FCC SAR Test Report

APPLICANT	:	**Realtek Semiconductor Corp.**
EQUIPMENT	:	**802.11a/b/g/n/ac RTL8821CE Combo module**
BRAND NAME	:	**REALTEK**
MODEL NAME	:	**RTL8821CE**
FCC ID	:	**TX2-RTL8821CE**
STANDARD	:	**FCC 47 CFR Part 2 (2.1093)** **ANSI/IEEE C95.1-1992** **IEEE 1528-2013**

We, SPORTON INTERNATIONAL INC., would like to declare that the tested sample has been evaluated in accordance with the procedures and had been in compliance with the applicable technical standards.

The test results in this report apply exclusively to the tested model / sample. Without written approval of SPORTON INTERNATIONAL INC., the test report shall not be reproduced except in full.

Eric Huang

Reviewed by: Eric Huang / Manager

Jones Tsai

Approved by: Jones Tsai / Manager

Testing Laboratory
1190

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Table of Contents

Revision History

REPORT NO.	VERSION	DESCRIPTION	ISSUED DATE
FA692918-04	Rev. 01	Initial issue of report	Jan. 20, 2017
FA692918-04	Rev. 02	Added SPLSR analysis in section 13.2	Jan. 25, 2017
FA692918-04	Rev. 03	1. Updated 5GHz WLAN Tune-up Limit and conducted RF output power in section 11. 2. Re-test 5GHz WLAN SAR also updated appendix A and B. 3. Revised section 13.	Feb. 9, 2017
FA692918-04	Rev. 04	1. Updated general note 6 in section 11. 2. Updated general note 4/5/6 in section 12. 3. Updated section 13.2.	Feb. 20, 2017
FA692918-04	Rev. 05	1. Updated section 4.1. 2. Updated general note 5 / 6 in section 12. 3. Added general note 7 in section 12. 4. Updated section 13.2.	Mar. 2, 2017
FA692918-04	Rev. 06	1. Added remark 2 in section 4.1 2. Added general note 7 and updated power table in section 11 3. Added general note 7(c) in section 12 4. Removed section 13.2.	Mar. 31, 2017
FA692918-04	Rev. 07	1. Added remark 2 and remark 4 in section 4.1	May. 9, 2017

1. Statement of Compliance

The maximum results of Specific Absorption Rate (SAR) found during testing for **Realtek Semiconductor Corp., 802.11a/b/g/n/ac RTL8821CE Combo module, RTL8821CE**, are as follows.

Equipment Class	Frequency Band	Highest SAR Summary Body (Separation 5mm) 1g SAR (W/kg)	Highest Simultaneous Transmission 1g SAR (W/kg)
DTS	2.4GHz WLAN	0.79	
NII	5GHz WLAN	0.74	0.76
DSS	Bluetooth	0.07	
Date of Testing:		2016/12/22 ~ 2017/2/2	

This device is in compliance with Specific Absorption Rate (SAR) for general population/uncontrolled exposure limits (1.6 W/kg) specified in FCC 47 CFR part 2 (2.1093) and ANSI/IEEE C95.1-1992, and had been tested in accordance with the measurement methods and procedures specified in IEEE 1528-2013 and FCC KDB publications

2. Administration Data

Testing Laboratory	
Test Site	SPORTON INTERNATIONAL INC.
Test Site Location	No.52, Hwa Ya 1st Rd., Hwa Ya Technology Park, Kwei-Shan District, Taoyuan City, Taiwan (R.O.C.) TEL: +886-3-327-3456 FAX: +886-3-328-4978

Applicant	
Company Name	Realtek Semiconductor Corp.
Address	No. 2,Innovation Road II, Hsinchu Science Park, Hsinchu 300,Taiwan

Manufacturer	
Company Name	Realtek Semiconductor Corp.
Address	No. 2,Innovation Road II, Hsinchu Science Park, Hsinchu 300,Taiwan

3. Guidance Applied

The Specific Absorption Rate (SAR) testing specification, method, and procedure for this device is in accordance with the following standards:

- FCC 47 CFR Part 2 (2.1093)
- ANSI/IEEE C95.1-1992
- IEEE 1528-2013
- FCC KDB 865664 D01 SAR Measurement 100 MHz to 6 GHz v01r04
- FCC KDB 865664 D02 SAR Reporting v01r02
- FCC KDB 447498 D01 General RF Exposure Guidance v06
- FCC KDB 248227 D01 802.11 Wi-Fi SAR v02r02
- FCC KDB 616217 D04 SAR for laptop and tablets v01r02

4. Equipment Under Test (EUT) Information

4.1 General Information

Product Feature & Specification	
Equipment Name	802.11a/b/g/n/ac RTL8821CE Combo module
Brand Name	REALTEK
Model Name	RTL8821CE
FCC ID	TX2-RTL8821CE
Wireless Technology and Frequency Range	WLAN 2.4GHz Band: 2412 MHz ~ 2472 MHz WLAN 5.2GHz Band: 5180 MHz ~ 5240 MHz WLAN 5.3GHz Band: 5260 MHz ~ 5320 MHz WLAN 5.5GHz Band: 5500 MHz ~ 5720 MHz WLAN 5.8GHz Band: 5745 MHz ~ 5825 MHz Bluetooth: 2402 MHz ~ 2480 MHz
Mode	WLAN 2.4GHz : 802.11b/g/n/ac HT20/HT40/VHT20/VHT40 WLAN 5GHz : 802.11a/n/ac HT20/HT40/VHT20/VHT40/VHT80 Bluetooth BR/EDR/LE
HW Version	1v1
SW Version	v1.06
EUT Stage	Identical Prototype

Remark:

1. This devise have 4 configurations as following table, but due to both chains have the same Max. tune up power, therefore we tested Config.1 that single transmit mode at chain 1, and additional simultaneous transmission analysis in section 13.0 to cover 4 configurations of EUT.
2. EUT 1 and EUT 2 have 2 connectors, EUT 3 and EUT 4 only one of the connectors, the other one was removed from module.
3. EUT 3 and EUT 4 have the same TX transmission configuration, and only one connector can be used for connection with TX/RX antenna, the difference of them are the EUT 3 configuration was used chain 2 (Chain 1 was removed from the module), EUT 4 configuration was used chain 1(Chain 2 was removed from the module).

EUT	Configuration	Antenna Chain	Description
EUT 1	Config.1 Diversity	2 chains	The EUT supports the antenna with TX/RX diversity function for WLAN and Bluetooth. (Ex. Assume chain 1 was selected to conduct transmitting function in WLAN, so chain 2 was selected in Bluetooth Mode. Vice versa.) WLAN 2.4GHz and Bluetooth will be transmitting from the different chains; WLAN 5GHz and Bluetooth will be transmitting from the same chain. **WLAN function (1TX, 1RX) / Bluetooth function (1TX, 1RX)** The EUT supports 1TX/1RX function, and it supports TX/RX diversity function. Both chain 1 and chain 2 could be used as transmitting/receiving antenna, but only one of them could transmit/receive at the same time.
EUT 2	Config.2 Fixed	2 chains	**WLAN function (1TX, 1RX) / Bluetooth function (1TX, 1RX)** Chain 2 is designated for WLAN (2.4GHz), Chain 1 is designated for WLAN (5GHz) and Bluetooth.
EUT 3	Config.3 Single	1 chain	**WLAN function (1TX, 1RX) / Bluetooth function (1TX, 1RX)** WLAN and BT share a common chain, where WLAN (2.4GHz) and BT couldn't transmit/receive at the same time, but WLAN (5GHz) and BT could transmit/receive at the same time.
EUT 4	Config.4 Single	1 chain	**WLAN function (1TX, 1RX) / Bluetooth function (1TX, 1RX)** WLAN and BT share a common chain, where WLAN (2.4GHz) and BT couldn't transmit/receive at the same time, but WLAN (5GHz) and BT could transmit/receive at the same time.

4. The SAR test report and the integration manual only indicate 1 antenna going to be authorized in this c2pc, and the test lab has performed the test for 6 surfaces of this antenna with 5 mm separation distance to cover all of the polarizations and operations to compliance for the required display and/or keyboard installation conditions and separation distance.
   The antenna detail information as following.
   (a) Brand name : REALTEK
   (b) Model name : RTK-ANT-0006
   (c) Ant type : PIFA antenna
   (d) Connector : IPEX MHF4
   (e) Gain : 3.5 (dBi) for 2.4GHZ WLAN , 5 (dBi) for 5GHZ WLAN ,

5. RF Exposure Limits

5.1 Uncontrolled Environment

Uncontrolled Environments are defined as locations where there is the exposure of individuals who have no knowledge or control of their exposure. The general population/uncontrolled exposure limits are applicable to situations in which the general public may be exposed or in which persons who are exposed as a consequence of their employment may not be made fully aware of the potential for exposure or cannot exercise control over their exposure. Members of the general public would come under this category when exposure is not employment-related; for example, in the case of a wireless transmitter that exposes persons in its vicinity.

5.2 Controlled Environment

Controlled Environments are defined as locations where there is exposure that may be incurred by persons who are aware of the potential for exposure, (i.e. as a result of employment or occupation). In general, occupational/controlled exposure limits are applicable to situations in which persons are exposed as a consequence of their employment, who have been made fully aware of the potential for exposure and can exercise control over their exposure. The exposure category is also applicable when the exposure is of a transient nature due to incidental passage through a location where the exposure levels may be higher than the general population/uncontrolled limits, but the exposed person is fully aware of the potential for exposure and can exercise control over his or her exposure by leaving the area or by some other appropriate means.

Limits for Occupational/Controlled Exposure (W/kg)

Whole-Body	Partial-Body	Hands, Wrists, Feet and Ankles
0.4	8.0	20.0

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

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

1. Whole-Body SAR is averaged over the entire body, partial-body SAR is averaged over any 1gram 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.

6. Specific Absorption Rate (SAR)

6.1 Introduction

SAR is related to the rate at which energy is absorbed per unit mass in an object exposed to a radio field. The SAR distribution in a biological body is complicated and is usually carried out by experimental techniques or numerical modeling. The standard recommends limits for two tiers of groups, occupational/controlled and general population/uncontrolled, based on a person's awareness and ability to exercise control over his or her exposure. In general, occupational/controlled exposure limits are higher than the limits for general population/uncontrolled.

6.2 SAR Definition

The SAR definition is the time derivative (rate) of the incremental energy (dW) absorbed by (dissipated in) an incremental mass (dm) contained in a volume element (dv) of a given density (ρ). The equation description is as below:

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

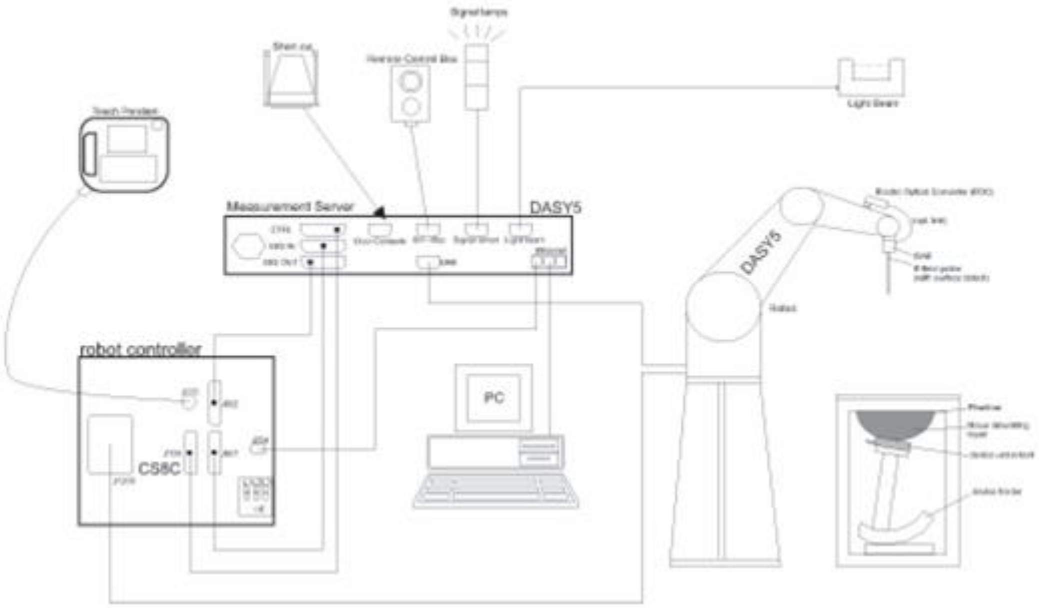
SAR is expressed in units of Watts per kilogram (W/kg)

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

Where: σ is the conductivity of the tissue, ρ is the mass density of the tissue and E is the RMS electrical field strength.

7. System Description and Setup

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



- A standard high precision 6-axis robot with controller, teach pendant and software. An arm extension for accommodating the data acquisition electronics (DAE).
- An isotropic Field probe optimized and calibrated for the targeted measurement.
- 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 from optical to electrical signals for the digital communication to the DAE. To use optical surface detection, a special version of the EOC is required. The EOC signal is transmitted 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.
- The Light Beam used is for probe alignment. This improves the (absolute) accuracy of the probe positioning.
- A computer running WinXP or Win7 and the DASY5 software.
- Remote control and teach pendant as well as additional circuitry for robot safety such as warning lamps, etc.
- The phantom, the device holder and other accessories according to the targeted measurement.

7.1 E-Field Probe

The SAR measurement is conducted with the dosimetric probe (manufactured by SPEAG).The probe is specially designed and calibrated for use in liquid with high permittivity. The dosimetric probe has special calibration in liquid at different frequency. This probe has a built in optical surface detection system to prevent from collision with phantom.

<ES3DV3 Probe>

Construction	Symmetric design with triangular core Interleaved sensors Built-in shielding against static charges PEEK enclosure material (resistant to organic solvents, e.g., DGBE)	
Frequency	10 MHz – 4 GHz; Linearity: ±0.2 dB (30 MHz – 4 GHz)	
Directivity	±0.2 dB in TSL (rotation around probe axis) ±0.3 dB in TSL (rotation normal to probe axis)	
Dynamic Range	5 µW/g – >100 mW/g; Linearity: ±0.2 dB	
Dimensions	Overall length: 337 mm (tip: 20 mm) Tip diameter: 3.9 mm (body: 12 mm) Distance from probe tip to dipole centers: 3.0 mm	

<EX3DV4 Probe>

Construction	Symmetric design with triangular core Built-in shielding against static charges PEEK enclosure material (resistant to organic solvents, e.g., DGBE)	
Frequency	10 MHz – >6 GHz Linearity: ±0.2 dB (30 MHz – 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 µW/g – >100 mW/g Linearity: ±0.2 dB (noise: typically <1 µW/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	

7.2 Data Acquisition Electronics (DAE)

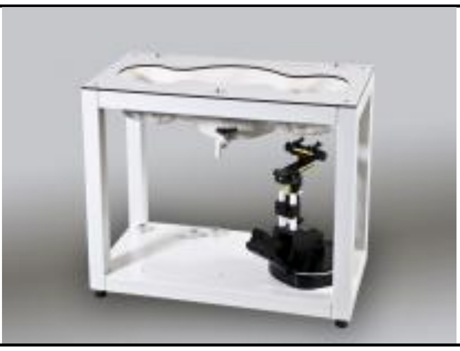
The data acquisition electronics (DAE) consists of a highly sensitive electrometer-grade preamplifier with auto-zeroing, a channel and gain-switching multiplexer, a fast 16 bit AD-converter and a command decoder and control logic unit. Transmission to the measurement server is accomplished through an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

The input impedance of the DAE is 200 MOhm; the inputs are symmetrical and floating. Common mode rejection is above 80 dB.

Fig 5.1 Photo of DAE

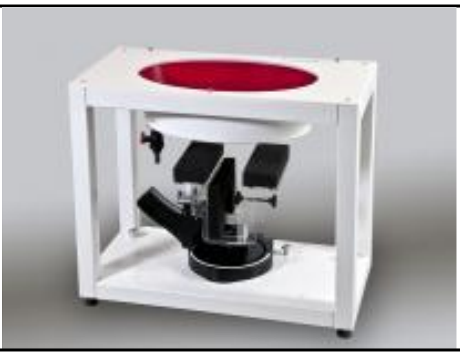
7.3 Phantom

<SAM Twin Phantom>

Shell Thickness	2 ± 0.2 mm; Center ear point: 6 ± 0.2 mm	
Filling Volume	Approx. 25 liters	
Dimensions	Length: 1000 mm; Width: 500 mm; Height: adjustable feet	
Measurement Areas	Left Hand, Right Hand, Flat Phantom	

The bottom plate contains three pair of bolts for locking the device holder. The device holder positions are adjusted to the standard measurement positions in the three sections. A white cover is provided to tap the phantom during off-periods to prevent water evaporation and changes in the liquid parameters. On the phantom top, three reference markers are provided to identify the phantom position with respect to the robot.

<ELI Phantom>

Shell Thickness	2 ± 0.2 mm (sagging: <1%)	
Filling Volume	Approx. 30 liters	
Dimensions	Major ellipse axis: 600 mm Minor axis: 400 mm	

The ELI phantom is intended 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 standard and all known tissue simulating liquids.

7.4 Device Holder

<Mounting Device for Hand-Held Transmitter>

In combination with the Twin SAM V5.0/V5.0c or ELI phantoms, the Mounting Device for Hand-Held Transmitters enables rotation of the mounted transmitter device to specified spherical coordinates. At the heads, the rotation axis is at the ear opening. Transmitter devices can be easily and accurately positioned according to IEC 62209-1, IEEE 1528, FCC, or other specifications. The device holder can be locked for positioning at different phantom sections (left head, right head, flat). And upgrade kit to Mounting Device to enable easy mounting of wider devices like big smart-phones, e-books, small tablets, etc. It holds devices with width up to 140 mm.

Mounting Device for Hand-Held Transmitters

Mounting Device Adaptor for Wide-Phones

<Mounting Device for Laptops and other Body-Worn Transmitters>

The extension is lightweight and made of POM, acrylic glass and foam. It fits easily on the upper part of the mounting device in place of the phone positioned. The extension is fully compatible with the SAM Twin and ELI phantoms.

Mounting Device for Laptops

8. Measurement Procedures

The measurement procedures are as follows:

<Conducted power measurement>

(a) For WWAN power measurement, use base station simulator to configure EUT WWAN transmission in conducted connection with RF cable, at maximum power in each supported wireless interface and frequency band.
(b) Read the WWAN RF power level from the base station simulator.
(c) For WLAN/BT power measurement, use engineering software to configure EUT WLAN/BT continuously transmission, at maximum RF power in each supported wireless interface and frequency band
(d) Connect EUT RF port through RF cable to the power meter, and measure WLAN/BT output power

<SAR measurement>

(a) Use base station simulator to configure EUT WWAN transmission in radiated connection, and engineering software to configure EUT WLAN/BT continuously transmission, at maximum RF power, in the highest power channel.
(b) Place the EUT in the positions as Appendix D demonstrates.
(c) Set scan area, grid size and other setting on the DASY software.
(d) Measure SAR results for the highest power channel on each testing position.
(e) Find out the largest SAR result on these testing positions of each band
(f) Measure SAR results for other channels in worst SAR testing position if the reported SAR of highest power channel is larger than 0.8 W/kg

According to the test standard, the recommended procedure for assessing the peak spatial-average SAR value consists of the following steps:

(a) Power reference measurement
(b) Area scan
(c) Zoom scan
(d) Power drift measurement

8.1 Spatial Peak SAR Evaluation

The procedure for spatial peak SAR evaluation has been implemented according to the test standard. It can be conducted for 1g and 10g, as well as for user-specific masses. The DASY software includes all numerical procedures necessary to evaluate the spatial peak SAR value.

The base for the evaluation is a "cube" measurement. The measured volume must include the 1g and 10g cubes with the highest averaged SAR values. For that purpose, the center of the measured volume is aligned to the interpolated peak SAR value of a previously performed area scan.

The entire evaluation of the spatial peak values is performed within the post-processing engine (SEMCAD). The system always gives the maximum values for the 1g and 10g cubes. The algorithm to find the cube with highest averaged SAR is divided into the following stages:

(a) Extraction of the measured data (grid and values) from the Zoom Scan
(b) Calculation of the SAR value at every measurement point based on all stored data (A/D values and measurement parameters)
(c) Generation of a high-resolution mesh within the measured volume
(d) Interpolation of all measured values form the measurement grid to the high-resolution grid
(e) Extrapolation of the entire 3-D field distribution to the phantom surface over the distance from sensor to surface
(f) Calculation of the averaged SAR within masses of 1g and 10g

8.2 Power Reference Measurement

The Power Reference Measurement and Power Drift Measurements are for monitoring the power drift of the device under test in the batch process. The minimum distance of probe sensors to surface determines the closest measurement point to phantom surface. This distance cannot be smaller than the distance of sensor calibration points to probe tip as defined in the probe properties.

8.3 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 fine measurement around the hot spot. The sophisticated interpolation routines implemented in DASY software can find the maximum found in the scanned area, within a range of the global maximum. The range (in dB0 is specified in the standards for compliance testing. For example, a 2 dB range is required in IEEE standard 1528 and IEC 62209 standards, whereby 3 dB is a requirement when compliance is assessed in accordance with the ARIB standard (Japan), if only one zoom scan follows the area scan, then only the absolute maximum will be taken as reference. For cases where multiple maximums are detected, the number of zoom scans has to be increased accordingly.

Area scan parameters extracted from FCC KDB 865664 D01v01r04 SAR measurement 100 MHz to 6 GHz.

	≤ 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° ± 1°	20° ± 1°
Maximum area scan spatial resolution: Δx_{Area}, Δy_{Area}	≤ 2 GHz: ≤ 15 mm 2 – 3 GHz: ≤ 12 mm	3 – 4 GHz: ≤ 12 mm 4 – 6 GHz: ≤ 10 mm
	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.	

8.4 Zoom Scan

Zoom scans are used assess the peak spatial SAR values within a cubic averaging volume containing 1 gram and 10 gram of simulated tissue. The zoom scan measures points (refer to table below) within a cube shoes base faces are centered on the maxima found in a preceding area scan job within the same procedure. When the measurement is done, the zoom scan evaluates the averaged SAR for 1 gram and 10 gram and displays these values next to the job's label.

Zoom scan parameters extracted from FCC KDB 865664 D01v01r04 SAR measurement 100 MHz to 6 GHz.

<table>
<tr><th colspan="3"></th><th>≤ 3 GHz</th><th>> 3 GHz</th></tr>
<tr><td colspan="3">Maximum zoom scan spatial resolution: Δx_{Zoom}, Δy_{Zoom}</td><td>≤ 2 GHz: ≤ 8 mm
2 – 3 GHz: ≤ 5 mm*</td><td>3 – 4 GHz: ≤ 5 mm*
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
4 – 5 GHz: ≤ 3 mm
5 – 6 GHz: ≤ 2 mm</td></tr>
<tr><td rowspan="2">graded grid</td><td>$\Delta z_{Zoom}(1)$: between 1st two points closest to phantom surface</td><td>≤ 4 mm</td><td>3 – 4 GHz: ≤ 3 mm
4 – 5 GHz: ≤ 2.5 mm
5 – 6 GHz: ≤ 2 mm</td></tr>
<tr><td>$\Delta z_{Zoom}(n>1)$: between subsequent points</td><td colspan="2">$\leq 1.5 \cdot \Delta z_{Zoom}(n-1)$</td></tr>
<tr><td>Minimum zoom scan volume</td><td colspan="2">x, y, z</td><td>≥ 30 mm</td><td>3 – 4 GHz: ≥ 28 mm
4 – 5 GHz: ≥ 25 mm
5 – 6 GHz: ≥ 22 mm</td></tr>
<tr><td colspan="5">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 area scan based 1-g SAR estimation 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.</td></tr>
</table>

8.5 Volume Scan Procedures

The volume scan is used for assess overlapping SAR distributions for antennas transmitting in different frequency bands. It is equivalent to an oversized zoom scan used in standalone measurements. The measurement volume will be used to enclose all the simultaneous transmitting antennas. For antennas transmitting simultaneously in different frequency bands, the volume scan is measured separately in each frequency band. In order to sum correctly to compute the 1g aggregate SAR, the EUT remain in the same test position for all measurements and all volume scan use the same spatial resolution and grid spacing. When all volume scan were completed, the software, SEMCAD postprocessor can combine and subsequently superpose these measurement data to calculating the multiband SAR.

8.6 Power Drift Monitoring

All SAR testing is under the EUT install full charged battery and transmit maximum output power. In DASY measurement software, the power reference measurement and power drift measurement procedures are used for monitoring the power drift of EUT during SAR test. Both these procedures measure the field at a specified reference position before and after the SAR testing. The software will calculate the field difference in dB. If the power drifts more than 5%, the SAR will be retested.

9. Test Equipment List

Manufacturer	Name of Equipment	Type/Model	Serial Number	Calibration	
				Last Cal.	Due Date
SPEAG	2450MHz System Validation Kit	D2450V2	926	Jul. 25, 2016	Jul. 24, 2017
SPEAG	2450MHz System Validation Kit	D2450V2	736	Aug. 30, 2016	Aug. 29, 2017
SPEAG	5GHz System Validation Kit	D5GHzV2	1006	Sep. 27, 2016	Sep. 26, 2017
SPEAG	Data Acquisition Electronics	DAE4	1388	Oct. 10, 2016	Oct. 09, 2017
SPEAG	Data Acquisition Electronics	DAE3	495	May. 27, 2016	May. 26, 2017
SPEAG	Data Acquisition Electronics	DAE4	1399	Nov. 17, 2016	Nov. 16, 2017
SPEAG	Data Acquisition Electronics	DAE4	778	May. 12, 2016	May. 11, 2017
SPEAG	Dosimetric E-Field Probe	EX3DV4	3697	Oct. 25, 2016	Oct. 24, 2017
SPEAG	Dosimetric E-Field Probe	EX3DV4	3925	May. 26, 2016	May. 25, 2017
SPEAG	Dosimetric E-Field Probe	EX3DV4	3955	Nov. 24, 2016	Nov. 23, 2017
SPEAG	Dosimetric E-Field Probe	ES3DV3	3270	Aug. 26, 2016	Aug. 25, 2017
WonDer	Thermometer	WD-5015	TM685	Oct. 12, 2016	Oct. 11, 2017
WonDer	Thermometer	WD-5015	TM642	Oct. 12, 2016	Oct. 11, 2017
WonDer	Thermometer	WD-5015	TM281	Oct. 12, 2016	Oct. 11, 2017
Wisewind	Thermometer	HTC-1	TM560	Oct. 12, 2016	Oct. 11, 2017
SPEAG	Device Holder	N/A	N/A	N/A	N/A
Anritsu	Signal Generator	MG3710A	6201502524	Dec. 09, 2016	Dec. 08, 2017
Agilent	ENA Network Analyzer	E5071C	MY46316648	Jan. 12, 2016	Jan. 11, 2017
SPEAG	Dielectric Probe Kit	DAK-3.5	1126	Jul. 19, 2016	Jul. 18, 2017
LINE SEIKI	Digital Thermometer	LKMelectronic	DTM3000SPEZIAL	Sep. 05, 2016	Sep. 04, 2017
Anritsu	Power Meter	ML2495A	1419002	May. 10, 2016	May. 09, 2017
Anritsu	Power Sensor	MA2411B	1339124	May. 10, 2016	May. 09, 2017
Agilent	Spectrum Analyzer	E4408B	MY44211028	Aug. 22, 2016	Aug. 21, 2017
Mini-Circuits	Power Amplifier	ZVE-8G+	D120604	Mar. 16, 2016	Mar. 15, 2017
Mini-Circuits	Power Amplifier	ZHL-42W+	QA1344002	Mar. 16, 2016	Mar. 15, 2017
ATM	Dual Directional Coupler	C122H-10	P610410z-02	Note 1	
Woken	Attenuator 1	WK0602-XX	N/A	Note 1	
PE	Attenuator 2	PE7005-10	N/A	Note 1	
PE	Attenuator 3	PE7005- 3	N/A	Note 1	

General Note:

1. Prior to system verification and validation, the path loss from the signal generator to the system check source and the power meter, which includes the amplifier, cable, attenuator and directional coupler, was measured by the network analyzer. The reading of the power meter was offset by the path loss difference between the path to the power meter and the path to the system check source to monitor the actual power level fed to the system check source.

10. System Verification

10.1 Tissue Simulating Liquids

For the measurement of the field distribution inside the SAM phantom with DASY, the phantom must be filled with around 25 liters of homogeneous body tissue simulating liquid. For head SAR testing, the liquid height from the ear reference point (ERP) of the phantom to the liquid top surface is larger than 15 cm, which is shown in Fig. 10.1. For body SAR testing, the liquid height from the center of the flat phantom to the liquid top surface is larger than 15 cm, which is shown in Fig. 10.2.

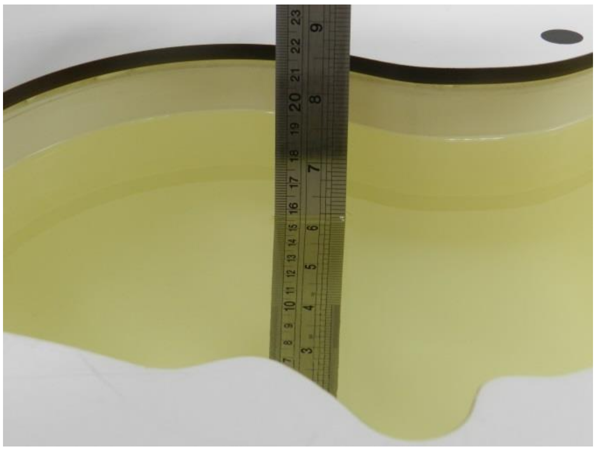


Fig 10.1Photo of Liquid Height for Head SAR

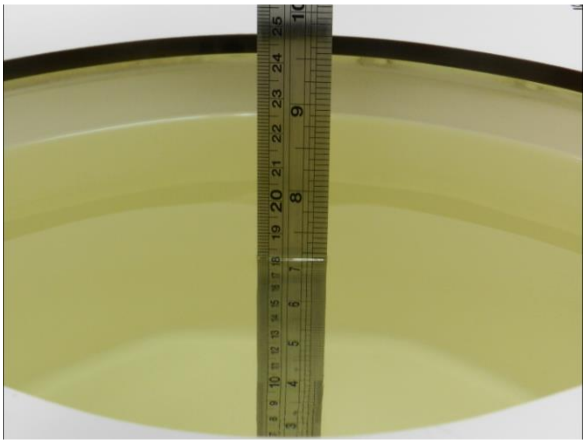


Fig 10.2 Photo of Liquid Height for Body SAR

10.2 Tissue Verification

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.

Frequency (MHz)	Water (%)	Sugar (%)	Cellulose (%)	Salt (%)	Preventol (%)	DGBE (%)	Conductivity (σ)	Permittivity (εr)
For Head								
750	41.1	57.0	0.2	1.4	0.2	0	0.89	41.9
835	40.3	57.9	0.2	1.4	0.2	0	0.90	41.5
900	40.3	57.9	0.2	1.4	0.2	0	0.97	41.5
1800, 1900, 2000	55.2	0	0	0.3	0	44.5	1.40	40.0
2450	55.0	0	0	0	0	45.0	1.80	39.2
2600	54.8	0	0	0.1	0	45.1	1.96	39.0
For Body								
750	51.7	47.2	0	0.9	0.1	0	0.96	55.5
835	50.8	48.2	0	0.9	0.1	0	0.97	55.2
900	50.8	48.2	0	0.9	0.1	0	1.05	55.0
1800, 1900, 2000	70.2	0	0	0.4	0	29.4	1.52	53.3
2450	68.6	0	0	0	0	31.4	1.95	52.7
2600	68.1	0	0	0.1	0	31.8	2.16	52.5

Simulating Liquid for 5GHz, Manufactured by SPEAG

Ingredients	(% by weight)
Water	64~78%
Mineral oil	11~18%
Emulsifiers	9~15%
Additives and Salt	2~3%

<Tissue Dielectric Parameter Check Results>

Frequency (MHz)	Tissue Type	Liquid Temp. (℃)	Conductivity (σ)	Permittivity (ε_r)	Conductivity Target (σ)	Permittivity Target (ε_r)	Delta (σ) (%)	Delta (ε_r) (%)	Limit (%)	Date
2450	MSL	22.2	2.009	54.047	1.95	52.70	3.03	2.56	±5	2016/12/22
2450	MSL	22.2	2.009	54.047	1.95	52.70	3.03	2.56	±5	2016/12/22
2450	MSL	22.3	1.953	52.970	1.95	52.70	0.15	0.51	±5	2016/12/28
5250	MSL	22.2	5.464	47.364	5.36	48.95	1.94	-3.24	±5	2017/2/2
5600	MSL	22.4	5.949	46.205	5.77	48.50	3.10	-4.73	±5	2016/12/27
5600	MSL	22.2	5.929	46.764	5.77	48.50	2.76	-3.58	±5	2017/2/2
5750	MSL	22.2	6.134	46.525	5.94	48.28	3.27	-3.64	±5	2017/2/2

10.3 System Performance Check Results

Comparing to the original SAR value provided by SPEAG, the verification data should be within its specification of 10 %. Below table shows the target SAR and measured SAR after normalized to 1W input power. The table below indicates the system performance check can meet the variation criterion and the plots can be referred to Appendix A of this report.

Date	Frequency (MHz)	Tissue Type	Input Power (mW)	Dipole S/N	Probe S/N	DAE S/N	Measured 1g SAR (W/kg)	Targeted 1g SAR (W/kg)	Normalized 1g SAR (W/kg)	Deviation (%)
2016/12/22	2450	MSL	250	D2450V2-926	ES3DV3 - SN3270	DAE4 Sn778	12.90	51.20	51.60	0.78
2016/12/22	2450	MSL	250	D2450V2-926	EX3DV4 - SN3697	DAE4 Sn1388	12.30	51.20	49.20	-3.91
2016/12/28	2450	MSL	250	D2450V2-736	EX3DV4 - SN3925	DAE3 Sn495	12.40	52.10	49.60	-4.80
2017/2/2	5250	MSL	100	D5GHzV2-1006	EX3DV4 - SN3955	DAE4 Sn1399	7.45	75.50	74.50	-1.32
2016/12/27	5600	MSL	100	D5GHzV2-1006	EX3DV4 - SN3955	DAE4 Sn1399	8.26	78.60	82.60	5.09
2017/2/2	5600	MSL	100	D5GHzV2-1006	EX3DV4 - SN3955	DAE4 Sn1399	8.42	78.60	84.20	7.12
2017/2/2	5750	MSL	100	D5GHzV2-1006	EX3DV4 - SN3955	DAE4 Sn1399	7.34	74.60	73.40	-1.61

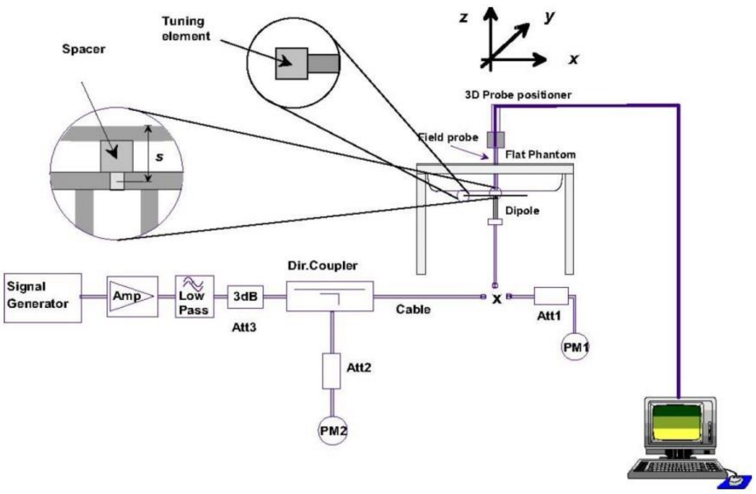


Fig 8.3.1 System Performance Check Setup

Fig 8.3.2 Setup Photo

11. Conducted RF Output Power (Unit: dBm)

<WLAN Conducted Power>

General Note:

1. Per KDB 248227 D01v02r02, SAR test reduction is determined according to 802.11 transmission mode configurations and certain exposure conditions with multiple test positions. In the 2.4 GHz band, separate SAR procedures are applied to DSSS and OFDM configurations to simplify DSSS test requirements. For OFDM, in both 2.4 and 5 GHz bands, an initial test configuration must be determined for each standalone and aggregated frequency band, according to the transmission mode configuration with the highest maximum output power specified for production units to perform SAR measurements. If the same highest maximum output power applies to different combinations of channel bandwidths, modulations and data rates, additional procedures are applied to determine which test configurations require SAR measurement. When applicable, an initial test position may be applied to reduce the number of SAR measurements required for next to the ear, UMPC mini-tablet or hotspot mode configurations with multiple test positions.
2. For 2.4 GHz 802.11b DSSS, either the initial test position procedure for multiple exposure test positions or the DSSS procedure for fixed exposure position is applied; these are mutually exclusive. For 2.4 GHz and 5 GHz OFDM configurations, the initial test configuration is applied to measure SAR using either the initial test position procedure for multiple exposure test position configurations or the initial test configuration procedures for fixed exposure test conditions. Based on the reported SAR of the measured configurations and maximum output power of the transmission mode configurations that are not included in the initial test configuration, the subsequent test configuration and initial test position procedures are applied to determine if SAR measurements are required for the remaining OFDM transmission configurations. In general, the number of test channels that require SAR measurement is minimized based on maximum output power measured for the test sample(s).
3. For OFDM transmission configurations in the 2.4 GHz and 5 GHz bands, When the same maximum power is specified for multiple transmission modes in a frequency band, the largest channel bandwidth, lowest order modulation, lowest data rate and lowest order 802.11a/g/n/ac mode is used for SAR measurement, on the highest measured output power channel for each frequency band.
4. 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.18 The initial test position procedure is described in the following:
   a. When the reported SAR of 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 802.11 transmission mode combinations within the frequency band or aggregated band.
   b. When the reported SAR of the test position is > 0.4 W/kg, SAR is repeated for the 802.11 transmission mode 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 report SAR is ≤ 0.8 W/kg or all required test position are tested.
   c. For all positions/configurations, 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.
5. For RTL8821CE, channel #12 and #13 SAR testing are not necessary, due to the maximum power is smaller than other channels, the maximum power please refer to WLAN conducted power table.
6. The module supported 802.11ac for 2.4GHz WLAN by manufacturer, due to 802.11ac and 802.11n have the same OFDM modulation, only difference is 802.11ac supported additional MCS8 and MCS9 data rate, and based on the power smaller than 802.11b (DSSS),according to KDB248227 test reduction procedure, when reported 1-g SAR < 1.2 W/kg of DSSS，OFDM SAR is not required.
7. Since the module supported two RF chains, and the RF chain 1 and RF chain 2 have the same maximum tune up power, therefore we measured all of the frequency bands and modulations on RF chain1 to cover other configurations.

<2.4GHz WLAN_RF chain 1>

	Mode	Channel	Frequency (MHz)	Data Rate	Average power (dBm)	Tune-Up Limit	Duty Cycle %
2.4GHz WLAN	802.11b	CH 1	2412	1Mbps	16.14	16.50	98.50
		CH 6	2437		17.86	18.00	
		CH 11	2462		17.29	17.50	
		CH 12	2467		13.59	14.00	
		CH 13	2472		9.13	9.50	
	802.11g	CH 1	2412	6Mbps	16.29	16.50	98.10
		CH 6	2437		17.82	18.00	
		CH 11	2462		16.03	16.50	
		CH 12	2467		14.82	15.00	
		CH 13	2472		9.04	9.50	
	802.11ac-VHT20	CH 1	2412	MCS0	14.72	15.00	98.50
		CH 6	2437		17.88	18.00	
		CH 11	2462		15.15	15.50	
		CH 12	2467		15.26	15.50	
		CH 13	2472		6.93	7.00	
	802.11ac-VHT40	CH 3	2422	MCS0	13.73	14.00	98.10
		CH 6	2437		15.84	16.00	
		CH 9	2452		14.20	14.50	
		CH 10	2457		15.37	15.50	
		CH 11	2462		11.55	12.00	

<5GHz WLAN_RF chain 1>

	Mode	Channel	Frequency (MHz)	Data Rate	Average power (dBm)	Tune-Up Limit	Duty Cycle %
5.2GHz WLAN	802.11a	CH 36	5180	6Mbps	14.88	15.00	99.80
		CH 40	5200		14.91	15.00	
		CH 44	5220		14.99	15.00	
		CH 48	5240		14.97	15.00	
	802.11ac-VHT20	CH 36	5180	MCS0	14.83	15.00	99.40
		CH 40	5200		14.76	15.00	
		CH 44	5220		14.93	15.00	
		CH 48	5240		14.94	15.00	
	802.11ac-VHT40	CH 38	5190	MCS0	12.34	12.50	99.90
		CH 46	5230		13.48	13.50	
	802.11ac-VHT80	CH 42	5210	MCS0	11.17	11.50	99.10

	Mode	Channel	Frequency (MHz)	Data Rate	Average power (dBm)	Tune-Up Limit	Duty Cycle %
5.3GHz WLAN	802.11a	CH 52	5260	6Mbps	14.88	15.00	99.80
		CH 56	5280		14.91	15.00	
		CH 60	5300		14.86	15.00	
		CH 64	5320		14.93	15.00	
	802.11ac-VHT20	CH 52	5260	MCS0	14.96	15.00	99.40
		CH 56	5280		14.85	15.00	
		CH 60	5300		14.98	15.00	
		CH 64	5320		14.92	15.00	
	802.11ac-VHT40	CH 54	5270	MCS0	14.89	15.00	99.90
		CH 62	5310		13.11	13.50	
	802.11ac-VHT80	CH 58	5290	MCS0	12.63	13.00	99.10

	Mode	Channel	Frequency (MHz)	Data Rate	Average power (dBm)	Tune-Up Limit	Duty Cycle %
5.5GHz WLAN	802.11a	CH 100	5500	6Mbps	14.79	15.00	99.80
		CH 116	5580		14.54	15.00	
		CH 124	5620		14.21	15.00	
		CH 132	5660		14.52	15.00	
		CH 144	5720		14.71	15.00	
	802.11ac-VHT20	CH 100	5500	MCS0	14.58	15.00	99.40
		CH 116	5580		14.37	15.00	
		CH 124	5620		14.65	15.00	
		CH 132	5660		14.36	15.00	
		CH 144	5720		14.26	15.00	
	802.11ac-VHT40	CH 102	5510	MCS0	14.99	15.00	99.90
		CH 110	5550		14.56	15.00	
		CH 126	5630		14.47	15.00	
		CH 134	5670		14.42	15.00	
		CH 142	5710		14.74	15.00	
	802.11ac-VHT80	CH 106	5530	MCS0	10.41	11.00	99.10
		CH 122	5610		14.27	15.00	
		CH 138	5690		14.98	15.00	

	Mode	Channel	Frequency (MHz)	Data Rate	Average power (dBm)	Tune-Up Limit	Duty Cycle %
5.8GHz WLAN	802.11a	CH 149	5745	MCS0	15.45	15.50	99.80
		CH 157	5785		15.42	15.50	
		CH 165	5825		15.36	15.50	
	802.11ac-VHT20	CH 149	5745	MCS0	15.42	15.50	99.40
		CH 157	5785		15.35	15.50	
		CH 165	5825		15.33	15.50	
	802.11ac-VHT40	CH 151	5755	MCS0	15.39	15.50	99.90
		CH 159	5795		15.35	15.50	
	802.11ac-VHT80	CH 155	5775	MCS0	15.43	15.50	99.10

<2.4GHz Bluetooth>

General Note:

1. For 2.4GHz Bluetooth SAR testing was selected 1Mbps, due to its highest average power.
2. The duty factor is selected theoretical 83.3% perform Bluetooth SAR testing.

<2.4GHz Bluetooth_RFchain 1>

Mode	Channel	Frequency (MHz)	Average power (dBm)		
			1Mbps	2Mbps	3Mbps
BR / EDR	CH 00	2402	5.43	4.75	4.72
	CH 39	2441	4.72	4.36	4.37
	CH 78	2480	4.84	4.52	4.48
Tune-up Limit			6	6	6

Mode	Channel	Frequency (MHz)	Average power (dBm)
			GFSK
LE	CH 00	2402	5.53
	CH 19	2440	4.89
	CH 39	2480	5.05
Tune-up Limit			6

12. SAR Test Results

General Note:

1. Per KDB 447498 D01v06, the reported SAR is the measured SAR value adjusted for maximum tune-up tolerance.
   a. Tune-up scaling Factor = tune-up limit power (mW) / EUT RF power (mW), where tune-up limit is the maximum rated power among all production units.
   b. For SAR testing of WLAN signal with non-100% duty cycle, the measured SAR is scaled-up by the duty cycle scaling factor which is equal to "1/(duty cycle)"
   c. For Bluetooth: Reported SAR(W/kg)= Measured SAR(W/kg)*Tune-up Scaling Factor
   d. For WLAN: Reported SAR(W/kg)= Measured SAR(W/kg)* Duty Cycle scaling factor * Tune-up scaling factor
2. Per KDB 447498 D01v06, for each exposure position, testing of other required channels within the operating mode of a frequency band is not required when the *reported* 1-g or 10-g SAR for the mid-band or highest output power channel is:
   - ≤ 0.8 W/kg or 2.0 W/kg, for 1-g or 10-g respectively, when the transmission band is ≤ 100 MHz
   - ≤ 0.6 W/kg or 1.5 W/kg, for 1-g or 10-g respectively, when the transmission band is between 100 MHz and 200 MHz
   - ≤ 0.4 W/kg or 1.0 W/kg, for 1-g or 10-g respectively, when the transmission band is ≥ 200 MHz
3. Per KDB 865664 D01v01r04, for each frequency band, repeated SAR measurement is required only when the measured SAR is ≥0.8W/kg.
4. For SAR tested was used an external antenna and connected to a module to perform on Front / Back / Top / Bottom / Right / Left positions of antenna and tests separation is 5mm, the test setup photo please referred to appendix D.
5. According to KDB 616217 D04 v01r02 section 3.2 states that when the test separation distances and test setups described in this document for the laptop and tablet host platforms are satisfied by the antenna and host configurations and the highest reported SAR for a host platform is ≤ 0.8 W/kg, testing in representative hosts is optional for the modular approach.
6. For the module SAR testing antenna detail information as following.
   (f) Brand name : REALTEK
   (g) Model name : RTK-ANT-0006
   (h) Ant type : PIFA antenna
   (i) Connector : IPEX MHF4
   (j) Gain : 3.5 (dBi) for 2.4GHZ WLAN , 5 (dBi) for 5GHZ WLAN ,
7. According to KDB616217 section 5.2, for modular transmitters to qualify for incorporation into these platforms, the separation distances required for laptop host platform testing, without using a representative host, must be applied to determine SAR compliance.
   (a) The transmitter was controlled by a representative host computer with the actual firmware, software drivers and other associated device operating software required for testing the wireless technologies.
   (b) For implementations that an antenna be connected to the transmitter through RF cable(s), the antenna assembly, which is typically the standalone antenna, and be tested independently for SAR. The same type of antenna cable specified in the installation requirements be used to connect the antenna to the transmitter for testing. The shortest antenna cable be used in the SAR tests, with the antenna located at least 10 cm away from the host computer or equivalent testing platform and other supporting equipment in the SAR measurement setup.
   (c) The antenna was tested in the mounting and installation orientations supported by the actual implementations used in the host platform. Testing in both horizontal and vertical mounting orientations for installation in horizontal and vertical edges of laptop and tablet computers.
   (d) The antenna was tested six surfaces with 5mm distance and have included on all polarizations and operations, and have been tested for compliance for the required display and/or keyboard installation conditions and test separation distance
   (e) The antenna was mounted on lossless foam material for SAR testing to qualify for installation in hosts with low-loss materials near the antenna.

WLAN Note:

1. Per KDB 248227 D01v02r02, for 2.4GHz 802.11g/n SAR testing is not required 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.
2. Per KDB 248227 D01v02r02, U-NII-1 SAR testing is not required when the U-NII-2A band highest reported SAR for a test configuration is ≤ 1.2 W/kg, SAR is not required for U-NII-1 band.
3. When the reported SAR of the test position is > 0.4 W/kg, SAR is repeated for the 802.11 transmission mode 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 report SAR is ≤ 0.8 W/kg or all required test position are tested.
4. For all positions / configurations, 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.
5. During SAR testing the WLAN transmission was verified using a spectrum analyzer.
6. According to KDB248227 test reduction requirement, for WLAN 5GHz UNII-2a SAR testing of all positions were selected the highest measured maximum output power channel 138, and the 1g reported SAR <0.8W/kg, subsequent next highest measured output power channel 106 and 122 that SAR testing is not required, therefore the channel 106 of WLAN 5GHz UNII-2a SAR test results were submitted voluntarily in section 12.0, and all of the SAR test results are comply with SAR criteria. Actually the channel 106 (VHT80 mode) that the maximum tune up power was restricted by band edge of rule part 15E and confirmed from manufacturer, therefore it really is 4dB lower than the other configurations. Therefore we don't think that have any SAR test concern and issue.

12.1 Body SAR

<WLAN SAR>

Plot No.	Band	Mode	Test Position	Gap (mm)	Ch.	Freq. (MHz)	Average Power (dBm)	Tune-Up Limit (dBm)	Tune-up Scaling Factor	Duty Cycle %	Duty Cycle Scaling Factor	Power Drift (dB)	Measured 1g SAR (W/kg)	Reported 1g SAR (W/kg)
	WLAN2.4GHz	802.11b 1Mbps	Front	5mm	6	2437	17.86	18.00	1.033	98.5	1.015	-0.17	0.644	0.675
01	WLAN2.4GHz	802.11b 1Mbps	Back	5mm	6	2437	17.86	18.00	1.033	98.5	1.015	-0.02	0.751	0.787
	WLAN2.4GHz	802.11b 1Mbps	Back	5mm	1	2412	16.14	16.50	1.086	98.5	1.015	-0.15	0.377	0.416
	WLAN2.4GHz	802.11b 1Mbps	Back	5mm	11	2462	17.29	17.50	1.050	98.5	1.015	-0.18	0.719	0.766
	WLAN2.4GHz	802.11b 1Mbps	Left Side	5mm	6	2437	17.86	18.00	1.033	98.5	1.015	0.19	0.051	0.053
	WLAN2.4GHz	802.11b 1Mbps	Right Side	5mm	6	2437	17.86	18.00	1.033	98.5	1.015	0.08	0.101	0.106
	WLAN2.4GHz	802.11b 1Mbps	Top Side	5mm	6	2437	17.86	18.00	1.033	98.5	1.015	-0.15	0.225	0.236
	WLAN2.4GHz	802.11b 1Mbps	Bottom Side	5mm	6	2437	17.86	18.00	1.033	98.5	1.015	-0.13	0.432	0.453
	WLAN5GHz	802.11ac-VHT40 MCS0	Front	5mm	54	5270	14.89	15.00	1.026	99.9	1.001	-0.12	0.561	0.576
02	WLAN5GHz	802.11ac-VHT40 MCS0	Back	5mm	54	5270	14.89	15.00	1.026	99.9	1.001	-0.13	0.583	0.599
	WLAN5GHz	802.11ac-VHT40 MCS0	Left Side	5mm	54	5270	14.89	15.00	1.026	99.9	1.001	-0.09	0.041	0.042
	WLAN5GHz	802.11ac-VHT40 MCS0	Right Side	5mm	54	5270	14.89	15.00	1.026	99.9	1.001	-0.12	0.488	0.501
	WLAN5GHz	802.11ac-VHT40 MCS0	Top Side	5mm	54	5270	14.89	15.00	1.026	99.9	1.001	0.13	0.226	0.232
	WLAN5GHz	802.11ac-VHT40 MCS0	Bottom Side	5mm	54	5270	14.89	15.00	1.026	99.9	1.001	-0.08	0.072	0.074
	WLAN5GHz	802.11ac-VHT40 MCS0	Back	5mm	62	5310	13.11	13.50	1.094	99.9	1.001	0.02	0.332	0.364
03	WLAN5GHz	802.11ac-VHT80 MCS0	Front	5mm	138	5690	14.98	15.00	1.005	99.1	1.009	0.1	0.734	0.744
	WLAN5GHz	802.11ac-VHT80 MCS0	Front	5mm	106	5530	10.41	11.00	1.146	99.1	1.009	-0.09	0.127	0.147
	WLAN5GHz	802.11ac-VHT80 MCS0	Back	5mm	138	5690	14.98	15.00	1.005	99.1	1.009	0.1	0.687	0.696
	WLAN5GHz	802.11ac-VHT80 MCS0	Left Side	5mm	138	5690	14.98	15.00	1.005	99.1	1.009	-0.18	0.067	0.068
	WLAN5GHz	802.11ac-VHT80 MCS0	Right Side	5mm	138	5690	14.98	15.00	1.005	99.1	1.009	-0.09	0.646	0.655
	WLAN5GHz	802.11ac-VHT80 MCS0	Top Side	5mm	138	5690	14.98	15.00	1.005	99.1	1.009	0.17	0.197	0.200
	WLAN5GHz	802.11ac-VHT80 MCS0	Bottom Side	5mm	138	5690	14.98	15.00	1.005	99.1	1.009	-0.18	0.223	0.226
	WLAN5GHz	802.11ac-VHT80 MCS0	Front	5mm	155	5775	15.43	15.50	1.016	99.1	1.009	0.1	0.576	0.591
04	WLAN5GHz	802.11ac-VHT80 MCS0	Back	5mm	155	5775	15.43	15.50	1.016	99.1	1.009	0.05	0.626	0.642
	WLAN5GHz	802.11ac-VHT80 MCS0	Left Side	5mm	155	5775	15.43	15.50	1.016	99.1	1.009	-0.17	0.029	0.030
	WLAN5GHz	802.11ac-VHT80 MCS0	Right Side	5mm	155	5775	15.43	15.50	1.016	99.1	1.009	-0.15	0.351	0.360
	WLAN5GHz	802.11ac-VHT80 MCS0	Top Side	5mm	155	5775	15.43	15.50	1.016	99.1	1.009	0.13	0.162	0.166
	WLAN5GHz	802.11ac-VHT80 MCS0	Bottom Side	5mm	155	5775	15.43	15.50	1.016	99.1	1.009	0.09	0.148	0.152

<Bluetooth SAR>

Plot No.	Band	Mode	Test Position	Gap (mm)	Ch.	Freq. (MHz)	Average Power (dBm)	Tune-Up Limit (dBm)	Tune-up Scaling Factor	Power Drift (dB)	Measured 1g SAR (W/kg)	Reported 1g SAR (W/kg)
	Bluetooth	1Mbps	Front	5mm	0	2402	5.43	6.00	1.140	0.09	0.026	0.030
	Bluetooth	1Mbps	Back	5mm	0	2402	5.43	6.00	1.140	0.04	0.029	0.033
	Bluetooth	1Mbps	Back	5mm	39	2441	4.72	6.00	1.343	0.13	0.048	0.064
05	Bluetooth	1Mbps	Back	5mm	78	2480	4.84	6.00	1.306	0.15	0.051	0.067
	Bluetooth	1Mbps	Left Side	5mm	0	2402	5.43	6.00	1.140	0	0.001	0.001
	Bluetooth	1Mbps	Right Side	5mm	0	2402	5.43	6.00	1.140	0.14	0.004	0.004
	Bluetooth	1Mbps	Top Side	5mm	0	2402	5.43	6.00	1.140	-0.12	0.007	0.008
	Bluetooth	1Mbps	Bottom Side	5mm	0	2402	5.43	6.00	1.140	-0.18	0.007	0.008

13. Simultaneous Transmission Analysis

NO.	Simultaneous Transmission Configurations	Support
1.	2.4GHz WLAN + 5GHz WLAN	No
2.	2.4GHz WLAN + Bluetooth	No
3.	5GHz WLAN + Bluetooth	Yes

General Note:

1. The EUT supports the antenna with TX/RX diversity function for WLAN and Bluetooth. (Ex. Assume antenna 1 was selected to conduct transmitting function in WLAN, so antenna 2 was selected in Bluetooth mode. Vice versa.) WLAN 2.4GHz and Bluetooth will be transmitting from the different antennas; WLAN 5GHz and Bluetooth will be transmitting from the same antenna.
2. EUT will choose either WLAN 2.4GHz or WLAN 5GHz according to the network signal condition; therefore, 2.4GHz WLAN and 5GHz WLAN will not operate simultaneously at any moment.
3. The Scaled SAR summation is calculated based on the same configuration and test position.
4. Per KDB 447498 D01v06, simultaneous transmission SAR is compliant if,
   i) Scalar SAR summation < 1.6W/kg.
   ii) SPLSR = (SAR1 + SAR2)^1.5 / (min. separation distance, mm), and the peak separation distance is determined from the square root of [(x1-x2)2 + (y1-y2)2 + (z1-z2)2], where (x1, y1, z1) and (x2, y2, z2) are the coordinates of the extrapolated peak SAR locations in the zoom scan.
   iii) If SPLSR ≤ 0.04, simultaneously transmission SAR measurement is not necessary.
   iv) Simultaneously transmission SAR measurement, and the reported multi-band SAR < 1.6W/kg.

13.1 Body Exposure Conditions

Exposure Position	1	2	1+2
	5GHz WLAN	Bluetooth	Summed
	1g SAR (W/kg)	1g SAR (W/kg)	1g SAR (W/kg)
Front	0.744	0.030	**0.774**
Back	0.696	0.067	**0.763**
Left side	0.068	0.001	**0.069**
Right side	0.655	0.004	**0.659**
Top side	0.232	0.008	**0.240**
Bottom side	0.226	0.008	**0.234**

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14. Uncertainty Assessment

The component of uncertainly may generally be categorized according to the methods used to evaluate them. The evaluation of uncertainly by the statistical analysis of a series of observations is termed a Type An evaluation of uncertainty. The evaluation of uncertainty by means other than the statistical analysis of a series of observation is termed a Type B evaluation of uncertainty. Each component of uncertainty, however evaluated, is represented by an estimated standard deviation, termed standard uncertainty, which is determined by the positive square root of the estimated variance.

A Type A evaluation of standard uncertainty may be based on any valid statistical method for treating data. This includes calculating the standard deviation of the mean of a series of independent observations; using the method of least squares to fit a curve to the data in order to estimate the parameter of the curve and their standard deviations; or carrying out an analysis of variance in order to identify and quantify random effects in certain kinds of measurement.

A type B evaluation of standard uncertainty is typically based on scientific judgment using all of the relevant information available. These may include previous measurement data, experience, and knowledge of the behavior and properties of relevant materials and instruments, manufacture's specification, data provided in calibration reports and uncertainties assigned to reference data taken from handbooks. Broadly speaking, the uncertainty is either obtained from an outdoor source or obtained from an assumed distribution, such as the normal distribution, rectangular or triangular distributions indicated in table below.

Uncertainty Distributions	Normal	Rectangular	Triangular	U-Shape
Multi-plying Factor[(a)]	1/k[(b)]	$1/\sqrt{3}$	$1/\sqrt{6}$	$1/\sqrt{2}$

(a) standard uncertainty is determined as the product of the multiplying factor and the estimated range of variations in the measured quantity

(b) κ is the coverage factor

Table 14.1. Standard Uncertainty for Assumed Distribution

The combined standard uncertainty of the measurement result represents the estimated standard deviation of the result. It is obtained by combining the individual standard uncertainties of both Type A and Type B evaluation using the usual "root-sum-squares" (RSS) methods of combining standard deviations by taking the positive square root of the estimated variances.

Expanded uncertainty is a measure of uncertainty that defines an interval about the measurement result within which the measured value is confidently believed to lie. It is obtained by multiplying the combined standard uncertainty by a coverage factor. Typically, the coverage factor ranges from 2 to 3. Using a coverage factor allows the true value of a measured quantity to be specified with a defined probability within the specified uncertainty range. For purpose of this document, a coverage factor two is used, which corresponds to confidence interval of about 95 %. The DASY uncertainty Budget is shown in the following tables.

Error Description	Uncertainty Value (±%)	Probability	Divisor	(Ci) 1g	(Ci) 10g	Standard Uncertainty (1g) (±%)	Standard Uncertainty (10g) (±%)
Measurement System							
Probe Calibration	6.00	N	1	1	1	6.0	6.0
Axial Isotropy	4.70	R	1.732	0.7	0.7	1.9	1.9
Hemispherical Isotropy	9.60	R	1.732	0.7	0.7	3.9	3.9
Boundary Effects	1.00	R	1.732	1	1	0.6	0.6
Linearity	4.70	R	1.732	1	1	2.7	2.7
System Detection Limits	1.00	R	1.732	1	1	0.6	0.6
Modulation Response	4.68	R	1.732	1	1	2.7	2.7
Readout Electronics	0.30	N	1	1	1	0.3	0.3
Response Time	0.00	R	1.732	1	1	0.0	0.0
Integration Time	2.60	R	1.732	1	1	1.5	1.5
RF Ambient Noise	3.00	R	1.732	1	1	1.7	1.7
RF Ambient Reflections	3.00	R	1.732	1	1	1.7	1.7
Probe Positioner	0.40	R	1.732	1	1	0.2	0.2
Probe Positioning	2.90	R	1.732	1	1	1.7	1.7
Max. SAR Eval.	2.00	R	1.732	1	1	1.2	1.2
Test Sample Related							
Device Positioning	3.03	N	1	1	1	3.0	3.0
Device Holder	3.60	N	1	1	1	3.6	3.6
Power Drift	5.00	R	1.732	1	1	2.9	2.9
Power Scaling	0.00	R	1.732	1	1	0.0	0.0
Phantom and Setup							
Phantom Uncertainty	6.10	R	1.732	1	1	3.5	3.5
SAR correction	0.00	R	1.732	1	0.84	0.0	0.0
Liquid Conductivity Repeatability	0.03	N	1	0.78	0.71	0.0	0.0
Liquid Conductivity (target)	5.00	R	1.732	0.78	0.71	2.3	2.0
Liquid Conductivity (mea.)	2.50	R	1.732	0.78	0.71	1.1	1.0
Temp. unc. - Conductivity	3.68	R	1.732	0.78	0.71	1.7	1.5
Liquid Permittivity Repeatability	0.02	N	1	0.23	0.26	0.0	0.0
Liquid Permittivity (target)	5.00	R	1.732	0.23	0.26	0.7	0.8
Liquid Permittivity (mea.)	2.50	R	1.732	0.23	0.26	0.3	0.4
Temp. unc. - Permittivity	0.84	R	1.732	0.23	0.26	0.1	0.1
Combined Std. Uncertainty						11.6%	11.6%
Coverage Factor for 95 %						K=2	K=2
Expanded STD Uncertainty						23.2%	23.1%

Table 14.2. Uncertainty Budget for frequency range 300 MHz to 3 GHz

Error Description	Uncertainty Value (±%)	Probability	Divisor	(Ci) 1g	(Ci) 10g	Standard Uncertainty (1g) (±%)	Standard Uncertainty (10g) (±%)
Measurement System							
Probe Calibration	7.00	N	1	1	1	7.0	7.0
Axial Isotropy	4.70	R	1.732	0.7	0.7	1.9	1.9
Hemispherical Isotropy	9.60	R	1.732	0.7	0.7	3.9	3.9
Boundary Effects	2.00	R	1.732	1	1	1.2	1.2
Linearity	4.70	R	1.732	1	1	2.7	2.7
System Detection Limits	1.00	R	1.732	1	1	0.6	0.6
Modulation Response	4.68	R	1.732	1	1	2.7	2.7
Readout Electronics	0.30	N	1	1	1	0.3	0.3
Response Time	0.00	R	1.732	1	1	0.0	0.0
Integration Time	2.60	R	1.732	1	1	1.5	1.5
RF Ambient Noise	3.00	R	1.732	1	1	1.7	1.7
RF Ambient Reflections	3.00	R	1.732	1	1	1.7	1.7
Probe Positioner	0.40	R	1.732	1	1	0.2	0.2
Probe Positioning	6.70	R	1.732	1	1	3.9	3.9
Max. SAR Eval.	4.00	R	1.732	1	1	2.3	2.3
Test Sample Related							
Device Positioning	3.03	N	1	1	1	3.0	3.0
Device Holder	3.60	N	1	1	1	3.6	3.6
Power Drift	5.00	R	1.732	1	1	2.9	2.9
Power Scaling	0.00	R	1.732	1	1	0.0	0.0
Phantom and Setup							
Phantom Uncertainty	6.60	R	1.732	1	1	3.8	3.8
SAR correction	0.00	R	1.732	1	0.84	0.0	0.0
Liquid Conductivity Repeatability	0.03	N	1	0.78	0.71	0.0	0.0
Liquid Conductivity (target)	5.00	R	1.732	0.78	0.71	2.3	2.0
Liquid Conductivity (mea.)	2.50	R	1.732	0.78	0.71	1.1	1.0
Temp. unc. - Conductivity	3.68	R	1.732	0.78	0.71	1.7	1.5
Liquid Permittivity Repeatability	0.02	N	1	0.23	0.26	0.0	0.0
Liquid Permittivity (target)	5.00	R	1.732	0.23	0.26	0.7	0.8
Liquid Permittivity (mea.)	2.50	R	1.732	0.23	0.26	0.3	0.4
Temp. unc. - Permittivity	0.84	R	1.732	0.23	0.26	0.1	0.1
Combined Std. Uncertainty						12.9%	12.9%
Coverage Factor for 95 %						K=2	K=2
Expanded STD Uncertainty						25.9%	25.8%

Table 14.3. Uncertainty Budget for frequency range 3 GHz to 6 GHz

15. References

[1] FCC 47 CFR Part 2 “Frequency Allocations and Radio Treaty Matters; General Rules and Regulations”

[2] ANSI/IEEE Std. C95.1-1992, “IEEE Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz”, September 1992

[3] IEEE Std. 1528-2013, “IEEE Recommended Practice for Determining the Peak Spatial-Average Specific Absorption Rate (SAR) in the Human Head from Wireless Communications Devices: Measurement Techniques”, Sep 2013

[4] SPEAG DASY System Handbook

[5] FCC KDB 248227 D01 v02r02, “SAR Guidance for IEEE 802.11 (WiFi) Transmitters”, Oct 2015.

[6] FCC KDB 447498 D01 v06, “Mobile and Portable Device RF Exposure Procedures and Equipment Authorization Policies”, Oct 2015

[7] FCC KDB 865664 D01 v01r04, "SAR Measurement Requirements for 100 MHz to 6 GHz", Aug 2015.

[8] FCC KDB 865664 D02 v01r02, “RF Exposure Compliance Reporting and Documentation Considerations” Oct 2015.

[9] FCC KDB 616217 D04 v01r02, “SAR Evaluation Considerations for Laptop, Notebook, Netbook and Tablet Computers”, Oct 2015