed reading thermometer | MingGao | T809 | NA | 2018-03-13 | 2019-03-12 |
| <input checked="" type="checkbox"/> Humidity and Temperature Indicator | KIMTOKA | KIMTOKA | NA | 2018-03-13 | 2019-03-12 |

7 Measurement Uncertainty

Measurements and results are all in compliance with the standards listed. All measurements and results are recorded and maintained at the laboratory performing the tests and measurement uncertainties are taken into account when comparing measurements to pass/ fail criteria. The Expanded uncertainty (95% CONFIDENCE INTERVAL) is **21.02%**.

| A | b1 | c | d | e = f(d,k) | g | i = C*g/e | k |
|--|---------------------|------------|-----------------|---------------|---------------|--------------|--------------|
| Uncertainty Component | Section in P1528 | Tol (%) | Prob . Dist. | Div. | Ci (1g) | 1g ui (%) | Vi (Veff) |
| Probe calibration | E.2.1 | 6.65 | N | 1 | 1 | 6.65 | ∞ |
| Axial isotropy | E.2.2 | 0.5 | R | $\sqrt{3}$ | $(1 - Cp)1/2$ | 0.20 | ∞ |
| hemispherical isotropy | E.2.2 | 2.6 | R | $\sqrt{3}$ | \sqrt{Cp} | 1.06 | ∞ |
| Boundary effect | E.2.3 | 1.0 | R | $\sqrt{3}$ | 1 | 0.58 | ∞ |
| Linearity | E.2.4 | 0.6 | R | $\sqrt{3}$ | 1 | 0.35 | ∞ |
| System detection limit | E.2.5 | 0.25 | R | $\sqrt{3}$ | 1 | 0.14 | ∞ |
| Readout electronics | E.2.6 | 0.3 | N | 1 | 1 | 0.30 | ∞ |
| Response time | E.2.7 | 0 | R | $\sqrt{3}$ | 1 | 0.00 | ∞ |
| Integration time | E.2.8 | 2.6 | R | $\sqrt{3}$ | 1 | 1.50 | ∞ |
| RF ambient Condition -Noise | E.6.1 | 3 | R | $\sqrt{3}$ | 1 | 1.73 | ∞ |
| RF ambient Condition - reflections | E.6.1 | 3 | R | $\sqrt{3}$ | 1 | 1.73 | ∞ |
| Probe positioning- mechanical tolerance | E.6.2 | 1.5 | R | $\sqrt{3}$ | 1 | 0.87 | ∞ |
| Probe positioning- with respect to phantom | E.6.3 | 2.9 | R | $\sqrt{3}$ | 1 | 1.67 | ∞ |
| Max. SAR evaluation | E.5.2 | 1 | R | $\sqrt{3}$ | 1 | 0.58 | ∞ |
| Test sample positioning | E.4.2 | 3.7 | N | 1 | 1 | 3.70 | 9 |
| Device holder uncertainty | E.4.1 | 3.6 | N | 1 | 1 | 3.60 | ∞ |
| Output power variation -SAR drift measurement | 6.6.2 | 5 | R | $\sqrt{3}$ | 1 | 2.89 | ∞ |
| Phantom uncertainty (shape and thickness tolerances) | E.3.1 | 4 | R | $\sqrt{3}$ | 1 | 2.31 | ∞ |
| Liquid conductivity - deviation from target values | E.3.2 | 5 | R | $\sqrt{3}$ | 0.64 | 1.85 | ∞ |
| Liquid conductivity - measurement uncertainty | E.3.2 | 5.78 | N | 1 | 0.64 | 3.68 | 5 |
| Liquid permittivity - deviation from target values | E.3.3 | 5 | R | $\sqrt{3}$ | 0.6 | 1.73 | ∞ |

| | | | | | | | |
|--|-------|------|---|-----|-----|--------------|-----|
| Liquid permittivity - measurement uncertainty | E.3.3 | 0.62 | N | 1 | 0.6 | 0.372 | 5 |
| Combined standard uncertainty | | | | RSS | | 10.52 | 335 |
| Expanded uncertainty (95% CONFIDENCE INTERVAL) | | | | K=2 | | 21.02 | |

Table 6 : Measurement Uncertainty

8 Calibration certificate

Please see the Appendix C

9 Photographs

Please see the Appendix D

Appendix A: Detailed System Validation Results

Appendix B: Detailed Test Results

Appendix C: Calibration certificate

Appendix D: Photographs

---END---
