SAR EVALUATION REPORT

FCC 47 CFR § 2.1093
IEEE Std 1528-2013

For
Wi-Fi Internet of Things Module

FCC ID: 2AC7Z-ESP32S2WROOM
Model Name: ESP32-S2-WROOM

Report Number: 4790201427-US-S0-V1
Issue Date: 4/14/2022

Prepared for
ESPRESSIF SYSTEMS (SHANGHAI) CO., LTD.
Suite 204, Block 2, 690 Bibo Road, Zhang Jiang Hi-Tech Park, Shanghai, 201203 China

Prepared by
Underwriters Laboratories Taiwan Co., Ltd.,
Building B and Building E, No. 372-7, Sec. 4, Zhongxing Rd.,
Zhudong Township, Hsinchu County, Taiwan
TEL: +886-2-7737-3000
FAX: +886-3-583-7948
Website: www.ul.com

Testing Laboratory
3398

REVISION HISTORY

Rev.	Date	Revisions	Revised By
V0	3/2/2022	Initial Issue	Sally Lu
V1	4/14/2022	Revised highest reported SAR on page 4.	Sally Lu

Table of Contents

1. Attestation of Test Results 4

2. Test Specification, Methods and Procedures 5

3. Facilities and Accreditation 6

4. SAR Measurement System & Test Equipment 7

4.1. SAR Measurement System 7

4.2. SAR Scan Procedures 8

4.3. Test Equipment 10

5. Measurement Uncertainty 11

6. Device Under Test (DUT) Information 12

6.1. DUT Description 12

6.2. Wireless Technologies 13

7. RF Exposure Conditions (Test Configurations) 14

7.1. Standalone SAR Test Exclusion Considerations 14

8. Dielectric Property Measurements & System Check 16

8.1. Dielectric Property Measurements 16

8.2. System Check 18

9. Conducted Output Power Measurements 19

9.1. Wi-Fi 2.4GHz (DTS Band) 19

9.2. Bluetooth 20

10. Measured and Reported (Scaled) SAR Results 21

10.1. Test Condition 22

10.2. Wi-Fi (DTS Band) 23

11. Simultaneous Transmission SAR Analysis 24

11.1. Sum of the SAR for Wi-Fi 26

Appendixes 27

4790201427-US-S0-V1_Appendix A: SAR Setup Photos 27

4790201427-US-S0-V1_Appendix B: Antenna Dimensions and Separation Distances 27

4790201427-US-S0-V1_Appendix C: SAR System Check Plots 27

4790201427-US-S0-V1_Appendix D: Highest SAR Test Plots 27

4790201427-US-S0-V1_Appendix E: SAR Probe and Dipole Calibration Certificates 27

1. Attestation of Test Results

Applicant Name	ESPRESSIF SYSTEMS (SHANGHAI) CO., LTD.	
FCC ID	2AC7Z-ESP32S2WROOM	
Model Name	ESP32-S2-WROOM	
Exposure Category	General Population/Uncontrolled Exposure	
Applicable Standards	FCC 47 CFR § 2.1093 Published RF exposure KDB procedures IEEE Std 1528-2013	
Exposure Category	SAR Limits (W/Kg)	
	Peak spatial-average(1g of tissue)	Extremities (hands, wrists, ankles, etc.) (10g of tissue)
General population/Uncontrolled exposure	1.6	4
RF Exposure Conditions	Equipment Class - Highest Reported SAR (W/kg)	
	DTS	
Standalone	1.310	
Date Tested	2022/1/10	
Test Results	Pass	

Underwriters Laboratories Taiwan Co., Ltd. tested the above equipment in accordance with the requirements set forth in the above standards. All indications of Pass/Fail in this report are opinions expressed by Underwriters Laboratories Taiwan Co., Ltd. based on interpretations and/or observations of test results. The test results show that the equipment tested is capable of demonstrating compliance with the requirements as documented in this report.

Note: The results documented in this report apply only to the tested sample, under the conditions and modes of operation as described herein. This document may not be altered or revised in any way unless done so by Underwriters Laboratories Taiwan Co., Ltd. and all revisions are duly noted in the revisions section. Any alteration of this document not carried out by Underwriters Laboratories Taiwan Co., Ltd. will constitute fraud and shall nullify the document. This report must not be used by the client to claim product certification, approval, or endorsement by TAF or any agency of any government. This report is written to support regulatory compliance of the applicable standards stated above.

Approved and Authorized By:	Prepared By:
	
Jeff Shih Senior Project Engineer Underwriters Laboratories Taiwan Co., Ltd.	Sally Lu Project Handler Underwriters Laboratories Taiwan Co., Ltd.

2. Test Specification, Methods and Procedures

The tests documented in this report were performed in accordance with FCC 47 CFR § 2.1093, IEEE STD 1528-2013, the following FCC Published RF exposure KDB procedures:

- 248227 D01 802.11 Wi-Fi SAR v02r02
- 447498 D01 General RF Exposure Guidance v06
- 865664 D01 SAR measurement 100 MHz to 6 GHz v01r04
- 865664 D02 RF Exposure Reporting v01r02

3. Facilities and Accreditation

The test sites and measurement facilities used to collect data are located at

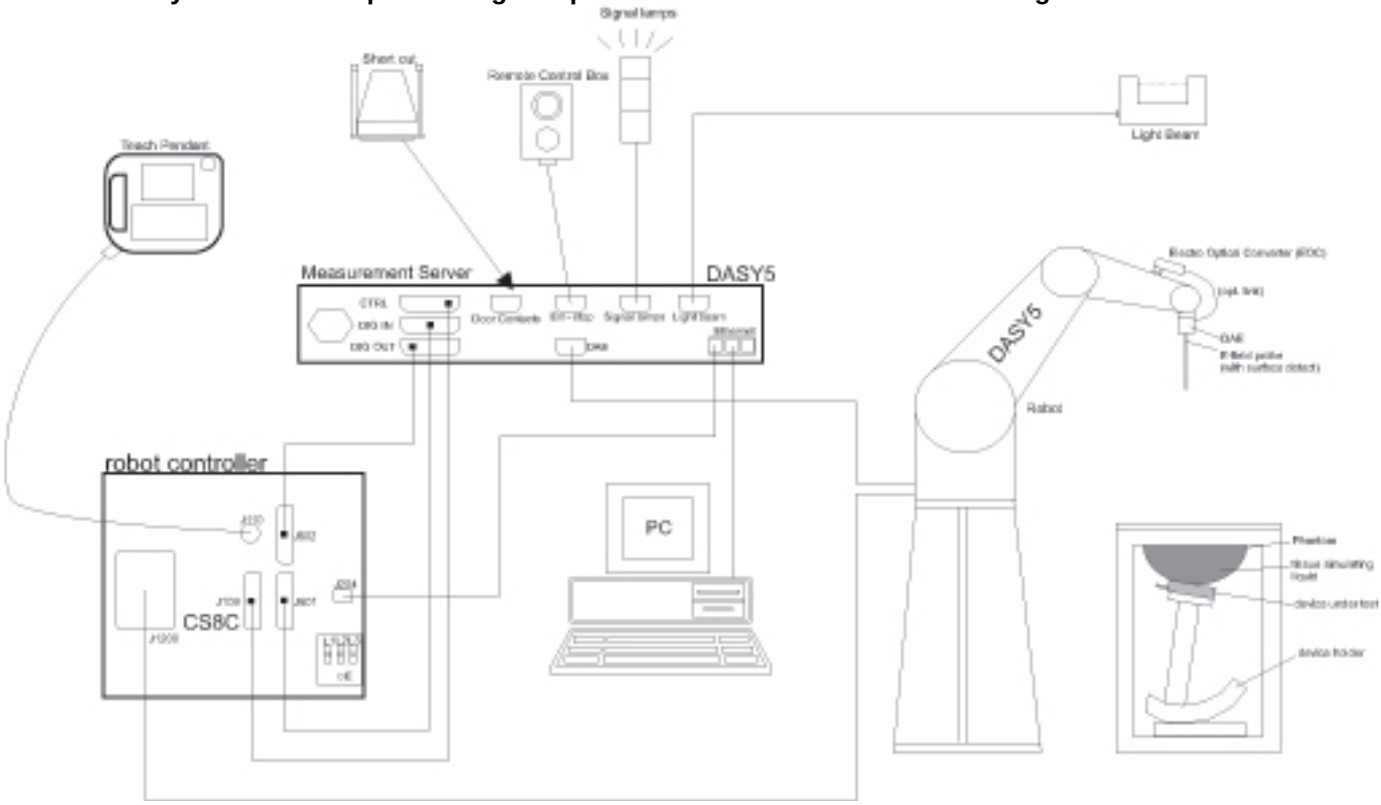
Underwriters Laboratories Taiwan Co., Ltd.,
SAR Room

Underwriters Laboratories Taiwan Co., Ltd. is accredited by TAF, Laboratory Code 3398.

4. SAR Measurement System & Test Equipment

4.1. SAR Measurement System

The DASY5 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 Win7 or Win10 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.

4.2. SAR Scan Procedures

Step 1: 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. The minimum distance of probe sensors to surface is 2.1 mm. This distance cannot be smaller than the distance of sensor calibration points to probe tip as defined in the probe properties.

Step 2: Area Scan

The Area Scan is used as a fast scan in two dimensions to find the area of high field values, before doing a fine measurement around the hot spot. The sophisticated interpolation routines implemented in DASY software can find the maximum locations even in relatively coarse grids. When an Area Scan has measured all reachable points, it computes the field maximal found in the scanned area, within a range of the global maximum. The range (in dB) is specified in the standards for compliance testing. For example, a 2 dB range is required in IEEE 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 KDB 865664 D01 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	½·δ·ln(2) ± 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.	

Step 3: Zoom Scan

Zoom Scans are used to assess the peak spatial SAR values within a cubic averaging volume containing 1 g and 10 g of simulated tissue. The Zoom Scan measures points (refer to table below) within a cube whose 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 g and 10 g and displays these values next to the job's label.

Zoom Scan Parameters extracted from KDB 865664 D01 SAR Measurement 100 MHz to 6 GHz

			≤ 3 GHz	> 3 GHz
Maximum zoom scan spatial resolution: Δx_{Zoom}, Δy_{Zoom}			≤ 2 GHz: ≤ 8 mm 2 – 3 GHz: ≤ 5 mm*	3 – 4 GHz: ≤ 5 mm* 4 – 6 GHz: ≤ 4 mm*
Maximum zoom scan spatial resolution, normal to phantom surface	uniform grid: $\Delta z_{Zoom}(n)$		≤ 5 mm	3 – 4 GHz: ≤ 4 mm 4 – 5 GHz: ≤ 3 mm 5 – 6 GHz: ≤ 2 mm
	graded grid	$\Delta z_{Zoom}(1)$: between 1st two points closest to phantom surface	≤ 4 mm	3 – 4 GHz: ≤ 3 mm 4 – 5 GHz: ≤ 2.5 mm 5 – 6 GHz: ≤ 2 mm
		$\Delta z_{Zoom}(n>1)$: between subsequent points	$\leq 1.5 \cdot \Delta z_{Zoom}(n-1)$	
Minimum zoom scan volume	x, y, z		≥ 30 mm	3 – 4 GHz: ≥ 28 mm 4 – 5 GHz: ≥ 25 mm 5 – 6 GHz: ≥ 22 mm

Note: δ is the penetration depth of a plane-wave at normal incidence to the tissue medium; see draft standard IEEE P1528-2011 for details.

* When zoom scan is required and the *reported* 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.

Step 4: Power drift measurement

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

4.3. Test Equipment

The measuring equipment used to perform the tests documented in this report has been calibrated in accordance with the manufacturers' recommendations, and is traceable to recognized national standards.

Dielectric Property Measurements

Name of Equipment	Manufacturer	Type/Model	Serial No.	Cal. Due Date
Network Analyzer	AGILENT	E5071C	MY46316588	2022/8/12
Dielectric Assessment Kit	SPEAG	DAK-3.5	1250	2022/9/23
Humidity/Temp meter	TECPEL	DTM-20	17020736	2022/5/24

System Check

Name of Equipment	Manufacturer	Type/Model	Serial No.	Cal. Due Date
EXG-B RF Vector Signal Generator	Keysight Technologies	N5172B	MY56200315	2022/5/26
Power Meter	Keysight Technologies	N1914A	MY56360007	2022/12/20
Power Sensor	Keysight Technologies	N8481H	MY56350009	2022/12/20
Power Meter	Anritsu	ML2495A	1645002	2022/12/21
Power Sensor	Anritsu	MA2411B	1531202	2022/12/21
Dosimetric E-Field Probe	SPEAG	EX3DV4	3826	2022/7/28
Data Acquisition Electronice	SPEAG	DAE4	1360	2022/10/7
System Validation Dipole	SPEAG	D2450V2	988	2022/11/9
Humidity/Temp meter	TECPEL	DTM-20	17020735	2022/4/11

UL Software

Software Version
DASY NEO52 D10.4 S14.6.14
SEMCAD-X-PostPro

5. Measurement Uncertainty

Measurement uncertainty for 300 MHz to 3 GHz

Source of Uncertainty	Tolerance (± %)	Probability Distribution	Divisor	Ci (1g)	Ci (10g)	Standard Uncertainty (± %, 1g)	Standard Uncertainty (± %, 10g)
Measurement System							
Probe Calibration	6.00	Normal	1	1	1	6.00	6.00
Axial Isotropy	4.70	Rectangular	1.732	0.7	0.7	1.90	1.90
Hemispherical Isotropy	9.60	Rectangular	1.732	0.7	0.7	3.88	3.88
Boundary Effect	1.00	Rectangular	1.732	1	1	0.58	0.58
Probe Linearity	4.70	Rectangular	1.732	1	1	2.71	2.71
System Detection Limits	0.25	Rectangular	1.732	1	1	0.14	0.14
Readout Electronics	0.30	Normal	1	1	1	0.30	0.30
Probe Modulation Response	2.40	Rectangular	1.732	1	1	1.39	1.39
Response Time	0.00	Rectangular	1.732	1	1	0.00	0.00
Integration Time	2.60	Rectangular	1.732	1	1	1.50	1.50
RF Ambient Conditions – Noise	3.00	Rectangular	1.732	1	1	1.73	1.73
RF Ambient Conditions – Reflections	3.00	Rectangular	1.732	1	1	1.73	1.73
Probe Positioner Mechanical Restrictions	0.40	Rectangular	1.732	1	1	0.23	0.23
Probe Positioning with Respect to Phantom Shell	2.90	Rectangular	1.732	1	1	1.67	1.67
Interpolation, Extrapolation and Averaged SAR calculation algorithms of the Postprocessor	2.00	Rectangular	1.732	1	1	1.15	1.15
Test Sample Related							
Device Positioning	2.90	Normal	1	1	1	2.90	2.90
Device Holder Disturbance	3.60	Normal	1	1	1	3.60	3.60
DUT Power Drift of Measured SAR	5.00	Rectangular	1.732	1	1	2.89	2.89
SAR Scaling	0.00	Rectangular	1.732	1	1	0.00	0.00
Phantom and Setup							
Phantom Uncertainty - Shape,Thickness and Permittivity	7.20	Rectangular	1.732	1	1	4.16	4.16
SAR Correction for Deviations in Permittivity and Conductivity	1.90	Normal	1	1	0.84	1.90	1.60
Liquid Conductivity - measurement(DAK)	2.50	Normal	1	0.78	0.71	1.95	1.78
Liquid Permittivity - measurement(DAK)	2.50	Normal	1	0.23	0.26	0.58	0.65
Liquid Conductivity – Temperature Uncertainty	3.40	Rectangular	1.732	0.78	0.71	1.53	1.39
Liquid Permittivity – Temperature Uncertainty	0.40	Rectangular	1.732	0.23	0.26	0.05	0.06
Combined Standard Uncertainty (K=1)						11.57	11.48
Expanded Uncertainty U (K=2)						**23.14**	**22.97**

6. Device Under Test (DUT) Information

6.1. DUT Description

Product	Wi-Fi Internet of Things Module
Model Name	ESP32-S2-WROOM
Operating Frequency	Wi-Fi 2.4GHz : 2412 ~ 2462 MHz
Power source	3Vdc ~ 3.6Vdc
Sample ID	4424546
Received Date	2021/10/8

Note:

1. Host information:

Product	Brand	Model
FluentPet Connect	FluentPet	B100

6.2. Wireless Technologies

Wireless technologies	Frequency bands	Operating mode	Duty Cycle used for SAR testing
Wi-Fi	2.4 GHz	802.11b 802.11g 802.11n (HT20) 802.11n (HT40)	88.06% 85.29% 84.62% 81.25%

7. RF Exposure Conditions (Test Configurations)

Refer to Appendix B for the specific details of the antenna-to-antenna and antenna-to-edge(s) distances.

7.1. Standalone SAR Test Exclusion Considerations

Since the *Dedicated Host Approach* is applied, the standalone SAR test exclusion procedure in KDB 447498 § 4.3.1 (RSS-102 Issue 5 § 2.5.1) is applied in conjunction with KDB 616217 § 4.3 to determine the minimum test separation distance:

- When the separation distance from the antenna to an adjacent edge is ≤ 5 mm, a distance of 5 mm is applied to determine SAR test exclusion.
- When the separation distance from the antenna to an adjacent edge is > 5 mm, the actual antenna-to-edge separation distance is applied to determine SAR test exclusion.

SAR Test Exclusion Calculations for WLAN

Antennas < 50mm to adjacent edges

Tx Interface	Frequency (MHz)	Output Power		Separation Distances (mm)							
		dBm	mW	Front	Back	Edge 1	Edge 2	Edge 3	Edge 4	Edge 5	Edge 6
Wi-Fi 2.4 GHz	2462	17.00	50	13	10	52	19	52	135	177	135
Bluetooth	2480	1.50	1	13	10	5	46	138	192	142	53

Tx Interface	Frequency (MHz)	Output Power		Calculated Threshold Value							
		dBm	mW	Front	Back	Edge 1	Edge 2	Edge 3	Edge 4	Edge 5	Edge 6
Wi-Fi 2.4 GHz	2462	17.00	50	6 -MEASURE-	7.8 -MEASURE-	*> 50 mm*	4.1 -MEASURE-	*> 50 mm*	*> 50 mm*	*> 50 mm*	*> 50 mm*
Bluetooth	2480	1.50	1	0.1 -EXEMPT-	0.2 -EXEMPT-	0.3 -EXEMPT-	0 -EXEMPT-	*> 50 mm*	*> 50 mm*	*> 50 mm*	*> 50 mm*

Note(s):

According to RSS-102 Issue 5 § 2.5.1, if the calculated threshold value is >3 then SAR testing is required.

Antennas > 50mm to adjacent edges

Tx Interface	Frequency (MHz)	Output Power		Separation Distances (mm)							
		dBm	mW	Front	Back	Edge 1	Edge 2	Edge 3	Edge 4	Edge 5	Edge 6
Wi-Fi 2.4 GHz	2462	17.00	50	13	10	52	19	52	135	177	135
Bluetooth	2480	1.50	1	13	10	5	46	138	192	142	53

Tx Interface	Frequency (MHz)	Output Power		Calculated Threshold Value							
		dBm	mW	Front	Back	Edge 1	Edge 2	Edge 3	Edge 4	Edge 5	Edge 6
Wi-Fi 2.4 GHz	2462	17.00	50	*< 50 mm*	*< 50 mm*	115.6 mW -EXEMPT-	*< 50 mm*	115.6 mW -EXEMPT-	945.6 mW -EXEMPT-	1365.6 mW -EXEMPT-	945.6 mW -EXEMPT-
Bluetooth	2480	1.50	1	*< 50 mm*	*< 50 mm*	*< 50 mm*	*< 50 mm*	975.3 mW -EXEMPT-	1515.3 mW -EXEMPT-	1015.3 mW -EXEMPT-	125.3 mW -EXEMPT-

Note(s):

According to RSS-102 Issue 5 § 2.5.1, if the calculated Power threshold is less than the output power then SAR testing is required.

8. Dielectric Property Measurements & System Check

8.1. Dielectric Property Measurements

The temperature of the tissue-equivalent medium used during measurement must also be within 18°C to 25°C and within ± 2°C of the temperature when the tissue parameters are characterized.
The dielectric parameters must be measured before the tissue-equivalent medium is used in a series of SAR measurements. The parameters should be re-measured after each 3 – 4 days of use; or earlier if the dielectric parameters can become out of tolerance; for example, when the parameters are marginal at the beginning of the measurement series.
Tissue dielectric parameters were measured at the low, middle and high frequency of each operating frequency range of the test device.
The dielectric constant (εr) and conductivity (σ) of typical tissue-equivalent media recipes are expected to be within ± 5% of the required target values; but for SAR measurement systems that have implemented the SAR error compensation algorithms documented in IEEE Std 1528-2013, to automatically compensate the measured SAR results for deviations between the measured and required tissue dielectric parameters, the tolerance for εr and σ may be relaxed to ± 10%. This is limited to frequencies ≤ 3 GHz.

Tissue Dielectric Parameters

FCC KDB 865664 D01 SAR Measurement 100 MHz to 6 GHz

Target Frequency (MHz)	Head	
	ε_r	σ (S/m)
150	52.3	0.76
300	45.3	0.87
450	43.5	0.87
835	41.5	0.90
900	41.5	0.97
915	41.5	0.98
1450	40.5	1.20
1610	40.3	1.29
1800 – 2000	40.0	1.40
2450	39.2	1.80
3000	38.5	2.40
5000	36.2	4.45
5100	36.1	4.55
5200	36.0	4.66
5300	35.9	4.76
5400	35.8	4.86
5500	35.6	4.96
5600	35.5	5.07
5700	35.4	5.17
5800	35.3	5.27

IEEE Std 1528-2013

Refer to Table 3 within the IEEE Std 1528-2013

Dielectric Property Measurements Results:

Date	Tissue Type	Frequency (MHz)	Relative Permittivity (εr)			Conductivity (σ)		
			Measured	Target	Delta (%)	Measured	Target	Delta (%)
2022/1/10	Head	2412	38.35	39.26	-2.31	1.84	1.76	3.97
		2422	38.32	39.24	-2.34	1.85	1.77	4.29
		2437	38.31	39.22	-2.31	1.87	1.79	4.54
		2450	38.27	39.20	-2.38	1.88	1.80	4.42
		2452	38.26	39.20	-2.38	1.88	1.80	4.44
		2462	38.24	39.18	-2.42	1.89	1.81	4.28

8.2. System Check

SAR system verification is required to confirm measurement accuracy, according to the tissue dielectric media, probe calibration points and other system operating parameters required for measuring the SAR of a test device. The system verification must be performed for each frequency band and within the valid range of each probe calibration point required for testing the device. The same SAR probe(s) and tissue-equivalent media combinations used with each specific SAR system for system verification must be used for device testing. When multiple probe calibration points are required to cover substantially large transmission bands, independent system verifications are required for each probe calibration point. A system verification must be performed before each series of SAR measurements using the same probe calibration point and tissue-equivalent medium. Additional system verification should be considered according to the conditions of the tissue-equivalent medium and measured tissue dielectric parameters, typically every three to four days when the liquid parameters are re-measured or sooner when marginal liquid parameters are used at the beginning of a series of measurements.

System Check Results

The 1-g and 10-g SAR measured with a reference dipole, using the required tissue-equivalent medium at the test frequency, must be within 10% of the manufacturer calibrated dipole SAR target.

Date	Tissue Type	Dipole S/N	Input Power (mW)	Measured 1g SAR (W/kg)	Targeted 1g SAR (W/kg)	Normalized 1g SAR (W/kg)	Delta 1g ±10 (%)	Measured 10g SAR (W/kg)	Targeted 10g SAR (W/kg)	Normalized 10g SAR (W/kg)	Delta 10g ±10 (%)
2022/1/10	Head	D2450V2-988	250	12.7	52.20	50.8	-2.68	5.85	23.90	23.4	-2.09

9. Conducted Output Power Measurements

9.1. Wi-Fi 2.4GHz (DTS Band)

Measured Results

Band	Mode	Data Rate	Ch #	Freq. (MHz)	Meas. Avg Pwr (dBm)	Tune-up Limit (dBm)	SAR Test (Yes/No)
2.4GHz (DTS)	802.11b	1 Mbps	1	2412	15.25	17	Yes
			6	2437	16.60	17	
			11	2462	16.03	17	
	802.11g	6 Mbps	1	2412	12.94	13	No
			6	2437	15.47	16	
			11	2462	13.52	14	
	802.11n (HT20)	MCS0	1	2412	12.69	13	No
			6	2437	15.58	16	
			11	2462	12.86	13	
	802.11n (HT40)	MCS0	3	2422	11.31	12	No
			6	2437	13.10	14	
			9	2452	11.68	12	

Note(s):

1. SAR is not required for 802.11g/n modes when the adjusted SAR for 802.11b is < 1.2 W/kg.
2. For “Not required”, SAR Test reduction was applied from KDB 248227 guidance, Sec. 2.1, b), 1) 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 in the initial test configuration, for each frequency band. Additional output power measurements were not deemed necessary.
3. Additionally, SAR is not required for Channels 12 and 13 because the tune-up limit and the measured output power for these two channels are no greater than those for the default test channels. Refer to §6.3.

9.2. Bluetooth

Average Power Measured Results

Band	Mode	Data Rate	Ch #	Freq. (MHz)	Meas. Avg Pwr (dBm)	Tune-up Limit (dBm)	SAR Test (Yes/No)
Bluetooth	BLE	1 Mbps	0	2402	1.13	1.5	No
			19	2440	1.17	1.5	
			39	2480	1.05	1.5	

10. Measured and Reported (Scaled) SAR Results

SAR Test Reduction criteria are as follows:

KDB 447498 D01 General RF Exposure Guidance:

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

KDB 248227 D01 SAR meas for 802.11:

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*.

10.1. Test Condition

Test Item	Test Site No.	Environmental Condition	Test Date	Tested by
SAR	SAR1	22.6°C	2022/1/10	Edison Hu

10.2. Wi-Fi (DTS Band)

RF Exposure Conditions	Mode	Dist. (mm)	Test Position	Ch #.	Freq. (MHz)	Duty Cycle	Power (dBm)		1-g SAR (W/kg)		10-g SAR (W/kg)	
							Tune-up Limit	Meas.	Meas.	Scaled	Meas.	Scaled
Body	802.11b (1Mbps)	0	Front	6	2442	88.06%	17.0	16.60	0.373	0.464	0.200	0.249
Body	802.11b (1Mbps)	0	Back	6	2442	88.06%	17.0	16.60	0.792	0.986	0.369	0.459
Body	802.11b (1Mbps)	0	Back	1	2412	88.06%	17.0	15.25	0.771	**1.310**	0.360	**0.612**
Body	802.11b (1Mbps)	0	Back	11	2462	88.06%	17.0	16.03	0.767	1.089	0.355	0.504
Body	802.11b (1Mbps)	0	Edge 2	6	2442	88.06%	17.0	16.60	0.243	0.303	0.137	0.171

11. Simultaneous Transmission SAR Analysis

KDB 447498 D01 General RF Exposure Guidance explains how to calculate the SAR to Peak Location Ratio (SPLSR) between pairs of simultaneously transmitting antennas:

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

Where:

SAR_1 is the highest measured 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 measured 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

Ri 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 $\mathbf{[(x_1-x_2)^2 + (y_1-y_2)^2 + (z_1-z_2)^2]}$

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:

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

Simultaneous Transmission Condition

RF Exposure Condition	Item	Capable Transmit Configurations		
Standalone	1	DTS	+	BT

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
3. Please refer to Estimated SAR Tables to see which test positions are inherently compliant as they consist of only estimated SAR values for all applicable transmitters and consequently will always have sum of SAR values < 1.2 W/kg. Simultaneous transmission SAR analysis was therefore not performed for these test positions.

Estimated SAR for WLAN

Tx Interface	Frequency (MHz)	Output Power		Separation Distances (mm)							
		dBm	mW	Front	Back	Edge 1	Edge 2	Edge 3	Edge 4	Edge 5	Edge 6
Wi-Fi 2.4 GHz	2462	17	50	13	10	52	19	52	135	177	135
Bluetooth	2480	1.5	1	13	10	5	46	138	192	142	53

Tx Interface	Frequency (MHz)	Output Power		Estimated 1-g SAR Value (W/kg)							
		dBm	mW	Front	Back	Edge 1	Edge 2	Edge 3	Edge 4	Edge 5	Edge 6
Wi-Fi 2.4 GHz	2462	17	50	-MEASURE-	-MEASURE-	0.400	-MEASURE-	0.400	0.400	0.400	0.400
Bluetooth	2480	1.5	1	0.016	0.021	0.042	0.005	0.400	0.400	0.400	0.400

Note(s):

The device is placed or fixed on a flat surface and user is not near the rear of the device, therefore, not need to evaluate the rear.

11.1. Sum of the SAR for Wi-Fi

Test Position	**DTS**	**DSS**	**∑ 1-g SAR (W/kg)**
Front	0.464	0.016*	0.480*
Back	1.310	0.021*	1.331*
Edge 1	0.4*	0.042*	0.442*
Edge 2	0.303	0.005*	0.308*
Edge 3	0.4*	0.4*	0.8*
Edge 4	0.4*	0.4*	0.8*
Edge 5	0.4*	0.4*	0.8*
Edge 6	0.4*	0.4*	0.8*

*: Estimated SAR

Appendixes

Refer to separated files for the following appendixes.

4790201427-US-S0-V1_Appendix A: SAR Setup Photos

4790201427-US-S0-V1_Appendix B: Antenna Dimensions and Separation Distances

4790201427-US-S0-V1_Appendix C: SAR System Check Plots

4790201427-US-S0-V1_Appendix D: Highest SAR Test Plots

4790201427-US-S0-V1_Appendix E: SAR Probe and Dipole Calibration Certificates

END OF REPORT