# ANSI/IEEE Std. C95.1-2005

**in accordance with the requirements of**
**FCC Report and Order: ET Docket 93-62**

# FCC TEST REPORT

## For

## 802.11a/b/g/n/ac + BT 4.1 M.2 2230 Type Card
## (Tested inside of Notebook Computer, model: Lenovo ideapad 710S-13IKB)

## Trade Name: Qualcomm Atheros

## Model: QCNFA344A

Issued to

**Qualcomm Atheros, Inc.**
**1700 Technology Drive, San Jose, CA 95110**

Issued by

**Compliance Certification Services Inc.**
**No.11, Wugong 6th Rd., Wugu Dist.,**
**New Taipei City 24891,**
**Taiwan. (R.O.C.)**
**http://www.ccsrf.com**
**service@ccsrf.com**

Testing Laboratory
1309

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# Revision History

| Rev. | Issue Date | Revisions | Effect Page | Revised By |
|---|---|---|---|---|
| 00 | 2016/06/08 | Initial Issue | ALL | Andy Lin |

# Table of Contents

# 1 Certificate of Compliance (SAR Evaluation)

| | |
|---|---|
| **Applicant** | Qualcomm Atheros<br>1700 Technology Drive, San Jose, CA 95110 |
| **Equipment Under Test:** | 802.11a/b/g/n/ac + BT 4.1 M.2 2230 Type Card<br>(Tested inside of Notebook Computer, model: Lenovo ideapad 710S-13IKB) |
| **Trade Name:** | Qualcomm Atheros |
| **Model Number:** | QCNFA344A |
| **Date of Test:** | June 2, 2016 |
| **Device Category:** | PORTABLE DEVICES |
| **Exposure Category:** | GENERAL POPULATION/UNCONTROLLED EXPOSURE |

| **Applicable Standards** | |
|---|---|
| FCC | ● IEEE 1528 2013<br>● KDB 865664 D01 SAR Measurement 100 MHz to 6 GHz v01r04<br>● KDB 865664 D02 RF Exposure Reporting v01r02<br>● KDB 447498 D01 General RF Exposure Guidance v06<br>● KDB 616217 D04 SAR for laptop and tablets v01r02<br>● KDB 248227 D01 SAR Meas for 802.11 v02r02 |
| **Limit** | |
| 1.6 W/kg | |
| **Test Result** | |
| Pass | |

The test results in this report apply only to the tested sample of the stated device/equipment. Other similar device/equipment will not necessarily produce the same results due to production tolerance and measurement uncertainties.

*Approved by:*

Scott Hsu
Section Manager
Compliance Certification Services Inc.

*Tested by:*

Andy Lin
SAR Engineer
Compliance Certification Services Inc.

# 2 Description of Equipment Under Test

| | | | |
|---|---|---|---|
| Product | 802.11a/b/g/n/ac + BT 4.1 M.2 2230 Type Card<br>(Tested inside of Notebook Computer, model Lenovo ideapad 710S-13IKB) | | |
| Trade Name | Qualcomm Atheros | Model Number | QCNFA344A |
| Host Manufactrer | Lenovo | Host Model Name | Lenovo ideapad 710S-13IKB |
| RF Module | Qualcomm Atheros | Model: | QCNFA344A |
| Test Software | QCARCT | Version | 3.0.169.0 |
| Transmitters | Wi-Fi & Bluetooth | | |
| Modulation Technique | Bluetooth:GFSK for 1Mbps;π/4-DQPSK for 2Mbps;8DPSK for 3Mbps | | |
| | 802.11a: Orthogonal Frequency Division Multiplexing (OFDM) | | |
| | 802.11b: Direct Sequence Spread Spectrum(DSSS) | | |
| | 802.11g: Orthogonal Frequency Division Multiplexing (OFDM) | | |
| | 802.11n: Orthogonal Frequency Division Multiplexing (OFDM) | | |
| | 802.11ac: Orthogonal Frequency Division Multiplexing (OFDM) | | |
| Antenna Specification | Ant 1 | Brand name | High-Tek Electronics Co., Ltd |
| | | Parts Number | Main:025.900G0.0011 |
| | | | Aux:025.900G1.0011 |
| | | Type | PIFA |
| | Ant 2 | Brand name | Wistron Neweb Corporation |
| | | Parts Number | Main:025.900G0.0001 |
| | | | Aux:025.900G1.0001 |
| | | Type | PIFA |
| Rechargeable Li-polymer Battery–alternate | 1.Brand：LG<br>Model：L15L4PC0<br>Rating：7.6V/46WH<br><br>2.Brand：SIMPLO<br>Model：L15M4PC0<br>Rating：7.5V/46WH<br><br>Test is using battery No.1 There are difference rating of battery, we chooses No.1 to perform the SAR testing of maximum rating. | | |

**Remark:**

1. The sample selected for test was prototype that representative to production product and was provided by manufacturer

## 2.1 Summary of Highest SAR Values

Results for highest reported SAR values for each frequency band and mode.

| Technology/Band | Test configuration | Mode | Highest Reported 1g-SAR (W/kg) |
|---|---|---|---|
| Wi-Fi 2.4 GHz | Bottom | 802.11b | 0.795 |
| Wi-Fi 5.3 GHz(U-NII 2A) | Bottom | 802.11n HT40 | 0.767 |
| Wi-Fi 5.5 GHz(U-NII 2C) | Bottom | 802.11ac | 0.594 |
| Wi-Fi 5.8 GHz(U-NII 3) | Bottom | 802.11n HT40 | 0.702 |

# 3 Requirements for Compliance Testing Defined

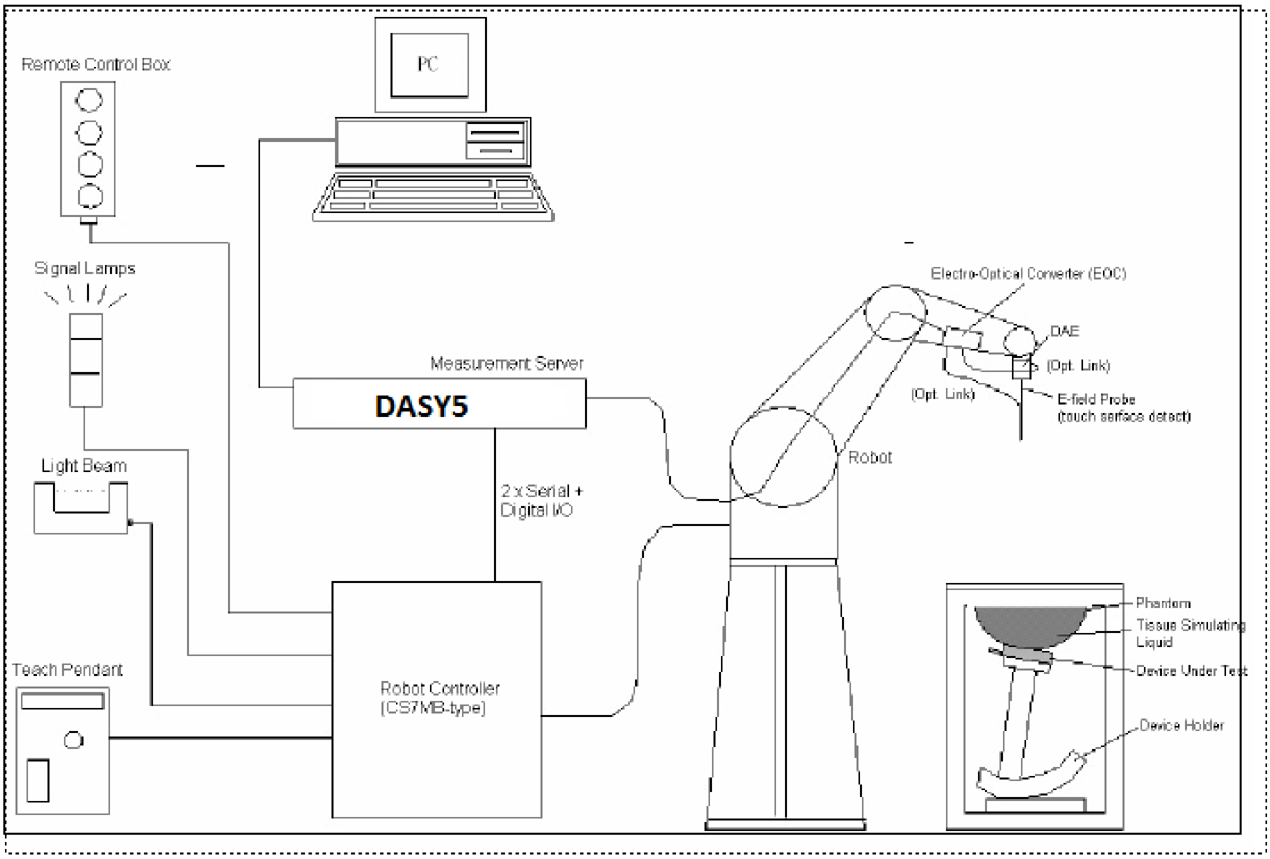
## 3.1 Requirements for Compliance Testing Defined by the FCC

The US Federal Communications Commission has released the report and order “Guidelines for Evaluating the Environmental Effects of RF Radiation", ET Docket No. 93-62 in August 1996 [1]. The 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 W/kg for an uncontrolled environment and 8.0 mW/g for an occupational/controlled environment as recommended by the ANSI/IEEE standard C95.1-2005 [6].

# 4 Dosimetric Assessment System

These measurements were performed with the automated near-field scanning system DASY4/DASY5 from Schmid & Partner Engineering AG (SPEAG). The system is based on a high precision robot (working range greater than 0.9 m) which positions the probes with a positional repeatability of better than ± 0.02 mm. 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 EX3DV4-SN: 7350 (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 ±0.25 dB. The phantom used was the SAM Twin Phantom as described in FCC supplement C, IEEE 1528 2013.

## 4.1 Measurement System Diagram




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

- A standard high precision 6-axis robot (St¨aubli 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 7 or Windows XP.
- DASY5 software version: 52.8.8.1222.
- 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 validating the proper functioning of the system.

## 4.2 System Components

| DASY4/DASY5 Measurement Server | |
|---|---|
|  | The DASY4/DASY5 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 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/DASY5 I/O-board, which is directly connected to the PC/104 bus of the CPU board.<br>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 pinout and therefore only the expansion cards provided by SPEAG can be inserted. Expansion cards from any other supplier could seriously damage the measurement server. Calibration: No calibration required. |

| Data Acquisition Electronics (DAE) | |
|---|---|
|  | The data acquisition electronics (DAE4) consists of a highly sensitive electrometer grade preamplifier with auto-zeroing, a channel and gain-switching multiplexer, a fast 16 bit AD converter and a command decoder and control logic unit. Transmission to the measurement server is accomplished through an optical downlink for data and status information as well as an optical uplink for commands and the clock. The mechanical probe mounting device includes two different sensor systems for frontal and sideways probe contacts. They are used for mechanical surface detection and probe collision detection. The input impedance of the DAE4 box is 200MOhm; the inputs are symmetrical and floating. Common mode rejection is above 80 dB. |

## EX3DV4 Isotropic E-Field Probe for Dosimetric Measurements

| | |
|---|---|
| **Construction:** | Symmetrical design with triangular core<br>Built-in shielding against static charges<br>PEEK enclosure material (resistant to organic solvents, e.g., DGBE) |
| **Calibration:** | Basic Broad Band Calibration in air: 10-3000 MHz.<br>Conversion Factors (CF) for HSL 900 and HSL 1800<br>CF-Calibration for other liquids and frequencies upon request. |
| **Frequency:** | 10 MHz to > 6 GHz; Linearity: ± 0.2 dB (30 MHz to 3 GHz) |
| **Directivity:** | ± 0.3 dB in HSL (rotation around probe axis)<br>± 0.5 dB in HSL (rotation normal to probe axis) |
| **Dynamic Range:** | 10 µW/g to > 100 mW/g; Linearity: ± 0.2 dB<br>(noise: typically < 1 µW/g) |
| **Dimensions:** | Overall length: 330 mm (Tip: 20 mm)<br>Tip diameter: 2.5 mm (Body: 12 mm)<br>Distance from probe tip to dipole centers: 1 mm |
| **Application:** | High precision dosimetric measurements in any exposure scenario (e.g., very strong gradient fields). Only probe which enables compliance testing for frequencies up to 6 GHz with precision of better 30%. |

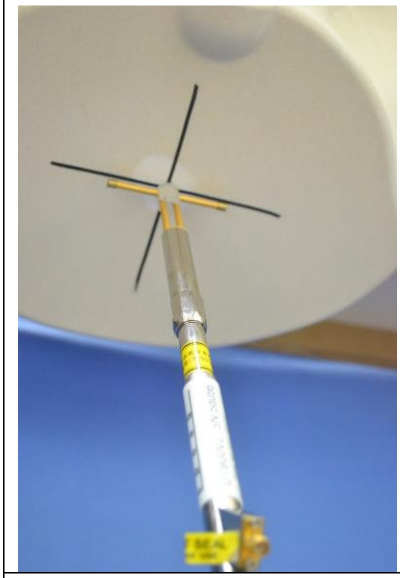
## SAM Phantom (V4.0)

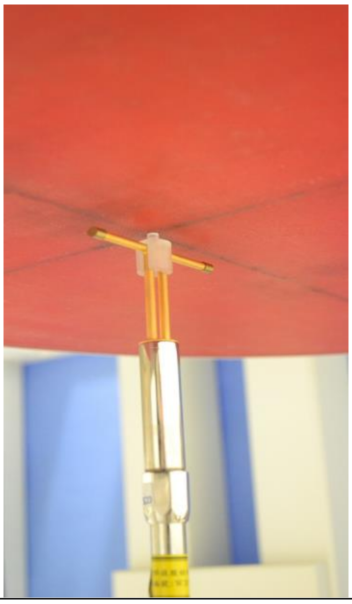
| | |
|---|---|
| **Construction:** | The shell corresponds to the specifications of the Specific Anthropomorphic Mannequin (SAM) phantom defined in IEEE 1528 2013, CENELEC 50361 and IEC 62209. It enables the dosimetric evaluation of left and right hand phone usage as well as body mounted usage at the 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 manually teaching three points with the robot. |
| **Shell Thickness:** | 2 ±0.2 mm |
| **Filling Volume:** | Approx. 25 liters |
| **Dimensions:** | Height: 810mm; Length: 1000mm; Width: 500mm |

## SAM Phantom (ELI4)

| | |
|---|---|
| **Construction:** | Phantom for compliance testing of handheld and body-mounted wireless devices in the frequency range of 30 MHz to 6 GHz. ELI4 is fully compatible with the latest draft of the standard IEC 62209 Part II and all known tissue simulating liquids. ELI4 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 supported by software version DASY4/DASY5 and higher and is compatible with all SPEAG dosimetric probes and dipoles |
| **Shell Thickness:** | 2.0 ± 0.2 mm (sagging: <1%) |
| **Filling Volume:** | Approx. 25 liters |
| **Dimensions:** | Major ellipse axis: 600 mm |
| **Minor axis:** | 400 mm 500mm |

| Device Holder for SAM Twin Phantom | | |
|---|---|---|
|  | **Construction:** | In combination with the Twin SAM Phantom V4.0 or Twin SAM, the Mounting Device (made from POM) enables the rotation of the mounted transmitter in spherical coordinates, whereby the rotation point is the ear opening. The devices can be easily and accurately positioned according to IEC, IEEE, CENELEC, FCC or other specifications. The device holder can be locked at different phantom locations (left head, right head, and flat phantom). |

| System Validation Kits for SAM Phantom (V4.0) | | |
|---|---|---|
|  | **Construction:** | Symmetrical dipole with l/4 balun Enables measurement of feedpoint impedance with NWA Matched for use near flat phantoms filled with brain simulating solutions Includes distance holder and tripod adaptor. |
| | **Frequency:** | 2450, 5300, 5600, 5800 MHz |
| | **Return loss:** | > 20 dB at specified validation position |
| | **Power capability:** | > 100 W (f < 1GHz); > 40 W (f > 1GHz) |
| | **Dimensions:** | D2450V2: dipole length: 51.5 mm; overall height: 290 mm<br>D5GHzV2: dipole length: 20.6 mm; overall height: 300 mm |

| System Validation Kits for ELI4 phantom | | |
|---|---|---|
|  | **Construction:** | Symmetrical dipole with l/4 balun Enables measurement of feedpoint impedance with NWA Matched for use near flat phantoms filled with brain simulating solutions Includes distance holder and tripod adaptor. |
| | **Frequency:** | 2450, 5200, 5300, 5600, 5800 MHz |
| | **Return loss:** | > 20 dB at specified validation position |
| | **Power capability:** | > 100 W (f < 1GHz); > 40 W (f > 1GHz) |
| | **Dimensions:** | D2450V2: dipole length: 51.5 mm; overall height: 290 mm<br>D5GHzV2: dipole length: 20.6 mm; overall height: 300 mm |

# 5 Evaluation Procedures

**Data Evaluation**

The DASY4/DASY5 post processing software (SEMCAD) automatically executes the following procedures to calculate the field units from the microvolt readings at the probe connector. The parameters used in the evaluation are stored in the configuration modules of the software:

| | | |
|---|---|---|
| Probe parameters: | - Sensitivity | $Norm_i$, $a_{i0}$, $a_{i1}$, $a_{i2}$ |
| | - Conversion factor | $ConvF_i$ |
| | - Diode compression point | $dcp_i$ |
| Device parameters: | - Frequency | $f$ |
| | - Crest factor | $cf$ |
| Media parameters: | - Conductivity | $\sigma$ |
| | - Density | $\rho$ |

These parameters must be set correctly in the software. They can be found in the component documents or be imported into the software from the configuration files issued for the DASY components. In the direct measuring mode of the multi-meter option, the parameters of the actual system setup are used. In the scan visualization and export modes, the parameters stored in the corresponding document files are used.

The first step of the evaluation is a linearization of the filtered input signal to account for the compression characteristics of the detector diode. The compensation depends on the input signal, the diode type and the DC-transmission factor from the diode to the evaluation electronics. If the exciting field is pulsed, the crest factor of the signal must be known to correctly compensate for peak power. The formula for each channel can be given as:

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

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

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

E-field probes: $$E_i = \sqrt{\frac{V_i}{Norm_i \bullet ConvF}}$$

H-field probes: $$H_i = \sqrt{Vi} \cdot \frac{a_{i10} + a_{i11} f + a_{i12} f^2}{f}$$

| | | | |
|---|---|---|---|
| with | $V_i$ | = Compensated signal of channel i | (i = x, y, z) |
| | $Norm_i$ | = Sensor sensitivity of channel i | (i = x, y, z) |

$\mu V/(V/m)^2$ for E0field 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):

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

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

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

with *SAR* = local specific absorption rate in W/kg

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

$\sigma$ = conductivity in [mho/m] or [Siemens/m]

$\rho$ = equivalent tissue density in $g/cm^3$

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

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

$$P_{pwe} = \frac{E_{tot}^2}{377} \quad \text{or} \quad P_{pwe} = H_{tot}^2 \cdot 37.7$$

with $P_{pwe}$ = Equivalent power density of a plane wave in $mW/cm^2$

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

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

# 6 SAR Measurement Procedures

## 6.1 Normal SAR Test Procedure

- **Power Reference Measurement**

The reference and drift 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.

- **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/DASY5 software can find the maximum locations even in relatively coarse grids. The scan 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, the grid resolution has to less than 15 mm by 15 mm at frequency ≤2GHz; the grid resolution has to less than 12mm by 12 mm at frequency between 2GHz to 4GHz; grid resolution has to less than 10 mm by 10 mm at frequency between 4GHz to 6GHz.

According to KDB 865664 D01 SAR measurement 100 MHz to 6 GHz v01r04

<table>
<tr><th></th><th>≤ 3 GHz</th><th>> 3 GHz</th></tr>
<tr><td>Maximum distance from closest measurement point (geometric center of probe sensors) to phantom surface</td><td>5 ± 1 mm</td><td>½·δ·ln(2) ± 0.5 mm</td></tr>
<tr><td>Maximum probe abgle from probe axis to phantom surface normal at the measurement location</td><td>30° ± 1°</td><td>20° ± 1°</td></tr>
<tr><td rowspan="2">Maximum area scan spatial resolution: $\Delta x_{Zoom}$, $\Delta y_{Zoom}$</td><td>≤ 2 GHz: ≤ 15 mm<br>2 – 3 GHz: ≤ 12 mm</td><td>3 – 4 GHz: ≤ 12 mm<br>4 – 6 GHz: ≤ 10 mm</td></tr>
<tr><td colspan="2">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 ≤ the corresponding x or y dimension of the test device with at least one measurement point on the test device.</td></tr>
</table>

- **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 points in accordance with the frequency can be divided into three parts. (1)The zoom scan volume was set to 5x5x7 points at frequency ≤ 2GHz. (2) The zoom scan volume was set to 7x7x7 points at frequency between 2GHz to 4GHz (3) The zoom scan volume was set to 7x7x12 points at frequency between 4GHz to 6GHz. The measures points within a cube whose base faces are centered around the maximum found in a preceding area scan job within the same procedure. If the preceding Area Scan job indicates more then one maximum, the number of Zoom Scans has to be enlarged accordingly.

According to KDB 865664 D01 SAR measurement 100 MHz to 6 GHz v01r04

<table>
<tr><td colspan="3"></td><td>≤ 3 GHz</td><td>> 3 GHz</td></tr>
<tr><td colspan="3">Maximum zoom scan spatial resolution: $\Delta x_{Zoom}$, $\Delta y_{Zoom}$</td><td>≤ 2 GHz: ≤ 8 mm<br>2 – 3 GHz: ≤ 5 mm</td><td>3 – 4 GHz: ≤ 5 mm<br>4 – 6 GHz: ≤ 4 mm</td></tr>
<tr><td rowspan="3">Maximum zoom scan spatial resolution, normal to phantom surface</td><td colspan="2">Uniform grid: $\Delta z_{Zoom}(n)$</td><td>≤ 5 mm</td><td>3 – 4 GHz: ≤ 4 mm<br>4 – 5 GHz: ≤ 3 mm<br>5 – 6 GHz: ≤ 2 mm</td></tr>
<tr><td rowspan="2">graded grid</td><td>$\Delta z_{Zoom}(1)$:between 1st two points losest to phantom surface</td><td>≤ 4 mm</td><td>3 – 4 GHz: ≤ 3 mm<br>4 – 5 GHz: ≤ 2.5 mm<br>5 – 6 GHz: ≤ 2 mm</td></tr>
<tr><td>$\Delta z_{Zoom}(n>1)$: between subsequent points</td><td colspan="2">≤ $1.5 \cdot \Delta z_{Zoom}(n-1)$</td></tr>
<tr><td>Maximum zoom scan volume</td><td>x, y, z</td><td>≥ 30 mm</td><td colspan="2">3 – 4 GHz: ≥ 28 mm<br>4 – 5 GHz: ≥ 25 mm<br>5 – 6 GHz: ≥ 22 mm</td></tr>
</table>

- **Power Drift Measurement**

The drift job measures the field at the same location as the most recent reference job within the same procedure, and with the same settings. The drift measurement gives the field difference in dB from the reading conducted within the last 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. In the properties of the Drift job, the user can specify a limit for the drift and have DASY4/DASY5 software stop the measurements if this limit is exceeded.

- **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 current probe location. As with any other grids, the local Z-axis of the anchor location establishes the Z-axis of the grid.

# 7 Measurement Uncertainty

According to KDB 865664 D01 SAR Measurement 100 MHz to 6 GHz section 2.8.2, SAR measurement uncertainty analysis is required in SAR reports only when the highest measured SAR in a frequency band is ≥ 1.5 W/kg for 1-g SAR, the extensive SAR measurement uncertainty analysis described in IEEE Std 1528-2013 is not required in SAR reports submitted for equipment approva

# 8 Device Under Test

## 8.1 Wireless Technologies

| Wireless technologies | Tx Frequency Bands | Operating mode | Duty Cycle used for testing |
|---|---|---|---|
| Wi-Fi | 2.4GHz Band | 802.11b<br>802.11g<br>802.11n(HT20)<br>802.11n(HT40) | 100% |
| | 5GHz Band | 802.11a<br>802.11n(HT20)<br>802.11n(HT40)<br>802.11ac(VHT20)<br>802.11ac(VHT40)<br>802.11ac(VHT80) | 100% |
| Bluetooth | 2.4GHz | 2.1<br>4.1 | N/A |

## 8.2 Maximum Tune-up Power

| Tolerance (dB): ± 1.5 | | RF Output Power (dBm) | |
|---|---|---|---|
| Band (GHz) | Mode | Target | Max. tune-up power |
| 2.4 | 802.11b | 19.0 | 20.5 |
| | 802.11g | 18.0 | 19.5 |
| | 802.11n HT20 | 18.0 | 19.5 |
| | 802.11n HT40 | 17.0 | 18.5 |
| Tolerance (dB): ± 2 | | RF Output Power (dBm) | |
| Band (GHz) | Mode | Target | Max. tune-up power |
| 5.2 (UNII-1) | 802.11a | 13.0 | 15.0 |
| | 802.11n HT20 | 13.0 | 15.0 |
| | 802.11n HT40 | 12.5 | 14.5 |
| | 802.11ac | 8.5 | 10.5 |
| 5.3 (UNII-2A) | 802.11a | 13.0 | 15.0 |
| | 802.11n HT20 | 13.0 | 15.0 |
| | 802.11n HT40 | 12.5 | 14.5 |
| | 802.11ac | 10.0 | 12.0 |
| 5.5 (UNII-2C) | 802.11a | 13.0 | 15.0 |
| | 802.11n HT20 | 13.0 | 15.0 |
| | 802.11n HT40 | 12.5 | 14.5 |
| | 802.11ac | 12.5 | 14.5 |
| 5.8 (UNII-3) | 802.11a | 13.0 | 15.0 |
| | 802.11n HT20 | 13.0 | 15.0 |
| | 802.11n HT40 | 12.5 | 14.5 |
| | 802.11ac | 8.0 | 10.0 |
| Mode | | Max. tune-up power | |
| Bluetooth | | 7.0 | |

## 8.3 Simultaneous Transmission

| RF Exposure Condition | Transmit Configurations |
|---|---|
| Wi-Fi | 2.4GHz(Chain 0)<br>2.4GHz(Chain 1)<br>2.4GHz(Chain 0 + Chain 1)<br>2.4GHz(Chain 0) + Bluetooth(Chain1)<br>5GHz(Chain 0)<br>5GHz(Chain 1)<br>5GHz(Chain 0 + Chain 1)<br>5GHz(Chain 0 + Chain 1) + Bluetooth(Chain1)<br>Bluetooth(Chain1) |

Note(s):

1. For WLAN mode can be used as transmitting/receiving on the Chain 0 and Chain 1.
2. WLAN and Bluetooth technology can transmit at same time.

# 9 Summary of SAR Test Exclusion Configurations

## 9.1 Standalone SAR Test Position

SAR testing is required for Notebook mode because the antenna-to-user separation distance is less than allowed per modular SAR in the original module grant. EUT was tested in the bottom of keyboard touch the phantom(0 mm).

According to KDB 447498 section 4.3.1, the 1-g SAR test exclusion thresholds at test separation distance ≤ 50 mm are determined by:
[(max. power of channel, including tune-up tolerance, mW) / (min. test separation distance, mm)] *·[$\sqrt{f(GHz)}$] ≤ 3.0

The Bluetooth calculated threshold value ≤ 3.0 .This power level qualifies not required for SAR testing.

| Band | Output Power | | Separation Distances(mm) | Calculated Threshold Value |
|---|---|---|---|---|
| | dBm | mW | | |
| Bluetooth | 7.0 | 5 | 8.1 | 1.0 |

# 10 Exposure Limit

(A). Limits for Occupational/Controlled Exposure (W/kg)

| Whole-Body | Partial-Body | Hands, Wrists, Feet and Ankles |
|---|---|---|
| 0.4 | 8.0 | 2.0 |

(B). Limits for General Population/Uncontrolled Exposure (W/kg)

| Whole-Body | Partial-Body | Hands, Wrists, Feet and Ankles |
|---|---|---|
| 0.08 | 1.6 | 4.0 |

NOTE: **Whole-Body SAR** is averaged over the entire body, **partial-body SAR** is averaged over any 1 gram of tissue defined as a tissue volume in the shape of a cube. **SAR for hands, wrists, feet and ankles** is averaged over any 10 grams of tissue defined as a tissue volume in the shape of a cube.

**Population/Uncontrolled Environments:**

are defined as locations where there is the exposure of individuals 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).

| NOTE<br>GENERAL POPULATION/UNCONTROLLED EXPOSURE<br>PARTIAL BODY LIMIT<br>1.6 W/kg |
|---|

# 11 Tissue Dielectric Properties

## 11.1 Test Liquid Confirmation

**Simulating Liquids Parameter Check**

The simulating liquids should be checked at the beginning of a series of SAR measurements to determine of the dielectric parameters are within the tolerances of the specified target values

The relative permittivity and conductivity of the tissue material should be within ± 5% of the values given in the table below 5% may not be easily achieved at certain frequencies.

The head tissue dielectric parameters recommended by the IEEE SCC-34/SC-2 in IEEE 1528 2013 have been incorporated in the following table. These head parameters are derived from planar layer models simulating the highest expected SAR for the dielectric properties and tissue thickness variations in a human head. Other head and body tissue parameters that have not been specified in IEEE 1528 2013 are derived from the tissue dielectric parameters computed from the 4-Cole-Cole equations and extrapolated according to the head parameters specified in IEEE 1528 2013

| Target Frequency (MHz) | Head | | Body | |
|---|---|---|---|---|
| | $\varepsilon_r$ | σ (S/m) | $\varepsilon_r$ | 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 |
| 5000 | 36.2 | 4.45 | 49.3 | 5.07 |
| 5100 | 36.1 | 4.55 | 49.1 | 5.18 |
| 5200 | 36.0 | 4.66 | 49.0 | 5.30 |
| 5300 | 35.9 | 4.76 | 48.9 | 5.42 |
| 5400 | 35.8 | 4.86 | 48.7 | 5.53 |
| 5500 | 35.6 | 4.96 | 48.6 | 5.65 |
| 5600 | 35.5 | 5.07 | 48.5 | 5.77 |
| 5700 | 35.4 | 5.17 | 48.3 | 5.88 |
| 5800 | 35.3 | 5.27 | 48.2 | 6.00 |

## 11.2 Typical Composition of Ingredients for Liquid Tissue Phantoms

The following tissue formulations are provided for reference only as some of the parameters have not been thoroughly verified. The composition of ingredients may be modified accordingly to achieve the desired target tissue parameters required for routine SAR evaluation.

| Ingredients (% by weight) | Frequency (MHz) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 450 | | 835 | | 915 | | 1900 | | 2450 | |
| **Tissue Type** | **Head** | **Body** | **Head** | **Body** | **Head** | **Body** | **Head** | **Body** | **Head** | **Body** |
| **Water** | 38.56 | 51.16 | 41.45 | 52.4 | 41.05 | 56.0 | 54.9 | 40.4 | 62.7 | 73.2 |
| **Salt (NaCl)** | 3.95 | 1.49 | 1.45 | 1.4 | 1.35 | 0.76 | 0.18 | 0.5 | 0.5 | 0.04 |
| **Sugar** | 56.32 | 46.78 | 56.0 | 45.0 | 56.5 | 41.76 | 0.0 | 58.0 | 0.0 | 0.0 |
| **HEC** | 0.98 | 0.52 | 1.0 | 1.0 | 1.0 | 1.21 | 0.0 | 1.0 | 0.0 | 0.0 |
| **Bactericide** | 0.19 | 0.05 | 0.1 | 0.1 | 0.1 | 0.27 | 0.0 | 0.1 | 0.0 | 0.0 |
| **Triton X-100** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 36.8 | 0.0 |
| **DGBE** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 44.92 | 0.0 | 0.0 | 26.7 |
| **Dielectric Constant** | 43.42 | 58.0 | 42.54 | 56.1 | 42.0 | 56.8 | 39.9 | 54.0 | 39.8 | 52.5 |
| **Conductivity (S/m)** | 0.85 | 0.83 | 0.91 | 0.95 | 1.0 | 1.07 | 1.42 | 1.45 | 1.88 | 1.78 |

alt: $99^{+}$% Pure Sodium Chloride Sugar: $98^{+}$% Pure Sucrose
Water: De-ionized, 16 $M\Omega^{+}$ resistivity HEC: Hydroxy thyl Cellulose
DGBE: $99^{+}$% Di(ethylene glycol) butyl ether, [2-(2-butoxyethoxy)ethanol]
Triton X-100 (ultra-pure): Polyethylene glycol mono [4-(1, 1, 3, 3-tetramethylbutyl)phenyl]ether

**Simulating Liquids for 5 GHz, Manufactured by SPEAG**

| Ingredients | (% by weight) |
|---|---|
| Water | 78 |
| Mineral oil | 11 |
| Emulsifiers | 9 |
| Additives and Salt | 2 |

## 11.3 Simulating Liquids Parameter Check Results

| Date | Band | Freq(MHz) | Measured | | | Standard | | Δ | | Limit(%) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | e' (εr) | e'' | σ | e' (εr) | σ | e' (εr) | σ | ±5 |
| 2016/6/2 | Body 2450 | 2412 | 50.20 | 14.18 | 1.90 | 52.75 | 1.91 | -4.83% | -0.74% | ±5 |
| | | 2437 | 50.17 | 14.58 | 1.97 | 52.72 | 1.94 | -4.83% | 1.86% | ±5 |
| | | 2442 | 50.22 | 14.64 | 1.99 | 52.71 | 1.94 | -4.72% | 2.24% | ±5 |
| | | 2450 | 50.29 | 14.72 | 2.00 | 52.70 | 1.95 | -4.58% | 2.74% | ±5 |
| | | 2462 | 50.50 | 14.83 | 2.03 | 52.68 | 1.97 | -4.16% | 3.10% | ±5 |
| | | 2472 | 50.61 | 14.81 | 2.03 | 52.67 | 1.98 | -3.91% | 2.68% | ±5 |
| 2016/6/2 | Body 5000 | 5180 | 49.37 | 17.91 | 5.15 | 49.02 | 5.28 | 0.72% | -2.30% | ±5 |
| | | 5200 | 49.33 | 17.93 | 5.18 | 49.00 | 5.30 | 0.67% | -2.24% | ±5 |
| | | 5220 | 49.30 | 17.95 | 5.21 | 48.98 | 5.32 | 0.65% | -2.21% | ±5 |
| | | 5240 | 49.26 | 17.96 | 5.23 | 48.96 | 5.35 | 0.60% | -2.22% | ±5 |
| | | 5260 | 49.22 | 18.00 | 5.26 | 48.94 | 5.37 | 0.57% | -2.08% | ±5 |
| | | 5280 | 49.19 | 18.03 | 5.29 | 48.92 | 5.40 | 0.56% | -2.01% | ±5 |
| | | 5300 | 49.16 | 18.03 | 5.31 | 48.90 | 5.42 | 0.53% | -2.07% | ±5 |
| | | 5320 | 49.12 | 18.05 | 5.34 | 48.86 | 5.44 | 0.52% | -1.96% | ±5 |
| | | 5500 | 48.80 | 18.24 | 5.57 | 48.60 | 5.65 | 0.40% | -1.35% | ±5 |
| | | 5520 | 48.76 | 18.25 | 5.60 | 48.58 | 5.67 | 0.36% | -1.35% | ±5 |
| | | 5540 | 48.73 | 18.29 | 5.63 | 48.56 | 5.70 | 0.35% | -1.22% | ±5 |
| | | 5560 | 48.70 | 18.30 | 5.65 | 48.54 | 5.72 | 0.32% | -1.24% | ±5 |
| | | 5580 | 48.66 | 18.32 | 5.68 | 48.52 | 5.75 | 0.29% | -1.18% | ±5 |
| | | 5600 | 48.63 | 18.35 | 5.71 | 48.50 | 5.77 | 0.26% | -1.07% | ±5 |
| | | 5620 | 48.60 | 18.35 | 5.73 | 48.46 | 5.79 | 0.29% | -1.10% | ±5 |
| | | 5640 | 48.55 | 18.37 | 5.76 | 48.42 | 5.81 | 0.26% | -0.98% | ±5 |
| | | 5660 | 48.52 | 18.39 | 5.78 | 48.38 | 5.84 | 0.29% | -0.90% | ±5 |
| | | 5680 | 48.48 | 18.42 | 5.81 | 48.34 | 5.86 | 0.29% | -0.80% | ±5 |
| | | 5700 | 48.45 | 18.46 | 5.84 | 48.30 | 5.88 | 0.30% | -0.60% | ±5 |
| | | 5745 | 48.38 | 18.48 | 5.90 | 48.26 | 5.93 | 0.26% | -0.58% | ±5 |
| | | 5765 | 48.35 | 18.51 | 5.93 | 48.24 | 5.96 | 0.25% | -0.52% | ±5 |
| | | 5785 | 48.31 | 18.52 | 5.95 | 48.22 | 5.98 | 0.20% | -0.50% | ±5 |
| | | 5805 | 48.27 | 18.55 | 5.98 | 48.19 | 6.01 | 0.17% | -0.39% | ±5 |
| | | 5825 | 48.24 | 18.58 | 6.01 | 48.15 | 6.03 | 0.20% | -0.31% | ±5 |

# 12 System Performance Check

The system performance check is performed prior to any usage of the system in order to guarantee reproducible results. The system performance check verifies that the system operates within its specifications. The system performance check results are tabulated below. And also the corresponding SAR plot is attached as well in the SAR plots files.

**System Performance Check Measurement Conditions**

- The measurements were performed in the flat section of the SAM twin phantom filled with Body simulating liquid of the following parameters.
- The DASY4/DASY5 system with an E-fileld probe EX3DV4 SN: 7350 was used for the measurements.
- The dipole was mounted on the small tripod so that the dipole feed point was positioned below the center marking of the flat phantom section and the dipole was oriented parallel to the body axis (the long side of the phantom). The standard measuring distance was 15 mm (below 1 GHz) and 10 mm (above 1 GHz) from dipole center to the simulating liquid surface.
- The coarse grid with a grid spacing of 10mm was aligned with the dipole.
- Special 7x7x7 fine cube was chosen for cube integration (dx=dy= 5 mm, dz= 5 mm).
- Distance between probe sensors and phantom surface was set to 3.0 mm.
- The dipole input power (forward power) was 100 mW±3%.
- The results are normalized to 1 W input power.

**Reference SAR Values for System Performance Check**

The reference SAR values can be obtained from the calibration certificate of system validation dipoles

| System Dipole | Serial No. | Cal. Date | Freq. (MHz) | Target SAR Values (W/kg) | | |
|---|---|---|---|---|---|---|
| | | | | 1g/10g | Head | Body |
| D2450V2 | 869 | 2015/6/19 | 2450 | 1g | 53.8 | 52.4 |
| | | | | 10g | 25.2 | 24.7 |
| D5GHzV2 | 1004 | 2015/11/20 | 5300 | 1g | 86.1 | 80.2 |
| | | | | 10g | 24.5 | 22.2 |
| D5GHzV2 | 1004 | 2015/11/20 | 5600 | 1g | 86.1 | 83.9 |
| | | | | 10g | 24.5 | 23.2 |
| D5GHzV2 | 1004 | 2015/11/20 | 5800 | 1g | 80.8 | 79.2 |
| | | | | 10g | 22.9 | 22.1 |

## 12.1 System Performance Check Results

| Date | System Dipole | | | Parameters | Target | Measured | Deviation[%] | Limited[%] |
|---|---|---|---|---|---|---|---|---|
| | Type | Serial No. | Liquid | | | | | |
| 2016/6/2 | D2450V2 | 869 | Body | 1g SAR: | 52.4 | 52.9 | 0.95 | ± 5 |
| | | | | 10g SAR: | 24.7 | 24.4 | -1.21 | ± 5 |
| 2016/6/2 | D5GHzV2 (5.3GHz) | 1004 | Body | 1g SAR: | 80.2 | 79.1 | -1.37 | ± 5 |
| | | | | 10g SAR: | 22.2 | 22.4 | 0.90 | ± 5 |
| 2016/6/2 | D5GHzV2 (5.6GHz) | 1004 | Body | 1g SAR: | 83.9 | 83.7 | -0.24 | ± 5 |
| | | | | 10g SAR: | 23.2 | 23.5 | 1.29 | ± 5 |
| 2016/6/2 | D5GHzV2 (5.8GHz) | 1004 | Body | 1g SAR: | 79.2 | 77.0 | -2.78 | ± 5 |
| | | | | 10g SAR: | 22.1 | 22.3 | 0.90 | ± 5 |

# 13 RF Output Power Measurement

According to KDB248227 D01 802.11 Wi-Fi SAR v02r02 section 4, the default power measurement procedures are:

1) Power must be measured at each transmit antenna port according to the DSSS and OFDM transmission configurations in each standalone and aggregated frequency band.

2) Power measurement is required for the transmission mode configuration with the highest maximum output power specified for production units.

a) When the same highest maximum output power specification applies to multiple transmission modes, the largest channel bandwidth configuration with the lowest order modulation and lowest data rate is measured.

b) When the same highest maximum output power is specified for multiple largest channel bandwidth configurations with the same lowest order modulation or lowest order modulation and lowest data rate, power measurement is required for all equivalent 802.11 configurations with the same maximum output power.

3) For each transmission mode configuration, power must be measured for the highest and lowest channels; and at the mid-band channel(s) when there are at least 3 channels. For configurations with multiple mid-band channels, due to an even number of channels, both channels should be measured.

## 13.1 Wi-Fi (2.4GHz Band)

| Band (GHz) | Mode | Data rate (Mbps) | Ch # | Freq. (MHz) | Avg. Pwr (dBm) | | Maximum Tune-up Pwr (dBm) | SAR Test (Yes/No) | Note |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | Main | Aux | | | |
| 2.4 | 802.11b | 1 | 1 | 2412 | 19.5 | | 20.50 | Yes | |
| | | | 6 | 2437 | 19.9 | | 20.50 | | |
| | | | 11 | 2462 | 19.4 | | 20.50 | | |
| | | | 1 | 2412 | | 19.5 | 20.50 | Yes | |
| | | | 6 | 2437 | | 19.6 | 20.50 | | |
| | | | 11 | 2462 | | 19.5 | 20.50 | | |
| | 802.11g | MCS0 | 1 | 2412 | No Required | | 18.00 | No | |
| | | | 6 | 2437 | | | 19.50 | | |
| | | | 11 | 2462 | | | 18.00 | | |
| | 802.11n HT20 | MCS0 | 1 | 2412 | No Required | | 17.00 | No | |
| | | | 6 | 2437 | | | 19.50 | | |
| | | | 11 | 2462 | | | 16.00 | | |
| | 802.11n HT40 | MCS0 | 3 | 2422 | No Required | | 13.00 | No | |
| | | | 6 | 2437 | | | 18.50 | | |
| | | | 9 | 2452 | | | 11.00 | | |

Note(s):

1. Output Power and SAR is not required for 802.11n HT20/HT40 channels 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.

## 13.2 Wi-Fi (5GHz Band)

| Band (GHz) | Mode | Data rate (Mbps) | Ch # | Freq. (MHz) | Avg. Pwr (dBm) | | Maximum Tune-up | SAR Test (Yes/No) |
|---|---|---|---|---|---|---|---|---|
| | | | | | Main | Aux | | |
| 5.2 (U-NII 1) | 802.11a | 6 | 36-48 | 5180-5240 | No Required | | 15.0 | No |
| | 802.11n (HT20) | MCS0 | 36-48 | 5180-5240 | | | 15.0 | No |
| | 802.11n (HT40) | MCS0 | 38 | 5190 | | | 11.5 | No |
| | | MCS0 | 46 | 5230 | | | 14.5 | No |
| | 802.11ac VHT20 | VHT0 | 36-48 | 5180-5240 | | | 15.0 | No |
| | 802.11ac VHT40 | VHT0 | 38 | 5190 | | | 11.5 | No |
| | | VHT0 | 46 | 5230 | | | 14.5 | No |
| | 802.11ac VHT80 | VHT0 | 42 | 5210 | | | 10.5 | No |
| 5.3 (U-NII 2A) | 802.11a | 6 | 52 | 5260 | 13.5 | | 15.0 | Yes |
| | | | 56 | 5280 | 13.5 | | 15.0 | Yes |
| | | | 60 | 5300 | 13.5 | | 15.0 | Yes |
| | | | 64 | 5320 | 13.5 | | 15.0 | Yes |
| | | | 52 | 5260 | | 13.2 | 15.0 | Yes |
| | | | 56 | 5280 | | 13.2 | 15.0 | Yes |
| | | | 60 | 5300 | | 13.1 | 15.0 | Yes |
| | | | 64 | 5320 | | 12.9 | 15.0 | Yes |
| | 802.11n (HT20) | MCS0 | 52-64 | 5260-5320 | No Required | | 15.0 | Yes |
| | 802.11n (HT40) | MCS0 | 54 | 5270 | | | 14.5 | No |
| | | MCS0 | 62 | 5310 | | | 14.0 | No |
| | 802.11ac VHT20 | VHT0 | 52-64 | 5260-5320 | | | 15.0 | No |
| | 802.11n (HT40) | VHT0 | 54 | 5270 | | | 14.5 | No |
| | | VHT0 | 62 | 5310 | | | 14.0 | No |
| | 802.11ac VHT80 | VHT0 | 58 | 5290 | | | 12.0 | No |

Note(s):

1. Output Power and SAR measurement is not required for 802.11n HT20/HT40/ac channels when the specified maximum tune-up powers are the same in 802.11n HT20/HT40/ac and the measured SAR is ≤ 1.2 W/Kg.
2. When the specified maximum output power is the same for both UNII band I and UNII band 2A, begin SAR measurement in UNII band 2A; and if the highest reported SAR for UNII band 2A is
   - 2.1. ≤ 1.2 W/kg, SAR is not required for UNII band I.
   - 2.2. > 1.2 W/kg, both bands should be tested independently for SAR.

| Band (GHz) | Mode | Data rate (Mbps) | Ch # | Freq. (MHz) | Avg. Pwr (dBm) | | Maximum Tune-up | SAR Test (Yes/No) |
|---|---|---|---|---|---|---|---|---|
| | | | | | Main | Aux | | |
| 5.5 (U-NII-2C) | 802.11a | 6 | 100 | 5500 | 13.5 | | 15.0 | Yes |
| | | | 104 | 5520 | 13.6 | | 15.0 | Yes |
| | | | 108 | 5540 | 13.3 | | 15.0 | Yes |
| | | | 112 | 5560 | 13.5 | | 15.0 | Yes |
| | | | 116 | 5580 | 13.4 | | 15.0 | Yes |
| | | | 132 | 5660 | 13.3 | | 15.0 | Yes |
| | | | 136 | 5680 | 13.0 | | 15.0 | Yes |
| | | | 140 | 5700 | 13.0 | | 15.0 | Yes |
| | | | 100 | 5500 | | 13.2 | 15.0 | Yes |
| | | | 104 | 5520 | | 12.9 | 15.0 | Yes |
| | | | 108 | 5540 | | 12.9 | 15.0 | Yes |
| | | | 112 | 5560 | | 13.6 | 15.0 | Yes |
| | | | 116 | 5580 | | 13.1 | 15.0 | Yes |
| | | | 132 | 5660 | | 13.2 | 15.0 | Yes |
| | | | 136 | 5680 | | 13.0 | 15.0 | Yes |
| | | | 140 | 5700 | | 13.2 | 15.0 | Yes |
| | 802.11n (HT20) | MCS0 | 100-140 | 5500-5700 | No Required | | 15.0 | No |
| | 802.11n (HT40) | MCS0 | 102 | 5510 | | | 11.5 | No |
| | | | 110-134 | 5550-5670 | | | 14.5 | No |
| | 802.11ac VHT20 | VHT0 | 100-140 | 5500-5700 | | | 15.0 | No |
| | 802.11ac VHT40 | VHT0 | 102 | 5510 | | | 11.5 | No |
| | | | 110-134 | 5550-5670 | | | 14.5 | No |
| | 802.11ac VHT80 | VHT0 | 106 | 5530 | | | 12.0 | No |
| | | | 122-138 | 5610-5690 | | | 14.5 | No |

Note(s):

1. Output Power and SAR measurement is not required for 802.11n HT20/HT40/ac channels when the specified maximum tune-up powers are the same in 802.11n HT20/HT40/ac and the measured SAR is ≤ 1.2 W/Kg.

| Band (GHz) | Mode | Data rate (Mbps) | Ch # | Freq. (MHz) | Avg. Pwr (dBm) | | Maximum Tune-up | SAR Test (Yes/No) |
|---|---|---|---|---|---|---|---|---|
| | | | | | Main | Aux | | |
| 5.8 (U-NII-3) | 802.11a | 6 | 149 | 5745 | 13.6 | | 15.0 | Yes |
| | | | 153 | 5765 | 13.4 | | 15.0 | Yes |
| | | | 157 | 5785 | 13.1 | | 15.0 | Yes |
| | | | 161 | 5805 | 13.2 | | 15.0 | Yes |
| | | | 165 | 5825 | 13.1 | | 15.0 | Yes |
| | | | 149 | 5745 | | 13.3 | 15.0 | Yes |
| | | | 153 | 5765 | | 13.3 | 15.0 | Yes |
| | | | 157 | 5785 | | 13.3 | 15.0 | Yes |
| | | | 161 | 5805 | | 13.2 | 15.0 | Yes |
| | | | 165 | 5825 | | 13.0 | 15.0 | Yes |
| | 802.11n (HT20) | MCS0 | 149-165 | 5745-5825 | No Required | | 15.0 | No |
| | 802.11n (HT40) | MCS0 | 151 | 5755 | | | 11.5 | No |
| | | | 159 | 5795 | | | 14.5 | No |
| | 802.11ac VHT20 | VHT0 | 149-165 | 5745-5825 | | | 15.0 | No |
| | 802.11ac VHT40 | VHT0 | 151 | 5755 | | | 11.5 | No |
| | | | 159 | 5795 | | | 14.5 | No |
| | 802.11ac VHT80 | VHT0 | 155 | 5775 | | | 10.0 | No |

Note(s):

1. Output Power and SAR measurement is not required for 802.11n HT20/HT40/ac channels when the specified maximum tune-up powers are the same in 802.11n HT20/HT40/ac and the measured SAR is ≤ 1.2 W/Kg.

## 13.3 Bluetooth

Refer section 9, the Bluetooth maximum tune-up power is 7 dBm .This power level qualifies not required for SAR testing.

# 14 SAR Measurements Results

According to KDB248227D01 802.11 Wi-Fi SAR v02r02, the SAR test reduction procedures are:

SAR test reduction for 802.11 Wi-Fi transmission mode configurations are considered separately for DSSS and OFDM. An initial test position is determined to reduce the number of tests required for certain exposure configurations with multiple test positions. An initial test configuration is determined for each frequency band and aggregated band according to maximum output power, channel bandwidth, wireless mode configurations and other operating parameters to streamline the measurement requirements. For 2.4 GHz DSSS, either the initial test position or DSSS procedure is applied to reduce the number of SAR tests; these are mutually exclusive. For OFDM, an initial test position is only applicable to next to the ear, UMPC mini-tablet and hotspot mode configurations, which is tested using the initial test configuration to facilitate test reduction. For other exposure conditions with a fixed test position, SAR test reduction is determined using only the initial test configuration.

The multiple test positions require SAR measurements in head, hotspot mode or UMPC mini-tablet configurations may be reduced according to the highest reported SAR determined using the initial test position(s) by applying the DSSS or OFDM SAR measurement procedures in the required wireless mode test configuration(s). The initial test position(s) is measured using the highest measured maximum output power channel in the required wireless mode test configuration(s). When the reported SAR for the initial test position is:

- ≤ 0.4 W/kg, further SAR measurement is not required for the other test positions in that exposure configuration and wireless mode combination within the frequency band or aggregated band. DSSS and OFDM configurations are considered separately according to the required SAR procedures.
- > 0.4 W/kg, SAR is repeated using the same wireless mode test configuration tested in the initial test position to measure the subsequent next closet/smallest test separation distance and maximum coupling test position, on the highest maximum output power channel, until the reported SAR is ≤ 0.8 W/kg or all required test positions are tested.
  - For subsequent test positions with equivalent test separation distance or when exposure is dominated by coupling conditions, the position for maximum coupling condition should be tested.
  - When it is unclear, all equivalent conditions must be tested.
- For all positions/configurations tested using the initial test position and subsequent test positions, when the reported SAR is > 0.8 W/kg, measure the SAR for these positions/configurations on the subsequent next highest measured output power channel(s) until the reported SAR is ≤ 1.2 W/kg or all required test channels are considered.
  - The additional power measurements required for this step should be limited to those necessary for identifying subsequent highest output power channels to apply the test reduction.
- When the specified maximum output power is the same for both UNII 1 and UNII 2A, begin SAR measurements in UNII 2A with the channel with the highest measured output power. If the reported SAR for UNII 2A is ≤ 1.2 W/kg, SAR is not required for UNII 1; otherwise treat the remaining bands separately and test them independently for SAR.
- When the specified maximum output power is different between UNII 1 and UNII 2A, begin SAR with the band that has the higher specified maximum output. If the highest reported SAR for the band with the highest specified power is ≤ 1.2 W/kg, testing for the band with the lower specified output power is not required; otherwise test the remaining bands independently for SAR.

To determine the initial test position, Area Scans were performed to determine the position with the Maximum Value of SAR (measured). The position that produced the highest Maximum Value of SAR is considered the worst case position; thus used as the initial test position

**Wi-Fi (2.4GHz Band):**

| Test Mode | Band (GHz) | Mode | Dist. (mm) | Test Position | Ch# | Freq. (MHz) | Chain | Power (dBm) | | Area Scan 1g SAR (W/Kg) | Zoom Scan 1g SAR (W/kg) | Reported SAR (W/kg) | Note | Plot No. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Tune up limit | Meas. | | | | | |
| Notebook | 2.4GHz | 802.11b | 0 | Bottom | 6 | 2437 | 0 | 20.5 | 19.9 | 0.610 | 0.639 | 0.734 | | |
| | | | 0 | Bottom | 6 | 2437 | 1 | 20.5 | 19.6 | 0.418 | 0.412 | 0.507 | | |
| | | | 0 | Bottom | 6 | 2437 | 0 | 20.5 | 19.9 | 0.620 | 0.692 | 0.795 | Ant2 | 1 |

Note(s):

1. The Ant 1 & Ant 2 are the same type and antenna location. So we choose the Ant 1 to perform the all SAR test. The Ant 2 was performed the SAR test of the worst channel of Ant 1. The reported SAR don't have over the limit value ,so SAR test of the Ant 2 performed spot check can cover test result.
2. Highest reported SAR is > 0.4 W/kg. Due to the highest reported SAR for this test position, other test positions in this exposure condition were evaluated until a SAR ≤ 0.8 W/kg was reported.

**Wi-Fi (5 GHz Band):**

| Test Mode | Band (GHz) | Mode | Dist. (mm) | Test Position | Ch# | Freq. (MHz) | Chain | Power (dBm) | | Area Scan 1g SAR (W/Kg) | Zoom Scan 1g SAR (W/kg) | Reported SAR (W/kg) | Note | Plot No. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Tune up limit | Meas. | | | | | |
| Notebook | 5.3 (U-NII-2A) | 802.11a | 0 | Bottom | 56 | 5280 | 0 | 15.0 | 13.5 | 0.361 | 0.526 | 0.743 | | 1 |
| | | | 0 | Bottom | 52 | 5260 | 1 | 15.0 | 13.2 | 0.206 | 0.240 | 0.360 | | |
| | 5.5 (U-NII-2C) | | 0 | Bottom | 104 | 5520 | 0 | 15.0 | 13.6 | 0.329 | 0.430 | 0.594 | | 2 |
| | | | 0 | Bottom | 112 | 5560 | 1 | 15.0 | 13.6 | 0.177 | 0.336 | 0.464 | | |
| | 5.8 (U-NII-3) | | 0 | Bottom | 149 | 5745 | 0 | 15.0 | 13.6 | 0.452 | 0.503 | 0.702 | | 3 |
| | | | 0 | Bottom | 157 | 5785 | 1 | 15.0 | 13.3 | 0.207 | 0.311 | 0.460 | | |
| | 5.3 (U-NII-2A) | | 0 | Bottom | 56 | 5280 | 0 | 15.0 | 13.5 | 0.361 | 0.543 | 0.767 | Ant2 | 4 |

Note(s):

1. Highest reported SAR is > 0.4 W/kg. Due to the highest reported SAR for this test position, other test positions in this exposure condition were evaluated until a SAR ≤ 0.8 W/kg was reported.
2. The Ant 1 & Ant 2 are the same type and antenna location. So we choose the Ant 1 to perform the all SAR test. The Ant 2 was performed the SAR test of the worst channel of Ant 1. The reported SAR don't have over the limit value ,so SAR test of the Ant 2 performed spot check can cover test result.

# 15 Simultaneous Transmission SAR Analysis

KDB 447498 D01 General RF Exposure Guidance v06, introduces a new formula for calculating the SAR to Peak Location Ratio (SPLSR) between pairs of simultaneously transmitting antennas:

$SPLSR = (SAR_1 + SAR_2)^{1.5} / R_i$

Where:

***$SAR_1$*** is the highest Reported or estimated SAR for the first of a pair of simultaneous transmitting antennas, in a specific test operating mode and exposure condition

***$SAR_2$*** is the highest Reported or estimated SAR for the second of a pair of simultaneous transmitting antennas, in the same test operating mode and exposure condition as the first

***$R_i$*** is the separation distance between the pair of simultaneous transmitting antennas. When the SAR is measured, for both antennas in the pair, it is determined by the actual x, y and z coordinates in the 1-g SAR for each SAR peak location, based on the extrapolated and interpolated result in the zoom scan measurement, using the formula of $[(x_1-x_2)^2 + (y_1-y_2)^2 + (z_1-z_2)^2]$

A new threshold of 0.04 is also introduced in the draft KDB. Thus, in order for a pair of simultaneous transmitting antennas with the sum of 1-g SAR > 1.6 W/kg to qualify for exemption from Simultaneous Transmission SAR measurements, it has to satisfy the condition of:

$(SAR_1 + SAR_2)^{1.5} / R_i \leq 0.04$

## 15.1 Estimated SAR for Simultaneous Transmission SAR Analysis

**Considerations for SAR estimation**

1. When standalone SAR test exclusion applies, standalone SAR must also be estimated to determine simultaneous transmission SAR test exclusion.
2. Dedicated Host Approach criteria for SAR test exclusion is likewise applied to SAR estimation, with certain distinctions between test exclusion and SAR estimation:

- When the separation distance from the antenna to an adjacent edge is ≤ 5 mm, a distance of 5 mm is applied for SAR estimation; this is the same between test exclusion and SAR estimation calculations.
- When the separation distance from the antenna to an adjacent edge is > 5 mm but ≤ 50 mm, the actual antenna-to-edge separation distance is applied for SAR estimation.
- When the minimum test separation distance is > 50 mm, the estimated SAR value is 0.4 W/kg

### 15.1.1 Estimated SAR for Bluetooth

According to section 9, the Bluetooth must be estimated according to following to determine simultaneous transmission SAR test exclusion:

- *(max. power of channel, including tune-up tolerance, mW) / (min. test separation distance, mm)]·[√f$_{(GHz)}$/x]* W/kg for test separation distances ≤ 50 mm; where x = 7.5 for 1-g SAR, and x = 18.75 for 10-g SAR.
- 0.4 W/kg for 1-g SAR and 1.0 W/kg for 10-g SAR, when the test separation distances is > 50 mm.

| Antenna | Band | Frequency (MHz) | Output Power | | Separation Distances(mm) | | | | | Estimated 1-g SAR (W/Kg) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | dBm | mW | Bottom | Edge1 | Edge2 | Edge3 | Edge4 | Rear | Edge1 | Edge2 | Edge3 | Edge4 |
| Wi-Fi Main | 2.4GHz | 2437 | 17.5 | 56 | 8.1 | | | | | Measure | | | | |
| Wi-Fi Main | 5.2GHz | 5210 | 13.5 | 22 | 8.1 | | | | | Measure | | | | |
| Wi-Fi Main | 5.3GHz | 5290 | 13.5 | 22 | 8.1 | | | | | Measure | | | | |
| Wi-Fi Main | 5.5GHz | 5690 | 13.5 | 22 | 8.1 | | | | | Measure | | | | |
| Wi-Fi Main | 5.8GHz | 5755 | 13.5 | 22 | 8.1 | | | | | Measure | | | | |
| Wi-Fi Aux | Bluetooth | 2480 | 7.0 | 5 | 8.1 | | | | | 0.210 | | | | |

## 15.2 Sum of the SAR for Simultaneous Transmission Analysis

### 15.2.1 Sum of the SAR for Wi-Fi MIMO

Wi-Fi 2.4GHz

| Test Position | Simulataneous Transmission Scenario | | ∑ 1-g SAR (W/kg) | SPLSR (Yes/No) |
|---|---|---|---|---|
| | Wi-Fi Main | Wi-Fi Aux | | |
| Bottom | 0.795 | 0.507 | 1.302 | No |

Note(s):
As the Sum of the SAR is less than 1.6W/Kg, so SPLSR is not required.

Wi-Fi 5GHz

| Test Position | Simulataneous Transmission Scenario | | ∑ 1-g SAR (W/kg) | SPLSR (Yes/No) |
|---|---|---|---|---|
| | Wi-Fi Main | Wi-Fi Aux | | |
| Bottom | 0.767 | 0.464 | 1.231 | No |

Note(s):
As the Sum of the SAR is less than 1.6W/Kg, so SPLSR is not required.

### 15.2.2 Sum of the SAR for Wi-Fi & Bluetooth

| Band | Test Position | Simulataneous Transmission Scenario | | ∑ 1-g SAR (W/kg) | SPLSR (Yes/No) |
|---|---|---|---|---|---|
| | | Wi-Fi Main | Bluetooth | | |
| 2.4GHz | Bottom | 0.795 | 0.210 | 1.005 | No |

Note(s):
As the Sum of the SAR is less than 1.6W/Kg, so SPLSR is not required.

| Band | Test Position | Simulataneous Transmission Scenario | | | ∑ 1-g SAR (W/kg) | SPLSR (Yes/No) |
|---|---|---|---|---|---|---|
| | | Wi-Fi Main | Wi-Fi Aux | Bluetooth | | |
| 5GHz | Bottom | 0.767 | 0.464 | 0.210 | 1.441 | No |

Note(s):
As the Sum of the SAR is less than 1.6W/Kg, so SPLSR is not required.

# 16 Equipment List & Calibration Status

| Name of Equipment | Manufacturer | Type/Model | Serial Number | Calibration Cycle(year) | Calibration Due |
|---|---|---|---|---|---|
| S-Parameter Network Analyzer | Agilent | E5071C | MY46107234 | 1 | 2016/10/13 |
| Electronic Probe kit | Hewlett Packard | 85070D | N/A | N/A | N/A |
| Power Meter | Agilent | 4416 | GB41291611 | 1 | 2016/09/05 |
| Power Sensor | Agilent | 8481H | MY41091956 | 1 | 2016/09/05 |
| Data Acquisition Electronics (DAE) | SPEAG | DAE4 | 877 | 1 | 2017/3/20 |
| Dosimetric E-Field Probe | SPEAG | EX3DV4 | 7350 | 1 | 2016/12/16 |
| 2450 MHz System Validation Dipole | SPEAG | D2450V2 | 869 | 1 | 2016/06/18 |
| 5GHz System Validation Dipole | SPEAG | D5GHzV2 | 1004 | 1 | 2016/11/19 |
| Robot | Staubli | RX90L | F02/5T69A1/A/01 | N/A | N/A |
| Amplifier | Mini-Circuit | ZVE-8G | 665500309 | N/A | N/A |
| Amplifier | Mini-Circuit | ZHL-1724HLN | D072602#2 | N/A | N/A |

# 17 Facilities

All measurement facilities used to collect the measurement data are located at

☐ No. 81-1, Lane 210, Bade Rd. 2, Luchu Hsiang, Taoyuan Hsien, Taiwan, R.O.C.

☒ No.11, Wugong 6th Rd., Wugu Dist., New Taipei City 24891, Taiwan. (R.O.C.)

☐ No. 199, Chunghsen Road, Hsintien City, Taipei Hsien, Taiwan, R.O.C.

# 18 Reference

[1] Federal Communications Commission, \Report and order: Guidelines for evaluating the environ-mental effects of radiofrequency radiation", Tech. Rep. FCC 96-326, FCC, Washington, D.C. 20554, 1996.

[2] David L. Means Kwok Chan, Robert F. Cleveland, \Evaluating compliance with FCC guidelines for human exposure to radiofrequency electromagnetic fields", Tech. Rep., Federal Communication Commision, O_ce of Engineering & Technology, Washington, DC, 1997.

[3] Thomas Schmid, Oliver Egger, and Niels Kuster, \Automated E-_eld scanning system for dosimetric assessments", IEEE Transactions on Microwave Theory and Techniques, vol. 44, pp. 105{113, Jan. 1996.

[4] Niels Kuster, Ralph K.astle, and Thomas Schmid, \Dosimetric evaluation of mobile communications equipment with known precision", IEICE Transactions on Communications, vol. E80-B, no. 5, pp. 645{652, May 1997.

[5] CENELEC, \Considerations for evaluating of human exposure to electromagnetic fields (EMFs) from mobile telecommunication equipment (MTE) in the frequency range 30MHz - 6GHz", Tech. Rep., CENELEC, European Committee for Electrotechnical Standardization, Brussels, 1997.

[6] ANSI, ANSI/IEEE C95.1-2005: IEEE Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz, The Institute of Electrical and Electronics Engineers, Inc., New York, NY 10017, 2006.

[7] Katja Pokovic, Thomas Schmid, and Niels Kuster, \Robust setup for precise calibration of E-_eld probes in tissue simulating liquids at mobile communications frequencies", in ICECOM _ 97, Dubrovnik, October 15{17, 1997, pp. 120{124.

[8] Katja Pokovic, Thomas Schmid, and Niels Kuster, \E-_eld probe with improved isotropy in brain simulating liquids", in Proceedings of the ELMAR, Zadar, Croatia, 23{25 June, 1996, pp. 172{175.

[9] Volker Hombach, Klaus Meier, Michael Burkhardt, Eberhard K. uhn, and Niels Kuster, \The dependence of EM energy absorption upon human head modeling at 900 MHz", IEEE Transactions onMicrowave Theory and Techniques, vol. 44, no. 10, pp. 1865{1873, Oct. 1996.

[10] Klaus Meier, Ralf Kastle, Volker Hombach, Roger Tay, and Niels Kuster, \The dependence of EM energy absorption upon human head modeling at 1800 MHz", IEEE Transactions on Microwave Theory and Techniques, Oct. 1997, in press.

[11] W. Gander, Computermathematik, Birkhaeuser, Basel, 1992.

[12] W. H. Press, S. A. Teukolsky,W. T. Vetterling, and B. P. Flannery, Numerical Recepies in C, The Art of Scientific Computing, Second Edition, Cambridge University Press, 1992..Dosimetric Evaluation of Sample device, month 1998 9

[13] NIS81 NAMAS, \The treatment of uncertainity in EMC measurement", Tech. Rep., NAMAS Executive, National Physical Laboratory, Teddington, Middlesex, England, 1994.

[14] Barry N. Taylor and Christ E. Kuyatt, \Guidelines for evaluating and expressing the uncertainty of NIST measurement results", Tech. Rep., National Institute of Standards and Technology, 1994. Dosimetric Evaluation of Sample device, month 1998 10

# 19 Attachments

| Exhibit | Content |
|---|---|
| 1 | System Performance Check Plots |
| 2 | SAR Test Data Plots |
| 4 | SAR Equipment calibration report |
| 5 | T160530W01-SF PHOTOs |

**END OF REPORT**