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PART 0 SAR CHAR REPORT

Applicant Name:

Apple, Inc. One Apple Park Way Cupertino, CA 95014 **Date of Testing:**

08/22/2022 Test Report Issue Date: 06/06/2023

Test Site/Location:

Element, Morgan Hill, CA, USA

Document Serial No.: 1C2305090019-03.BCG

FCC ID: **BCGA2764**

APPLE, INC. APPLICANT:

Report Type Type: Part 0 SAR Chaaracterization

DUT Type: Tablet Device

Model(s): A2764

Only operations relevant to this permissive change were evaluated for compliance. Please see the original compliance evaluation in RF Exposure Technical Report S/N: 1C2205090028-25.BCG (Rev1) for complete evaluation of all other operating modes. The operation description includes a description of all changed items.

I attest to the accuracy of data. All measurements reported herein were performed by me or were made under my supervision and are correct to the best of my knowledge and belief. I assume full responsibility for the completeness of these measurements and vouch for the qualifications of all persons taking them.

Test results reported herein relate only to the item(s) tested.







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DEVICE UNDER TEST

1.1 Device Overview

Band & Mode	Operating Modes	Tx Frequency			
UMTS 850	Data	826.40 - 846.60 MHz			
UMTS 1750	Data	1712.4 - 1752.6 MHz			
UMTS 1900	Data	1852.4 - 1907.6 MHz			
LTE Band 71	Voice/Data	665.5 - 695.5 MHz			
LTE Band 12	Voice/Data	699.7 - 715.3 MHz			
LTE Band 17	Voice/Data	706.5 - 713.5 MHz			
LTE Band 13	Voice/Data	779.5 - 784.5 MHz			
LTE Band 14	Voice/Data	790.5 - 795.5 MHz			
LTE Band 26 (Cell)	Voice/Data	814.7 - 848.3 MHz			
LTE Band 5 (Cell)	Voice/Data	824.7 - 848.3 MHz			
LTE Band 66 (AWS)	Voice/Data	1710.7 - 1779.3 MHz			
LTE Band 4 (AWS)	Voice/Data	1710.7 - 1754.3 MHz			
LTE Band 25 (PCS)	Voice/Data	1850.7 - 1914.3 MHz			
LTE Band 2 (PCS)	Voice/Data	1850.7 - 1909.3 MHz			
LTE Band 2 (FCS)	Voice/Data	2307.5 - 2312.5 MHz			
LTE Band 7	Voice/Data	2502.5 - 2567.5 MHz			
LTE Band 41	Voice/Data	2498.5 - 2687.5 MHz			
LTE Band 48	Voice/Data Voice/Data	3552.5 - 3697.5 MHz			
	Data				
NR Band n71		665.5 - 695.5 MHz			
NR Band n12	Data	701.5 - 713.5 MHz			
NR Band n14	Data	790.5 - 795.5 MHz			
NR Band n26 (Cell)	Data	816.5 - 846.5 MHz			
NR Band n5 (Cell)	Data	826.5 - 846.5 MHz			
NR Band n70	Data	1697.5 - 1707.5 MHz			
NR Band n66 (AWS)	Data	1712.5 - 1777.5 MHz			
NR Band n25 (PCS)	Data	1852.5 - 1912.5 MHz			
NR Band n2 (PCS)	Data	1852.5 - 1907.5 MHz			
NR Band n30	Data	2307.5 - 2312.5 MHz			
NR Band n7	Data	2502.5 - 2567.5 MHz			
NR Band n41	Data	2506.02 - 2679.99 MHz			
NR Band n48	Data	3555.00 - 3694.98 MHz			
NR Band n77 DoD	Data	3455.01 - 3544.98 MHz			
NR Band n77 C	Data	3705.00 - 3975.00 MHz			
2.4 GHz WLAN	Voice/Data	2412 - 2472 MHz			
U-NII-1	Voice/Data	5180 - 5240 MHz			
U-NII-2A	Voice/Data	5260 - 5320 MHz			
U-NII-2C	Voice/Data	5500 - 5720 MHz			
U-NII-3	Voice/Data	5745 - 5825 MHz			
U-NII-5	Voice/Data	5955 - 6415 MHz			
U-NII-6	Voice/Data	6435 - 6515 MHz			
U-NII-7	Voice/Data	6535 - 6875 MHz			
U-NII-8	Voice/Data	6895 - 7115 MHz			
Bluetooth	Data	2402 - 2480 MHz			
NB UNII-1	Data	5162 - 5245 MHz			
NB UNII-3	Data	5733 - 5844 MHz			
NR Band n258	Data	24250 - 24450 MHz 24750 - 25250 MHz			
NR Band n260	Data	37000 - 40000 MHz			
NR Band n261	Data	27500 - 28350 MHz			
comm [®] Gen2 Smart Transmit feature to control and manage tr					

This device uses the Qualcomm® Gen2 Smart Transmit feature to control and manage transmitting power in real time and to ensure the time-averaged RF exposure is in compliance with the FCC requirement at all times for 2G/3G/4G/5G WWAN operations. Additionally, this device supports WLAN/BT technologies, but the output power of these modems is not controlled by the Smart Transmit algorithm.

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1.2 Time-Averaging for SAR and Power Density

This device is enabled with Qualcomm[®] Gen2 Smart Transmit algorithm to control and manage transmitting power in real time and to ensure that the time-averaged RF exposure from 2G/3G/4G/5G Sub-6 NR WWAN is in compliance with FCC requirements. This Part 0 report shows SAR characterization of WWAN radios for 5G Sub-6 NR. Characterization is achieved by determining P_{Limit} for 5G Sub-6 NR that corresponds to the exposure design targets after accounting for all device design related uncertainties, i.e., SAR_design_target (< FCC SAR limit) for sub-6 radio. The SAR characterization is denoted as SAR Char in this report. Section 1.3 includes a nomenclature of the specific terms used in this report.

The validation of the time-averaging algorithm and compliance under the dynamic (time- varying) transmission scenario for WWAN technologies are reported in Part 2 report (report SN could be found in Section 1.4 – Bibliography). See the original filing for all other operations that were not evaluated in this permissive change.

1.3 Nomenclature for Part 0 Report

Technology	y Term Description	
	P _{limit}	Power level that corresponds to the exposure design target (SAR_design_target) after accounting for all device
00/00/40/50		design related uncertainties
2G/3G/4G/5G Sub-6 NR	P _{max}	Maximum tune up output power
Sub-6 INK	SAR_design_target	Target SAR level < FCC SAR limit after accounting for all
		device design related uncertainties
	SAR Char	Table containing <i>Plimit</i> for all technologies and bands

1.4 Bibliography

Report Type	Report Serial Number
FCC SAR Evaluation Report (Part 1)	1C2305090019-02.BCG
Original RF Exposure Part 1 Test Report	Original Filing

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2 SAR AND POWER DENSITY MEASUREMENTS

2.1 SAR Definition

Specific Absorption Rate is defined as the time derivative (rate) of the incremental energy (dU) absorbed by (dissipated in) an incremental mass (dm) contained in a volume element (dV) of a given density (ρ). It is also defined as the rate of RF energy absorption per unit mass at a point in an absorbing body (see Equation 2-1).

Equation 2-1 SAR Mathematical Equation

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

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

$$SAR = \frac{\sigma \cdot E^2}{\rho}$$

where:

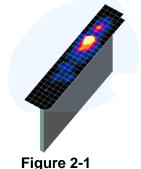
 σ = conductivity of the tissue-simulating material (S/m) ρ = mass density of the tissue-simulating material (kg/m³) E = Total RMS electric field strength (V/m)

NOTE: The primary factors that control rate of energy absorption were found to be the wavelength of the incident field in relation to the dimensions and geometry of the irradiated organism, the orientation of the organism in relation to the polarity of field vectors, the presence of reflecting surfaces, and whether conductive contact is made by the organism with a ground plane.[6]

2.2 SAR Measurement Procedure

The evaluation was performed using the following procedure compliant to FCC KDB Publication 865664 D01v01r04 and IEEE 1528-2013:

- 1. The SAR distribution at the exposed side of the head or body was measured at a distance no greater than 5.0 mm from the inner surface of the shell. The area covered the entire dimension of the device-head and body interface and the horizontal grid resolution was determined per FCC KDB Publication 865664 D01v01r04 (See Table) and IEEE 1528-2013.
- 2. The point SAR measurement was taken at the maximum SAR region determined from Step 1 to enable the monitoring of SAR fluctuations/drifts during the 1g/10g cube evaluation. SAR at this fixed point was measured and used as a reference value.



Sample SAR Area Scan

3. Based on the area scan data, the peak of the region with maximum SAR was determined by spline interpolation. Around this point, a volume was assessed according to the measurement resolution and volume size requirements of FCC KDB Publication 865664 D01v01r04 (See Table) and IEEE 1528-2013. On the

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basis of this data set, the spatial peak SAR value was evaluated with the following procedure (see references or the DASY manual online for more details):

- a. SAR values at the inner surface of the phantom are extrapolated from the measured values along the line away from the surface with spacing no greater than that in Table . The extrapolation was based on a least-squares algorithm. A polynomial of the fourth order was calculated through the points in the z-axis (normal to the phantom shell).
- b. After the maximum interpolated values were calculated between the points in the cube, the SAR was averaged over the spatial volume (1g or 10g) using a 3D-Spline interpolation algorithm. The 3D-spline is composed of three one-dimensional splines with the "Not a knot" condition (in x, y, and z directions). The volume was then integrated with the trapezoidal algorithm. One thousand points (10 x 10 x 10) were obtained through interpolation, in order to calculate the averaged SAR.
- c. All neighboring volumes were evaluated until no neighboring volume with a higher average value was found.
- 4. The SAR reference value, at the same location as step 2, was re-measured after the zoom scan was complete to calculate the SAR drift. If the drift deviated by more than 5%, the SAR test and drift measurements were repeated.

Table 2-1 Area and Zoom Scan Resolutions per FCC KDB Publication 865664 D01v01r04*

	Maximum Area Scan Description (1997) Resplicition (1997)		Maximum Zoom Scan Spatial Resolution (mm)			Minimum Zoom Scan
Frequency	Resolution (mm) (Δx _{arpa} , Δy _{arpa})	Resolution (mm) (Δx _{200m} , Δy _{200m})	Uniform Grid	Graded Grid		Volume (mm) (x,y,z)
			Δz _{zoom} (n)	Δz _{zoom} (1)*	Δz _{zoom} (n>1)*	
≤ 2 GHz	≤ 15	≤8	≤5	≤4	≤ 1.5*Δz _{zoom} (n-1)	≥ 30
2-3 GHz	≤ 12	≤5	≤5	≤4	$\leq 1.5*\Delta z_{zoom}(n-1)$	≥ 30
3-4 GHz	≤ 12	≤5	≤ 4	≤3	$\leq 1.5*\Delta z_{zoom}(n-1)$	≥ 28
4-5 GHz	≤ 10	≤4	≤3	≤2.5	$\leq 1.5*\Delta z_{zoom}(n-1)$	≥ 25
5-6 GHz	≤ 10	≤ 4	≤2	≤2	$\leq 1.5*\Delta z_{zoom}(n-1)$	≥ 22

^{*}Also compliant to IEEE 1528-2013 Table 6

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3 SAR CHARACTERIZATION

3.1 DSI and SAR Determination

This device uses different Device State Index (DSI) to configure different time averaged power levels based on certain exposure scenarios. Depending on the detection scheme implemented in the tablet, the worst-case SAR was determined by measurements for the relevant exposure conditions for that DSI. Detailed descriptions of the detection mechanisms are included in the operational description.

The device state index (DSI) conditions used in Table 3-1 represent different exposure scenarios.

Table 3-1
DSI and Corresponding Exposure Scenarios

Scenario	Description	SAR Test Cases
(DSI = 1)	Detect Mode Activated	Tablet SAR per KDB Publication 616217 D04

3.2 SAR Design Target

SAR_design_target is determined by ensuring that it is less than FCC SAR limit after accounting for total device designed related uncertainties specified by the manufacturer (see Table 3-2).

Table 3-2 SAR_design_target Calculations

SAR_design_target					
SAR_design_target< SAR_regula	$atory_limit \times 10^{rac{-Total\ Uncertainty}{10}}$				
1g SAR (W/kg)					
Total Uncertainty	1.0 dB				
SAR_regulatory_limit 1.6 W/kg					
SAR_design_target 0.8 W/kg					

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3.3 SAR Char

SAR test results corresponding to *Pmax* for each antenna/technology/band/DSI can be found in Appendix A.

Plimit is calculated by linearly scaling with the measured SAR at the Ppart0 to correspond to the SAR_design_target. When Plimit < Pmax, Ppart0 was used as Plimit in the Smart Transmit EFS. When Plimit > Pmax and Ppart0=Pmax, calculated Plimit was used in the Smart Transmit EFS. All reported SAR obtained from the Ppart0 SAR tests was less than SAR_Design_target+ 1 dB Uncertainty. The final Plimit determination for each exposure scenario corresponding to SAR_design_target are shown in Table 3-3.

Table 3-3 PLimit Determination

Device State Index (DSI)	PLimit Determination Scenarios
1	The worst-case SAR exposure is determined as maximum SAR normalized to the limit among: 1. Tablet SAR measured at 0 mm for Back, Top, Bottom, Right, Left surfaces

Note:

For DSI = 1, P_{limit} is calculated by:

 P_{limit} corresponding to 1g Tablet SAR evaluation at 0 mm for back, top, bottom, left and right surfaces

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Table 3-4 SAR Characterizations

Exposure Scenario:	Ant 1 Body	Ant 1 Maximum	Ant 2a/2b Body Ant 2a/2b		Ant 1 Maximum Ant 2a/2b Body		Ant 3a/2h Ant 3 Body		Ant 4b Body	Ant 4b Maximum						
Averaging Volume:	1g	Tune-up	1g	Maximum Tune-up	1g	Ant 3 Maximum Tune-up	1g	Tune-up								
Spacing:	0 mm	Output Power*	0 mm			Output Power*			0 mm	0 mm		Output Power*	0 mm	Output Power*		Plimit target
DSI:	1	Output Fower	1	Output Fower	1	Output Fower	1	Output Power*	Manufacturer's Smart	and UHB Pmax						
Technology/Band	Plimit corresponding to 0.8 W/kg	Pmax	Plimit corresponding to 0.8 W/kg	Pmax	Plimit corresponding to 0.8 W/kg		Plimit correspondin g to 0.8 W/kg		Transmit Uncertainty (dB)	target Tolerance (dB)						
NR Band n48	11.20	19.60	11.40	20.00	11.80	18.70	10.90	21.00	+/- 1.0	+/- 1.0						

Notes:

- 1. *Maximum tune up output power Pmax is used to configure EUT during RF tune up procedure. The maximum allowed output power is equal to maximum Tune up output power +1.0/-1.0 dB tolerance for UHB.
- 2. All P_{limit} EFS and maximum tune up output power P_{max} levels entered in above Table correspond to average power levels after accounting for duty cycle in the case of TDD modulation schemes (for e.g., LTE TDD).
- 3. See the original filing for all other operations that were not evaluated in this permissive change.

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13 EQUIPMENT LIST

For SAR measurements

Manufacturer	Model	Description	Cal Date	Cal Interval	Cal Due	Serial Number
Agilent	E4404B	Spectrum Analyzer	N/A	N/A	N/A	MY45113242
Agilent	E4438C	ESG Vector Signal Generator	5/10/2022	Annual	5/10/2023	MY42082659
Agilent	E4438C	ESG Vector Signal Generator	2/14/2022	Annual	2/14/2023	MY42082385
Agilent	N5182A	MXG Vector Signal Generator	7/20/2022	Annual	7/20/2023	MY47420800
Agilent	N5182A	MXG Vector Signal Generator	6/21/2022	Annual	6/21/2023	MY47420651
Agilent	8753ES	S-Parameter Vector Network Analyzer	2/11/2022	Annual	2/11/2023	MY40003841
Agilent	8753ES	S-Parameter Vector Network Analyzer	12/17/2021	Annual	12/17/2022	MY40000670
Amplifier Research	15S1G6	Amplifier	CBT	N/A	CBT	433972
Amplifier Research	15S1G6	Amplifier	CBT	N/A	CBT	433974
Anritsu	MA24106A	USB Power Sensor	8/12/2022	Annual	8/12/2023	1349513
Anritsu	MA24106A	USB Power Sensor	8/5/2022	Annual	8/5/2023	1344555
Control Company	4352	Long Stem Thermometer	9/10/2021	Biennial	9/10/2023	210774678
Control Company	4352	Long Stem Thermometer	9/10/2021	Biennial	9/10/2023	210774685
Control Company	4353	Long Stem Thermometer	10/28/2020	Biennial	10/28/2022	200670623
Control Company	4040	Therm./ Clock/ Humidity Monitor	1/21/2022	Annual	1/21/2023	160574418
Mitutoyo	500-196-30	CD-6"ASX 6Inch Digital Caliper	2/16/2022	Triennial	2/16/2025	A20238413
Keysight Technologies	N6705B	DC Power Analyzer	5/5/2021	Triennial	5/5/2024	MY53004059
Keysight Technologies	N9020A	MXA Signal Analyzer	4/14/2022	Annual	4/14/2023	MY48010233
MCL	BW-N6W5+	6dB Attenuator	CBT	N/A	CBT	1139
Mini-Circuits	VLF-6000+	Low Pass Filter DC to 6000 MHz	CBT	N/A	CBT	N/A
Mini-Circuits	BW-N20W5+	DC to 18 GHz Precision Fixed 20 dB Attenuator	CBT	N/A	CBT	N/A
Mini-Circuits	NLP-1200+	Low Pass Filter DC to 1000 MHz	CBT	N/A	CBT	N/A
Mini-Circuits	NLP-2950+	Low Pass Filter DC to 2700 MHz	CBT	N/A	CBT	N/A
Mini-Circuits	BW-N20W5	Power Attenuator	CBT	N/A	CBT	1226
Mini-Circuits	ZUDC10-83-S+	Directional Coupler	CBT	N/A	CBT	2050
Narda	4772-3	Attenuator (3dB)	CBT	N/A	CBT	9406
Narda	BW-S3W2	Attenuator (3dB)	CBT	N/A	CBT	120
Huber + Suhner	74Z-0-0-21	Torque Wrench	4/6/2022	Biennial	6/4/2024	83881
SPEAG	DAK-3.5	Dielectric Assessment Kit	1/6/2022	Annual	1/6/2023	1278
SPEAG	MAIA	Modulation and Audio Interference Analyzer	N/A	N/A	N/A	1379
SPEAG	D3500V2	3500 MHz SAR Dipole	6/9/2021	Biennial	6/9/2023	1126
SPEAG	D3700V2	3700 MHz SAR Dipole	10/17/2019	Triennial	10/17/2022	1002
SPEAG	DAE4	Dasy Data Acquisition Electronics	11/21/2021	Annual	11/21/2022	1646
SPEAG	EX3DV4	SAR Probe	11/16/2021	Annual	11/16/2022	7639

Note:

- CBT (Calibrated Before Testing). Prior to testing, the measurement paths containing a cable, amplifier, attenuator, coupler or filter
 were connected to a calibrated source (i.e. a signal generator) to determine the losses of the measurement path. The power meter
 offset was then adjusted to compensate for the measurement system losses. This level offset is stored within the power meter
 before measurements are made. This calibration verification procedure applies to the system verification and output power
 measurements. The calibrated reading is then taken directly from the power meter after compensation of the losses for all final
 power measurements.
- 2. Each equipment item was used solely within its respective calibration period.

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14 MEASUREMENT UNCERTAINTIES

For SAR Measurements

Measurements							i.		
а	b	С	d	e=	f	g	h =	i =	k
				f(d,k)			c x f/e	c x g/e	
	IEEE	Tol.	Prob.		Ci	Ci	1gm	10gms	
Uncertainty Component	1528 Sec.	(± %)	Dist.	Div.	1gm	10 gms	u _i	u _i	Vi
	000.						(± %)	(± %)	
Measurement System									
Probe Calibration	E.2.1	7	N	1	1	1	7.0	7.0	∞
Axial Isotropy	E.2.2	0.25	N	1	0.7	0.7	0.2	0.2	∞
Hemishperical Isotropy	E.2.2	1.3	N	1	0.7	0.7	0.9	0.9	∞
Boundary Effect	E.2.3	2	R	1.73	1	1	1.2	1.2	∞
Linearity	E.2.4	0.3	N	1	1	1	0.3	0.3	∞
System Detection Limits	E.2.4	0.25	R	1.73	1	1	0.1	0.1	∞
Modulation Response	E.2.5	4.8	R	1.73	1	1	2.8	2.8	~
Readout Electronics	E.2.6	0.3	N	1	1	1	0.3	0.3	∞
Response Time	E.2.7	0.8	R	1.73	1	1	0.5	0.5	∞
Integration Time	E.2.8	2.6	R	1.73	1	1	1.5	1.5	∞
RF Ambient Conditions - Noise	E.6.1	3	R	1.73	1	1	1.7	1.7	8
RF Ambient Conditions - Reflections	E.6.1	3	R	1.73	1	1	1.7	1.7	8
Probe Positioner Mechanical Tolerance		8.0	R	1.73	1	1	0.5	0.5	8
Probe Positioning w/ respect to Phantom		6.7	R	1.73	1	1	3.9	3.9	∞
Extrapolation, Interpolation & Integration algorithms for Max. SAR Evaluation		4	R	1.73	1	1	2.3	2.3	∞
Test Sample Related									
Test Sample Positioning	E.4.2	3.12	N	1	1	1	3.1	3.1	35
Device Holder Uncertainty	E.4.1	1.67	N	1	1	1	1.7	1.7	5
Output Power Variation - SAR drift measurement	E.2.9	5	R	1.73	1	1	2.9	2.9	8
SAR Scaling	E.6.5	0	R	1.73	1	1	0.0	0.0	∞
Phantom & Tissue Parameters									
Phantom Uncertainty (Shape & Thickness tolerances)	E.3.1	7.6	R	1.73	1.0	1.0	4.4	4.4	∞
Liquid Conductivity - measurement uncertainty	E.3.3	4.3	N	1	0.78	0.71	3.3	3.0	76
Liquid Permittivity - measurement uncertainty	E.3.3	4.2	N	1	0.23	0.26	1.0	1.1	75
Liquid Conductivity - Temperature Uncertainty	E.3.4	3.4	R	1.73	0.78	0.71	1.5	1.4	∞
Liquid Permittivity - Temperature Unceritainty		0.6	R	1.73	0.23	0.26	0.1	0.1	∞
Liquid Conductivity - deviation from target values	E.3.4 E.3.2	5.0	R	1.73	0.64	0.43	1.8	1.2	∞
Liquid Permittivity - deviation from target values	E.3.2	5.0	R	1.73	0.60	0.49	1.7	1.4	∞
Combined Standard Uncertainty (k=1) RSS							12.2	12.0	191
Expanded Uncertainty k=2							24.4	24.0	
(95% CONFIDENCE LEVEL)									

The above measurement uncertainties are according to IEEE Std. 1528-2013

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