

Exposure Calculation Report

Apple Inc
Model: A2816

In accordance with FCC CFR 47 Pt 2.1091

Prepared for: Apple Inc
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COMMERCIAL-IN-CONFIDENCE

FCC ID: BCGA2816

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SIGNATURE

A handwritten signature in blue ink, appearing to read 'Matthew Russell', is written over a white background.

NAME	JOB TITLE	RESPONSIBLE FOR	ISSUE DATE
Matthew Russell	Chief Engineer (RF)	Authorised Signatory	13 December 2022

Signatures in this approval box have checked this document in line with the requirements of TÜV SÜD document control rules.

EXECUTIVE SUMMARY

The calculation of exposure for this product was found to be compliant at a minimum distance of 20 cm with FCC CFR 47 Pt.2.1091 assuming continuous exposure of 6 minutes or more. If alternative antennas are used with greater gains, the distance must be recalculated.

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Report Summary

1.1 Report Modification Record

Alterations and additions to this report will be issued to the holders of each copy in the form of a complete document.

Issue	Description of Change	Date of Issue
1	First Issue	13-December-2022

Table 1

1.2 Introduction

Applicant	Apple Inc
Manufacturer	Apple Inc
Model Number(s)	A2816
Hardware Version(s)	REV 1.0
Software Version(s)	N/A
Specification/Issue/Date	FCC 47 CFR Part 2.1091: 2021
Order Number	540246998
Date	01-July-2022
Related Document(s)	- KDB 447498 D04 v01 - FCC 47 CFR Part 1.1307: 2021 - FCC 47 CFR Part 1.1310: 2021



1.3 Brief Summary of Results

The wireless device described within this report was compliant with the restrictions related to human exposure to electromagnetic fields for both general public and worker/occupational exposures for a separation distance of 20 cm.

The calculations shown in this report were made in accordance with the procedures specified in the applied test specification(s).



1.4 Product Information

1.4.1 Technical Description

The equipment under test was an Apple desktop computer with Bluetooth® and IEEE 802.11 a/b/g/n/ac/ax Wi-Fi in the 2.4 GHz, 5 GHz and 6 GHz bands.

1.4.2 Transmitter Description

The following radio access technologies and frequency bands are supported by the equipment under test.

Radio Access Technology	Core	Frequency Band (MHz)	Minimum Frequency (MHz)	Output Power (dBm)	Duty Cycle (%)
Bluetooth (SISO)	0	2400-2483.5	2402	16.5	77
Bluetooth (SISO)	1	2400-2483.5	2402	16.5	77
Bluetooth (SISO)	2	2400-2483.5	2402	16.5	77
Bluetooth (TxBF)	0 and 1	2400-2483.5	2402	16.5	77
2.4 GHz WLAN (SISO)	0	2400-2483.5	2412	22.50	100
2.4 GHz WLAN (SISO)	1	2400-2483.5	2412	22.50	100
2.4 GHz WLAN (2x2 MIMO)	0 and 1	2400-2483.5	2412	22.50	100
5 GHz WLAN (SISO)	0	5150 - 5850	5180	21.00	100
5 GHz WLAN (SISO)	1	5150 - 5850	5180	21.00	100
5 GHz WLAN (2x2 MIMO)	0 and 1	5150 - 5850	5180	21.00	100
6 GHz WLAN (SISO)	0	5925 - 7125	5935	12.75	100
6 GHz WLAN (SISO)	1	5925 - 7125	5935	12.75	100
6 GHz WLAN (2x2 MIMO)	0 and 1	5925 - 7125	5935	12.75	100
NB	0	5162 - 5844	5162	15.00	77
NB	1	5162 - 5844	5162	15.00	77

Table 2 – Transmitter Description- FCC

Note: Transmitter power includes upper bounds of uncertainty therefore maximum values are used.



1.4.3 Antenna Description

The following antennas are supported by the equipment under test.

Radio Access Technology	Antenna Model	Gain (dBi)	Antenna length (cm)	Minimum Separation Distance (cm)
BT Core 0	Not Specified	2.58	4.00	20
BT Core 1	Not Specified	6.24	5.07	20
BT Core 2	Not Specified	2.05	3.20	20
2.4 GHz WLAN Core 0	Not Specified	2.58	4.00	20
2.4 GHz WLAN Core 1	Not Specified	6.24	5.07	20
5 GHz WLAN Core 0	Not Specified	0.88	4.00	20
5 GHz WLAN Core 1	Not Specified	6.66	5.07	20
6 GHz WLAN Core 0	Not Specified	0.74	4.00	20
6 GHz WLAN Core 1	Not Specified	6.52	5.07	20
NB Core 0	Not Specified	0.88	4.00	20
NB Core 1	Not Specified	6.66	5.07	20

Table 3 – Antenna description

In the case of more than one type of antenna being supported by the equipment, the calculation is based on the maximum of the antenna gains. If other antennas can be used that have greater gains, the minimum separation distances will need to be recalculated.

Note: Antenna gain includes upper bounds of uncertainty therefore maximum values are used.

1.4.4 Equipment Configuration

Simultaneous transmission for the following configurations;

Combination 1 - 5 GHz WLAN (2x2 MIMO on Core 0 & 1) + Bluetooth (2x2 MIMO on Core 0 & 1)

Combination 2 - 6 GHz WLAN (2x2 MIMO on Core 0 & 1) + Bluetooth (2x2 MIMO on Core 0 & 1)

Combination 3 – 2.4 GHz WLAN (Core 1) + NB (Core 0)

Notes:

MIMO operation was confirmed as worst case compared to single antenna SISO operation.

2.4 GHz WLAN (Core 1) + NB (Core 0) was confirmed as worst case compared to 2.4 GHz WLAN (Core 0) + NB (Core 1)



2 Maximum Permissible Exposure

2.1 FCC CFR 47 Pt.1.1310 Worker/Occupational Limits

Frequency Range (MHz)	Power Density (mW/cm ²) Note 1	Electric Field Strength (V/m)	Magnetic Field Strength (A/m)
0 - 0.3	-	-	-
0.3 - 3	100	614	1.63
3 - 30	$900/f^2$	$1842/f$	$4.89/f$
30 - 300	1	61.4	0.163
300 - 1500	$f/300$	-	-
1500 - 100000	5	-	-

2.2 FCC CFR 47 Pt.1.1310 General Public Limits

Frequency Range (MHz)	Power Density (mW/cm ²) Note 1	Electric Field Strength (V/m)	Magnetic Field Strength (A/m)
0 - 0.3	-	-	-
0.3 - 3	100	614	1.63
3 - 30	$180/f^2$	$824/f$	$2.19/f$
30 - 300	0.2	27.5	0.073
300 - 1500	$f/1500$	-	-
1500 - 100000	1	-	-



3 Assessment Details

3.1 Single RF Source options for determination of exemption.

Option	Reference	RF Exposure Test Exemptions for Single Source												
A (1-mW Test Exemption)	FCC 1.1307(b)(3)(i)(A)	The available maximum time averaged power is no more than 1 mW, regardless of separation distance.												
B (SAR-Based Exemption)	FCC 1.1307(b)(3)(i)(B)	The available maximum timeaveraged power or effective radiated power (ERP), whichever is greater, is less than or equal to the threshold P_{th} (mW) described in the following formula. This method shall only be used at separation distances (cm) from 0.5 centimeters to 40 centimeters and at frequencies from 0.3 GHz to 6 GHz (inclusive). P_{th} is given by: $P_{th} \text{ (mW)} = \begin{cases} ERP_{20 \text{ cm}}(d/20 \text{ cm})^x & d \leq 20 \text{ cm} \\ ERP_{20 \text{ cm}} & 20 \text{ cm} < d \leq 40 \text{ cm} \end{cases}$ Where $x = -\log_{10}\left(\frac{60}{ERP_{20 \text{ cm}}\sqrt{f}}\right) \text{ and } f \text{ is in GHz;}$ and $ERP_{20 \text{ cm}} \text{ (mW)} = \begin{cases} 2040f & 0.3 \text{ GHz} \leq f < 1.5 \text{ GHz} \\ 3060 & 1.5 \text{ GHz} \leq f \leq 6 \text{ GHz} \end{cases}$ <i>d</i> = the separation distance (cm);												
C (MPE-Based Exemption)	FCC 1.1307(b)(3)(i)(C)	Or using Table 1 and the minimum separation distance (R in meters) from the body of a nearby person for the frequency (f in MHz) at which the source operates, the ERP (watts) is no more than the calculated value prescribed for that frequency. For the exemption in Table 1 to apply, R must be at least λ/2π, where λ is the free-space operating wavelength in meters. If the ERP of a single RF source is not easily obtained, then the available maximum time-averaged power may be used in lieu of ERP if the physical dimensions of the radiating structure(s) do not exceed the electrical length of λ/4 or if the antenna gain is less than that of a half-wave dipole (1.64 linear value). TABLE 1 TO § 1.1307(b)(3)(i)(C)—SINGLE RF SOURCES SUBJECT TO ROUTINE ENVIRONMENTAL EVALUATION <table><tr><th>RF Source frequency (MHz)</th><th>Threshold ERP (watts)</th></tr><tr><td>0.3–1.34</td><td>1,920 R².</td></tr><tr><td>1.34–30</td><td>3,450 R²/f².</td></tr><tr><td>30–300</td><td>3.83 R².</td></tr><tr><td>300–1,500</td><td>0.0128 R²f.</td></tr><tr><td>1,500–100,000</td><td>19.2R².</td></tr></table>	RF Source frequency (MHz)	Threshold ERP (watts)	0.3–1.34	1,920 R ² .	1.34–30	3,450 R ² /f ² .	30–300	3.83 R ² .	300–1,500	0.0128 R ² f.	1,500–100,000	19.2R ² .
RF Source frequency (MHz)	Threshold ERP (watts)													
0.3–1.34	1,920 R ² .													
1.34–30	3,450 R ² /f ² .													
30–300	3.83 R ² .													
300–1,500	0.0128 R ² f.													
1,500–100,000	19.2R ² .													



3.2 Multiple RF Sources options for determination of exemption.

Option	Reference	
A 1-mW Test Exemption for Multiple Sources	FCC 1.1307(b)(3)(ii)(A)	The available maximum time averaged power of each source is no more than 1 mW and there is a separation distance of two centimeters between any portion of a radiating structure operating and the nearest portion of any other radiating structure in the same device, except if the sum of multiple sources is less than 1 mW during the time-averaging period, in which case they may be treated as a single source (separation is not required). This exemption may not be used in conjunction with other exemption criteria other than those in paragraph (b)(3)(i)(A) of this section. Medical implant devices may only use this exemption and that in paragraph (b)(3)(i)(A).
B Simultaneous Transmission with both SAR-based and MPE- Based Test Exemptions	FCC 1.1307(b)(3)(ii)(B)	in the case of fixed RF sources operating in the same time-averaging period, or of multiple mobile or portable RF sources within a device operating in the same time averaging period, if the sum of the fractional contributions to the applicable thresholds is less than or equal to 1 as indicated in the following equation. $\sum_{i=1}^a \frac{P_i}{P_{th,i}} + \sum_{j=1}^b \frac{ERP_j}{ERP_{th,j}} + \sum_{k=1}^c \frac{Evaluated_k}{Exposure Limit_k} \leq 1$



3.3 Individual Antenna Port Exposure Results

3.3.1 Calculation of Exposure at Specified Separation Distance

The frequencies shown in the tables below have been chosen based on the lowest possible frequency that the EUT can transmit. A full list of the regional requirements is shown in Annex A.

RAT	Core	Frequency (MHz)	Conducted Power Output mW	Duty Cycle %	Time Average Conducted Power Output mW	Antenna Gain Ratio	Maximum Power (EIRP) mW	Maximum Power (ERP) mW	Test Separation Distance (mm)	Power Density (mW/cm ²)	Power Density Limit (mW/cm ²)	Mobile devices: 2.1091(C)(1) & 1.1307(b)(1)(i)(B) ERP20cm Exemption (Yes/No)** (300 MHz to 6 GHz, 20 cm to 40 cm)
Bluetooth	0	2402.0	44.67	77	34.39	1.811	62.30	37.99	200	0.007557302	1	Yes
Bluetooth	1	2402.0	44.67	77	34.39	4.207	144.71	88.24	200	0.017553624	1	Yes
Bluetooth	2	2402.0	44.67	77	34.39	1.603	55.14	33.62	200	0.006689086	1	Yes
2.4 GHz WLAN	0	2412.0	177.83	100	177.83	1.811	322.11	196.41	200	0.039072938	1	Yes
2.4 GHz WLAN	1	2412.0	177.83	100	177.83	4.207	748.17	456.20	200	0.090756150	1	Yes
5 GHz WLAN	0	5180.0	125.89	100	125.89	1.225	154.17	94.01	200	0.018701484	1	Yes
5 GHz WLAN	1	5180.0	125.89	100	125.89	4.634	583.45	355.76	200	0.070774379	1	Yes
6 GHz WLAN	0	5935.0	18.84	100	18.84	1.186	22.34	13.62	200	0.002709418	1	Yes
6 GHz WLAN	1	5935.0	18.84	100	18.84	4.487	84.53	51.54	200	0.010253593	1	Yes
NB	0	5162.0	31.62	77	24.35	1.225	29.82	18.18	200	0.003617152	1	Yes
NB	1	5162.0	31.62	77	24.35	4.634	112.85	68.81	200	0.013688845	1	Yes

Table 4 –Transmitter Result

The calculations show that the individual transmitters comply with FCC 1.1307(b)(3)(i)(C) MPE-based exemption at a minimum distance of 0.2 m.



3.4 Combined Antenna Port RF Exposure Results

3.4.1 Combination 1 - 5 GHz WLAN (2x2 MIMO on Core 0 & 1) + Bluetooth (2x2 MIMO on Core 0 & 1)

RAT	Core	Frequency (MHz)	Conducted Power Output mW	Duty Cycle %	Time Average Conducted Power Output mW	Antenna Gain Ratio	Maximum Power (EIRP) mW	Maximum Power (ERP) mW	Test Separation Distance (mm)	ERPj / ERPth
Bluetooth	0	2402.0	44.67	77	34.395	1.811	62.300	37.988	200	0.04946
Bluetooth	1	2402.0	44.67	77	34.395	4.207	144.707	88.236	200	0.11489
5 GHz WLAN	0	5180.0	125.89	100	125.893	1.225	154.170	94.006	200	0.12240
5 GHz WLAN	1	5180.0	125.89	100	125.893	4.634	583.445	355.759	200	0.46323
Calculated RF exposure level at minimum compliance boundary of 0.2 m as a fraction of the limit										0.7500

3.4.2 Combination 2 - 6 GHz WLAN (2x2 MIMO on Core 0 & 1) + Bluetooth (2x2 MIMO on Core 0 & 1)

RAT	Core	Frequency (MHz)	Conducted Power Output mW	Duty Cycle %	Time Average Conducted Power Output mW	Antenna Gain Ratio	Maximum Power (EIRP) mW	Maximum Power (ERP) mW	Test Separation Distance (mm)	ERPj / ERPth
Bluetooth	0	2402.0	44.67	77	34.395	1.811	62.300	37.988	200	0.04946
Bluetooth	1	2402.0	44.67	77	34.395	4.207	144.707	88.236	200	0.11489
6 GHz WLAN	0	5935.0	18.84	100	18.836	1.186	22.336	13.619	200	0.01773
6 GHz WLAN	1	5935.0	18.84	100	18.836	4.487	84.528	51.541	200	0.06711
Calculated RF exposure level at minimum compliance boundary of 0.2 m as a fraction of the limit										0.2492



3.4.3 Combination 3 – 2.4 GHz WLAN (Core 1) + NB (Core 0)

RAT	Core	Frequency (MHz)	Conducted Power Output mW	Duty Cycle %	Time Average Conducted Power Output mW	Antenna Gain Ratio	Maximum Power (EIRP) mW	Maximum Power (ERP) mW	Test Separation Distance (mm)	ERPj / ERPth
2.4 GHz WLAN	1	2412.0	177.83	100	177.828	4.207	748.170	456.201	200	0.59401
NB	0	5162.0	31.62	77	24.350	1.225	29.819	18.182	200	0.02367
Calculated RF exposure level at minimum compliance boundary of 0.2 m as a fraction of the limit										0.6177