



HAC RF EMISSIONS TEST REPORT

FCC 47 CFR § 20.19
ANSI C63.19-2011

For
SMARTPHONE

FCC ID: BCG-E4029A
Model Name: A2628

Report Number: 13802766-S3V3
Issue Date: 8/26/2021

Prepared for
APPLE INC.
1 APPLE PARK WAY
CUPERTINO, CA 95014-2084

Prepared by
UL VERIFICATION SERVICES INC.
47173 BENICIA STREET
FREMONT, CA 94538, U.S.A.
TEL: (510) 319-4000
FAX: (510) 661-0888



Revision History

Rev.	Date	Revisions	Revised By
V1	8/12/2021	Initial Issue	--
V2	8/16/2021	Sections 7.1 and 7.2 – removed unsupported bands	Dave Weaver
V3	8/26/2021	Section 8 – Added TAS statement	Dave Weaver

Table of Contents

1. Attestation of Test Results.....	5
2. Test Methodology	6
3. Facilities and Accreditation	6
4. Calibration and Uncertainty	7
4.1. <i>Measuring Instrument Calibration</i>	7
4.2. <i>Measurement Uncertainty.....</i>	8
5. System Specifications.....	9
6. System Validation.....	10
6.1. <i>System Validation Results</i>	11
7. Average Antenna Input Power & Evaluation for Low-power Exemption.....	12
7.1. <i>ANT 1</i>	12
7.2. <i>ANT 2</i>	13
7.3. <i>ANT 3</i>	14
7.4. <i>ANT 4</i>	15
7.5. <i>ANT 5</i>	15
7.6. <i>ANT 6</i>	16
7.7. <i>ANT 7</i>	16
7.8. <i>ANT 8</i>	16
7.9. <i>ANT 9</i>	16
8. Device Under Test.....	17
8.1. <i>Time Average SAR considerations</i>	17
8.2. <i>Air Interfaces and Operating Mode</i>	18
9. Modulation Interference Factor (MIF)	19
10. HAC RF Emissions Test Procedure.....	21
11. RF Emissions Measurement Criteria.....	24
12. HAC (RF Emissions) Test Results	25
12.1. <i>ANT 1</i>	25
12.2. <i>ANT 2</i>	26
12.3. <i>ANT 3</i>	26
12.4. <i>ANT 4</i>	27
12.5. <i>ANT 5</i>	27
12.6. <i>ANT 7</i>	28
12.7. <i>ANT 8</i>	28

12.8. ANT 9	28
12.9. Worst Case RF Emission Test Plot	29
Appendices	30
Appendix A: RF-E Setup Photo	30
Appendix B: RF-E System Validation Plots	30
Appendix C: RF-E Test Plots	30
Appendix D: RF-E MIF Attestation Letter	30
Appendix E: RF-E Probe Certificates	30
Appendix F: RF-E Dipole Certificates	30
Appendix G: RF-E UID Specifications	30

1. Attestation of Test Results

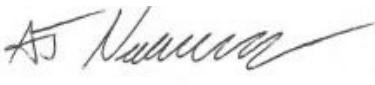
Applicant Name	APPLE, INC.
FCC ID	BCG-E4029A
Model Name	A2628
Applicable Standards	FCC 47 CFR § 20.19 ANSI C63.19-2011
HAC Rating	M3
Date Tested	6/15/2021 to 6/26/2021
Test Results	Pass

UL Verification Services Inc. tested the above equipment in accordance with the requirements set forth in the above standards. The test results show that the equipment tested is capable of demonstrating compliance with the requirements as documented in this report.

This report contains data provided by the customer which can impact the validity of results. UL Verification Services Inc. is only responsible for the validity of results after the integration of the data provided by the customer.

The results documented in this report apply only to the tested sample, under the conditions and modes of operation as described herein. It is the manufacturer's responsibility to assure that additional production units of this model are manufactured with identical electrical and mechanical components. All samples tested were in good operating condition throughout the entire test program. Measurement Uncertainties are published for informational purposes only and were not taken into account unless noted otherwise.

This document may not be altered or revised in any way unless done so by UL Verification Services Inc. and all revisions are duly noted in the revisions section. Any alteration of this document not carried out by UL Verification Services Inc. 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 A2LA, NIST, any agency of the Federal Government, or any agency of the U.S. government.

Approved & Released By:	Prepared By:
	

Devin Chang Senior Test Engineer UL Verification Services Inc.	AJ Newcomer Laboratory Engineer UL Verification Services Inc.
--	---

2. Test Methodology

The tests documented in this report were performed in accordance with ANSI C63.19-2011 Methods of Measurement of Compatibility between Wireless Communications Devices and Hearing Aids and FCC Published procedure

KDB 285076 D01 HAC Guidance v05r01

KDB 285076 D03 HAC FAQ v01r02

TCB workshop updates

3. Facilities and Accreditation

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

47173 Benicia Street
SAR Lab 1
SAR Lab 2

UL Verification Services Inc. is accredited by A2LA, Certificate Number 0751.05

The Test Lab Conformity Assessment Body Identifier (CABID)

Location	CABID	Company Number
47173 Benicia Street, Fremont, CA, 94538 UNITED STATES	US0104	2324A
47266 Benicia Street, Fremont, CA, 94538 UNITED STATES		22541

4. Calibration and Uncertainty

4.1. Measuring Instrument Calibration

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

Name of Equipment	Manufacturer	Type/Model	Serial No.	Cal. Due Date
Signal Generator	Keysight Technologies	N5181A-506	MY50140610	1/21/2022
Power Meter	Keysight Technologies	N1912A	MY50001018	1/21/2022
Power Sensor	Keysight Technologies	N1921A	MY53020038	1/28/2022
DC Power Supply	Ametek	XT15-4	1802A01877	N/A
Amplifier	Miteq	AMF-4D-00400600-50-30P	1795092	N/A
Signal Generator	Rohde & Schwarz	SMB100A03	180969	2/16/2022
3-Path Diode Power Sensor	Rohde & Schwarz	NRP18A	100992	2/16/2022
Signal Generator	Rohde & Schwarz	SMB100A03	180970	2/16/2022
Power Meter	Keysight Technologies	437B	3125U11347	1/26/2022
3-Path Diode Power Sensor	Rohde & Schwarz	NRP18A	100995	2/26/2022
Bi-Directional Coupler	Werlatone	C8060-102	4063	N/A
Data Acquisition Electronics (SAR 1)	SPEAG	DAE4	1352	11/17/2021
Data Acquisition Electronics (SAR 2)	SPEAG	DAE4	1377	9/10/2021
E-Field Probe (SAR 1)	SPEAG	EF3DV3	4041	3/22/2022
E-Field Probe (SAR 2)	SPEAG	EF3DV3	4028	7/22/2021
Calibration Dipole	SPEAG	CD835V3	1014	2/19/2022
Calibration Dipole	SPEAG	CD1880V3	1122	2/19/2022
Calibration Dipole	SPEAG	CD2450V3	1014	8/18/2021
Calibration Dipole	SPEAG	CD2600V3	1014	8/18/2021
Calibration Dipole	SPEAG	CD3500V3	1006	11/17/2021
Calibration Dipole	SPEAG	CD5500V3	1007	4/16/2022

Note(s):

1: According to SPEAG's Technical Report, "MIF Verification", Doc # TR-FB-12.09.04-1, issued date: 9/4/2012. E-field probes are calibrated with specified uncertainty according to ISO 17025 as described in their calibration certificate. The MIF according to the definition in ANSI C63.19 is specific for a modulation and can therefore be used as a constant value if the probe has been PMR calibrated.

4.2. Measurement Uncertainty

Error Description	Uncertainty value (±%)	Probe Dist.	Div.	(Ci) E	Std. Unc.(±%) E
Measurement System					
Probe Calibration	5.1	N	1	1	5.1
Axial Isotropy	4.7	R	1.732	1	2.7
Sensor Displacement	16.5	R	1.732	1	9.5
Boundary Effects	2.4	R	1.732	1	1.4
Phantom Boundary Effects	7.2	R	1.732	1	4.1
Linearity	4.7	R	1.732	1	2.7
Scaling to PMR Calibration	10.0	R	1.732	1	5.8
System Detection Limit	1.0	R	1.732	1	0.6
Readout Electronics	0.3	N	1	1	0.3
Response Time	0.8	R	1.732	1	0.5
Integration Time	2.6	R	1.732	1	1.5
RF Ambient Conditions	3.0	R	1.732	1	1.7
RF Reflections	12.0	R	1.732	1	6.9
Probe Positioner	1.2	R	1.732	1	0.7
Probe Positioning	4.7	R	1.732	1	2.7
Extrapolation and Interpolation	1.0	R	1.732	1	0.6
Test sample Related					
Test Positioning Vertical	4.7	R	1.732	1	2.7
Test Positioning Lateral	1.0	R	1.732	1	0.6
Device Holder and Phantom	2.4	R	1.732	1	1.4
Power Drift	5.0	R	1.732	1	2.9
Phantom and Setup Related					
Phantom Thickness	2.4	R	1.732	1	1.4
Combined Std. Uncertainty					16.3
Expanded Std. Uncertainty on Power (Coverage Factor for 95%, k = 2)					32.6
Expanded Std. Uncertainty on Field					16.3
Notes for table					
1. N - Nominal					
2. R - Rectangular					
3. Div. - Divisor used to obtain standard uncertainty					
4. Ci - is the sensitivity coefficient					

5. System Specifications

E-field measurements are performed using the DASY52 automated dosimetric assessment system. The DASY52 is made by Schmid & Partner Engineering AG (SPEAG) in Zurich, Switzerland.

The DASY52 HAC Extension consists of the following parts:

Test Arch Phantom

The specially designed Test Arch allows high precision positioning of both the device and any of the validation dipoles.

EF3DV3 Isotropic E-Field Probe

Construction:	One dipole parallel, two dipoles normal to probe axis Interleaved sensors Built-in shielding against static charges PEEK enclosure material
Calibration:	In air from 100 MHz to 3.0 GHz (absolute accuracy $\pm 6.0\%$, k=2) ISO/IEC 17025 <u>calibration service</u> available.
Frequency:	40 MHz – >6 GHz (can be extended to < 20 MHz); Linearity: ± 0.2 dB (100 MHz – 3 GHz)
Directivity:	± 0.2 dB in air (rotation around probe axis) ± 0.4 dB in air (rotation normal to probe axis)
Dynamic Range:	2 V/m to > 1000 V/m; 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: 1.5 mm Sensor displacement to probe's calibration point: <0.7 mm
Application:	General near-field measurements up to 6 GHz HAC measurements up to 6 GHz Field component measurements Fast automatic scanning in phantoms

6. System Validation

The test setup was validated when first configured and verified periodically thereafter to ensure proper function. The procedure provided in this section is a validation procedure using dipole antennas for which the field levels were computed by numeric modeling.

Procedure:

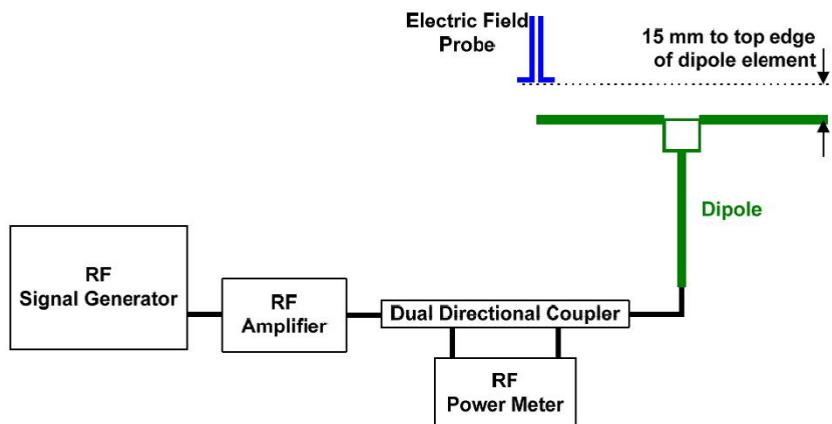
Place a dipole antenna meeting the requirements given in ANSI C63.19 in the normally occupied by the WD.

The dipole antenna serves as a known source for an electrical and magnetic output. Position the E-field probe so that the following occurs:

- The probes and their cables are parallel to the coaxial feed of the dipole antenna
- The probe cables and the coaxial feed of the dipole antenna approach the measurement area from opposite directions
- The center point of the probe element(s) is 15 mm from the closest surface of the dipole elements.

Scan the length of the dipole with the E-field probe and record the two maximum values found near the dipole ends. Average the two readings and compare the reading to the expected value in the calibration certificate or the expected value in this standard.

Setup diagram



6.1. System Validation Results

SAR Lab	Date	Dipole Type _Serial #_Freq.	Dipole Cal. Due Data	Max. measured from		Average max. above arm (V/m)	Target (V/m) (From SPEAG)	Deviation (note 1) ± %	Plot No.
				above high end (dBV/m)	above low end (dBV/m)				
1	6/17/2021	CD835V3_SN:1014_(835 MHz)	2/19/2022	41.12	40.94	112.60	107.40	4.84	1
1	6/17/2021	CD1880V3_SN:1122_(1880 MHz)	2/19/2022	38.00	38.39	81.26	86.00	-5.52	2
1	6/21/2021	CD835V3_SN:1014_(835 MHz)	2/19/2022	41.17	41.32	115.42	107.40	7.46	3
1	6/21/2021	CD1880V3_SN:1122_(1880 MHz)	2/19/2022	37.93	38.54	81.66	86.00	-5.04	4
2	6/15/2021	CD2450V3_SN:1014_(2450 MHz)	8/18/2021	39.27	38.95	90.28	85.80	5.22	5
2	6/15/2021	CD5500V3_SN:1007_(5500 MHz)	4/16/2022	39.00	38.91	88.67	102.20	-13.24	6
2	6/16/2021	CD2600V3_SN:1014_(2600 MHz)	8/18/2021	39.20	39.23	91.36	84.60	7.99	7
2	6/19/2021	CD3500V3_SN:1006_(3500 MHz)	11/17/2021	38.85	39.12	88.98	84.00	5.93	8
2	6/20/2021	CD835V3_SN:1014_(835 MHz)	2/19/2022	41.55	42.02	122.86	107.40	14.39	9
2	6/20/2021	CD1880V3_SN:1122_(1880 MHz)	2/19/2022	39.35	39.46	93.38	86.00	8.58	10
2	6/20/2021	CD2450V3_SN:1014_(2450 MHz)	8/18/2021	39.09	39.29	91.10	85.80	6.18	11
2	6/20/2021	CD5500V3_SN:1007_(5500 MHz)	4/16/2022	38.93	38.90	88.26	102.20	-13.64	12
2	6/24/2021	CD2450V3_SN:1014_(2450 MHz)	8/18/2021	39.25	38.88	89.81	85.80	4.68	13
2	6/24/2021	CD5500V3_SN:1007_(5500 MHz)	4/16/2022	38.95	39.00	88.87	102.20	-13.04	14

Notes:

- 1) Delta (Deviation) % = 100 * (Measured value minus Target value) divided by the Target value. Deltas within ±18% are acceptable, of which 12% is deviation and 13% is measurement uncertainty.
- 2) The maximum E-field or were evaluated and compared to the target values provided by SPEAG in the calibration certificate of specific dipoles.
- 3) Please refer to the appendix for detailed measurement data and plots.

7. Average Antenna Input Power & Evaluation for Low-power Exemption

An RF air interface technology of a device is exempt from testing when its average antenna input power plus its **MIF is \leq 17 dBm** for any of its operating modes. If a device supports multiple RF air interfaces, each RF air interface shall be evaluated individually.

7.1. ANT 1

Air-Interface	Antenna Input Power (dBm) ¹	Worst Case MIF (dB)	Input Power plus its MIF (dBm)	HAC Tested
GSM850	33.50	3.63	37.13	Yes
GSM1900	32.00	3.63	35.63	Yes
W-CDMA Band II	25.70	-27.23	-1.53	No
W-CDMA Band IV	25.70	-27.23	-1.53	No
W-CDMA Band V	25.70	-27.23	-1.53	No
CDMA BC0	22.50	3.26	25.76	Yes
CDMA BC1	25.70	3.26	28.96	Yes
CDMA BC10	25.70	3.26	28.96	Yes
LTE Band 2	25.70	-9.76	15.94	No
LTE Band 4	25.70	-9.76	15.94	No
LTE Band 5	25.70	-9.76	15.94	No
LTE Band 7	25.70	-9.76	15.94	No
LTE Band 12	25.70	-9.76	15.94	No
LTE Band 13	25.70	-9.76	15.94	No
LTE Band 17	25.70	-9.76	15.94	No
LTE Band 25	25.70	-9.76	15.94	No
LTE Band 26	25.70	-9.76	15.94	No
LTE Band 30	25.70	-9.76	15.94	No
LTE Band 41 (PC3)	25.70	-1.44	24.26	Yes
LTE Band 41 (PC2)	27.50	-1.44	26.06	Yes
LTE Band 66	25.70	-9.76	15.94	No
5G NR Band n2	25.70	-15.06	10.64	No
5G NR Band n5	25.70	-15.06	10.64	No
5G NR Band n7	25.70	-15.06	10.64	No
5G NR Band n12	25.70	-15.06	10.64	No
5G NR Band n25	25.70	-15.06	10.64	No
5G NR Band n30	25.70	-15.06	10.64	No
5G NR Band n41 (PC3)	25.70	-16.69	9.01	No
5G NR Band n41 (PC2) ²	24.70	-16.69	8.01	No
5G NR Band n66	25.70	-15.06	10.64	No

Notes:

1. Testing for all UL CA is not required because it uses same Tx band, modulations, and output power is equal or less than non-CA modes.
2. RF Emission Testing for PC2 is not required since the power is the same or less than PC3 equivalent.

7.2. ANT 2

Air-Interface	Antenna Input Power (dBm) ¹	Worst Case MIF (dB)	Input Power plus its MIF (dBm)	HAC Tested
GSM850	32.00	3.63	35.63	Yes
GSM1900	29.50	3.63	33.13	Yes
W-CDMA Band II	23.20	-27.23	-4.03	No
W-CDMA Band IV	23.20	-27.23	-4.03	No
W-CDMA Band V	24.70	-27.23	-2.53	No
CDMA BC0	22.00	3.26	25.26	Yes
CDMA BC1	23.20	3.26	26.46	Yes
CDMA BC10	24.70	3.26	27.96	Yes
LTE Band 2	23.20	-9.76	13.44	No
LTE Band 4	23.20	-9.76	13.44	No
LTE Band 5	24.70	-9.76	14.94	No
LTE Band 7	22.70	-9.76	12.94	No
LTE Band 12	24.70	-9.76	14.94	No
LTE Band 13	24.70	-9.76	14.94	No
LTE Band 17	24.70	-9.76	14.94	No
LTE Band 25	23.20	-9.76	13.44	No
LTE Band 26	24.70	-9.76	14.94	No
LTE Band 30	22.70	-9.76	12.94	No
LTE Band 41 (PC3)	24.50	-1.44	23.06	Yes
LTE Band 41 (PC2) ²	24.50	-1.44	N/A	No
LTE Band 66	23.20	-9.76	13.44	No
5G NR Band n2	23.20	-15.06	8.14	No
5G NR Band n5	24.70	-15.06	9.64	No
5G NR Band n7	22.70	-15.06	7.64	No
5G NR Band n12	24.70	-15.06	9.64	No
5G NR Band n25	23.20	-15.06	8.14	No
5G NR Band n30	22.70	-15.06	7.64	No
5G NR Band n41 (PC3)	25.70	-16.69	9.01	No
5G NR Band n41 (PC2)	27.70	-16.69	11.01	No
5G NR Band n66	23.20	-15.06	8.14	No

Notes:

1. Testing for all UL CA is not required because it uses same Tx band, modulations, and output power is equal or less than non-CA modes.
2. RF Emission Testing for PC2 is not required since the power is the same or less than PC3 equivalent.

7.3. ANT 3

Air-Interface	Antenna Input Power (dBm) ¹	Worst Case MIF (dB)	Input Power plus its MIF (dBm)	HAC Tested
GSM1900	31.00	3.63	34.63	Yes
W-CDMA Band II	25.20	-27.23	-2.03	No
W-CDMA Band IV	25.20	-27.23	-2.03	No
LTE Band 2	25.20	-9.76	15.44	No
LTE Band 4	25.20	-9.76	15.44	No
LTE Band 7	25.20	-9.76	15.44	No
LTE Band 25	25.20	-9.76	15.44	No
LTE Band 30	22.30	-9.76	12.54	No
LTE Band 41 (PC3)	25.20	-1.44	23.76	Yes
LTE Band 41 (PC2)	27.00	-1.44	25.56	Yes
LTE Band 66	25.20	-9.76	15.44	No
5G NR Band n2	25.20	-15.06	10.14	No
5G NR Band n7	25.20	-15.06	10.14	No
5G NR Band n25	25.20	-15.06	10.14	No
5G NR Band n30	22.30	-15.06	7.24	No
5G NR Band n41 (PC3)	24.70	-16.69	8.01	No
5G NR Band n41 (PC2) ²	24.70	-16.69	N/A	No
5G NR Band n66	25.20	-15.06	10.14	No
802.11b (2.4 GHz)	21.50	-2.02	19.48	Yes
802.11g (2.4 GHz)	21.50	0.12	21.62	Yes
802.11ax (2.4 GHz)	21.50	-5.58	15.92	No

Notes:

1. Testing for all UL CA is not required because it uses same Tx band, modulations, and output power is equal or less than non-CA modes.
2. RF Emission Testing for PC2 is not required since the power is the same or less than PC3 equivalent.

7.4. ANT 4

Air-Interface	Antenna Input Power (dBm) ¹	Worst Case MIF (dB)	Input Power plus its MIF (dBm)	HAC Tested
GSM1900	29.00	3.63	32.63	Yes
W-CDMA Band II	23.20	-27.23	-4.03	No
W-CDMA Band IV	23.20	-27.23	-4.03	No
LTE Band 2	23.20	-9.76	13.44	No
LTE Band 4	23.20	-9.76	13.44	No
LTE Band 7	22.70	-9.76	12.94	No
LTE Band 25	23.20	-9.76	13.44	No
LTE Band 30	22.70	-9.76	12.94	No
LTE Band 41 (PC3)	24.50	-1.44	23.06	Yes
LTE Band 41 (PC2) ²	24.50	-1.44	N/A	No
LTE Band 48	22.50	-1.44	21.06	Yes
LTE Band 66	23.20	-9.76	13.44	No
5G NR Band n2	23.20	-15.06	8.14	No
5G NR Band n7	22.70	-15.06	7.64	No
5G NR Band n25	23.20	-15.06	8.14	No
5G NR Band n30	22.70	-16.69	6.01	No
5G NR Band n41 (PC3)	25.70	-16.69	9.01	No
5G NR Band n41 (PC2)	27.20	-16.69	10.51	No
5G NR Band n66	23.20	-15.06	8.14	No
5G NR Band n77 (PC3)	24.00	-16.69	7.31	No
5G NR Band n77 (PC2)	24.20	-16.69	7.51	No
802.11b	19.75	-2.02	17.73	Yes
802.11g	19.75	0.12	19.87	Yes
802.11ax	19.75	-5.58	14.17	No

Notes:

1. Testing for all UL CA is not required because it uses same Tx band, modulations, and output power is equal or less than non-CA modes.
2. RF Emission Testing for PC2 is not required since the power is the same or less than PC3 equivalent.

7.5. ANT 5

Air-Interface	Antenna Input Power (dBm)	Worst Case MIF (dB)	Input Power plus its MIF (dBm)	HAC Tested
802.11a/n/ac (U-NII-1)	20.50	-3.15	17.35	Yes
802.11a/n/ac (U-NII-2A)	20.50	-3.15	17.35	Yes
802.11a/n/ac (U-NII-2C)	20.50	-3.15	17.35	Yes
802.11a/n/ac (U-NII-3)	21.50	-3.15	18.35	Yes
802.11ax (U-NII-1)	20.50	-5.58	14.92	No
802.11ax (U-NII-2A)	20.50	-5.58	14.92	No
802.11ax (U-NII-2C)	20.50	-5.58	14.92	No
802.11ax (U-NII-3)	21.50	-5.58	15.92	No

7.6. ANT 6

Air-Interface	Antenna Input Power (dBm)	Worst Case MIF (dB)	Input Power plus its MIF (dBm)	HAC Tested
802.11a/n/ac (U-NII-1)	19.50	-3.15	16.35	No
802.11a/n/ac (U-NII-2A)	19.00	-3.15	15.85	No
802.11a/n/ac (U-NII-2C)	18.00	-3.15	14.85	No
802.11a/n/ac (U-NII-3)	18.75	-3.15	15.6	No
802.11ax (U-NII-1)	19.50	-5.58	13.92	No
802.11ax (U-NII-2A)	19.00	-5.58	13.42	No
802.11ax (U-NII-2C)	18.00	-5.58	12.42	No
802.11ax (U-NII-3)	18.75	-5.58	13.17	No

7.7. ANT 7

Air-Interface	Antenna Input Power (dBm) ¹	Worst Case MIF (dB)	Input Power plus its MIF (dBm)	HAC Tested
LTE Band 48	25.70	-1.44	24.26	Yes
5G NR Band n77 (PC3)	25.70	-16.69	9.01	No
5G NR Band n77 (PC2)	27.70	-16.69	11.01	No

Notes:

1. Testing for all UL CA is not required because it uses same Tx band, modulations, and output power is equal or less than non-CA modes.

S

7.8. ANT 8

Air-Interface	Antenna Input Power (dBm) ¹	Worst Case MIF (dB)	Input Power plus its MIF (dBm)	HAC Tested
LTE Band 48	23.00	-1.44	21.56	Yes
5G NR Band n77 (PC3)	24.00	-16.69	7.31	No
5G NR Band n77 (PC2)	24.20	-16.69	7.51	No

Notes:

1. Testing for all UL CA is not required because it uses same Tx band, modulations, and output power is equal or less than non-CA modes.

7.9. ANT 9

Air-Interface	Antenna Input Power (dBm) ¹	Worst Case MIF (dB)	Input Power plus its MIF (dBm)	HAC Tested
LTE Band 48	25.20	-1.44	23.76	Yes
5G NR Band n77 (PC3)	25.70	-16.69	9.01	No
5G NR Band n77 (PC2)	27.20	-16.69	10.51	No

Notes:

1. Testing for all UL CA is not required because it uses same Tx band, modulations, and output power is equal or less than non-CA modes.

8. Device Under Test

The Apple iPhone is a smartphone with multimedia functions (music, application support, and video), cellular GSM, GPRS, EGPRS, UMTS, LTE, 5G, CDMA, IEEE 802.11a/b/g/n/ac/ax, Bluetooth, Ultra-Wideband, GPS, and NFC. All models support at least one UICC based SIM. The second SIM is either an UICC based p-SIM (physical SIM) or e-SIM (electronic SIM). The device supports a built-in inductive charging transmitter and receiver. The rechargeable battery is not user accessible

Normal operation	Held to head
Back Cover	Normal Battery Cover

8.1. Time Average SAR considerations

The DUT supports Time Average SAR (TAS) for both WWAN and WLAN. TAS was disabled during HAC testing. The WWAN and WLAN transmitters were configured to operate continuously at the maximum specified output power during testing.

8.2. Air Interfaces and Operating Mode

Air Interface	Bands (MHz)	Type	C63.19 Tested	Simultaneous Transmitter	Name of Voice Service	Power Reduction		
GSM	850	VO	Yes	Wi-Fi, BT	CMRS	N/A		
	1900					No		
	GPRS/EDGE	DT/VD	No ¹	Wi-Fi, BT	FaceTime	N/A		
W-CDMA (UMTS)	850	VO	No	Wi-Fi, BT	CMRS	N/A		
	1700							
	1900							
	HSPA	VD	No	Wi-Fi, BT	FaceTime	N/A		
CDMA	800	VO	Yes	Wi-Fi, BT	CMRS	N/A		
	1900							
	EVDO	VD	No	Wi-Fi, BT	FaceTime	N/A		
LTE - FDD	600 (B71)	VD	No	Wi-Fi, BT	FaceTime	N/A		
	700 (B12/13/14/17)							
	850 (B5/26)							
	1700 (B4/66)							
	1900 (B2/25)							
	2300 (B30)							
	2600 (B7)							
LTE - TDD	2500 (B41)	VD	Yes	Wi-Fi, BT	FaceTime	N/A		
	3600 (B48)							
5G NR(FR1) FDD	600 (n71)	VD	No	Wi-Fi, BT	FaceTime	N/A		
	700 (n12)							
	850 (n5)							
	1700 (n66)							
	1900 (n2/n25)							
	2300 (n30)							
	2600 (n7)							
5G NR(FR1) TDD	2500 (n41)	VD	No	Wi-Fi, BT	FaceTime	N/A		
	3700 (n77)							
Wi-Fi	2450	VD	Yes	WWAN	FaceTime	N/A		
	5200 (U-NII-1)			WWAN & BT				
	5300 (U-NII-2A)							
	5500 (U-NII-2C)							
	5800 (U-NII-3)							
BT	2450	DT	NA ¹	WWAN, Wi-Fi (5 GHz bands)	NA	N/A		
Type	Note:							
VO: Legacy Cellular Voice Service	1. Evaluated for MIF and low power exemption.							
DT: Digital Transport only (no voice)								
VD: IP Voice Service over Digital Transport								
CMRS: Commercial Mobile Radio Service								

9. Modulation Interference Factor (MIF)

The HAC Standard ANSI C63.19 defines a new scaling using the Modulation Interference Factor (MIF) which replaces the need for the Articulation Weighting Factor (AWF) during the evaluation and is applicable to any modulation scheme.

The Modulation Interference factor (MIF, in dB) is added to the measured average E-field (in dBV/m) and converts it to the RF Audio Interference level (in dBV/m). This level considers the audible amplitude modulation components in the RF E-field. CW fields without amplitude modulation are assumed to not interfere with the hearing aid electronics. Modulations without time slots and low fluctuations at low frequencies have low MIF values, TDMA modulations with narrow transmission and repetition rates of few 100 Hz have high MIF values and give similar classifications as ANSI C63.19.

Definitions

E-field probes have a bandwidth <10 kHz and can therefore not evaluate the RF envelope in the full audio band. DASY52 is therefore using the “indirect” measurement method according to ANSI C63.19 which is the primary method. These near field probes read the averaged E-field measurement. Especially for the new high peak-to-average (PAR) signal types, the probes shall be linearized by probe modulation response (PMR) calibration in order to not overestimate the field reading.

The evaluation method or the MIF is defined in ANSI C63.19 section D.7. An RMS demodulated RF signal is fed to a spectral filter (similar to an A weighting filter) and forwarded to a temporal filter acting as a quasi-peak detector. The averaged output of these filtering is called to a 1 kHz 80% AM signal as reference. MIF measurement requires additional instrumentation and is not well suited for evaluation by the end user with reasonable uncertainty. It may alternatively be determined through analysis and simulation, because it is constraint and characteristic for a communication signal. DASY52 uses well defined signals for PMR calibration. The MIF of these signals has been determined by simulation and is automatically applied.

MIF values were not tested by a probe or as specified in the standards but are based on analysis provided by SPEAG for all the air interfaces (GSM, WCDMA, CDMA, LTE, and Wi-Fi). The data included in this report are for the worst case operating modes. The UIDs used are listed below:

UID	Communication System Name	MIF (dB)
10021-DAC	GSM-FDD (TDMA, GMSK)	3.63
10011-CAB	UMTS-FDD (WCDMA)	-27.23
10295-AAB	CDMA2000 (1xRTT, RC1, SO3, 1/8 th Rate 25 fr.)	3.26
10170-CAE	LTE-FDD (SC-FDMA, 1 RB, 20 MHz, 16QAM)	-9.76
10182-CAE	LTE-FDD (SC-FDMA, 1 RB, 15 MHz, 16QAM)	-9.76
10176-CAF	LTE-FDD (SC-FDMA, 1 RB, 10 MHz, 16QAM)	-9.76
10173-CAF	LTE-TDD (SC-FDMA, 1 RB, 20 MHz, 16QAM)	-1.44
10061-CAB	IEEE 802.11b WiFi 2.4 GHz (DSSS, 11 Mbps)	-2.02
10077-CAB	IEEE 802.11g WiFi 2.4 GHz (DSSS/OFDM, 54 Mbps)	0.12
10069-CAC	IEEE 802.11a/n WiFi 5 GHz (OFDM, 54 Mbps)	-3.15
10671-AAA	IEEE 802.11ax (20MHz, MCS0, 90pc duty cycle)	-5.58
10866-AAC	5G NR (DFT-s-OFDM, 1 RB, 100 MHz, QPSK, 30 kHz)	-16.69
10903-AAA	5G NR (DFT-s-OFDM, 1 RB, 40 MHz, QPSK, 30 kHz)	-16.68
10929-AAA	5G NR (DFT-s-OFDM, 1 RB, 10 MHz, QPSK, 15 kHz)	-15.06
10930-AAA	5G NR (DFT-s-OFDM, 1 RB, 15 MHz, QPSK, 15 kHz)	-15.06
10931-AAA	5G NR (DFT-s-OFDM, 1 RB, 20 MHz, QPSK, 15 kHz)	-15.06
10934-AAA	5G NR (DFT-s-OFDM, 1 RB, 40 MHz, QPSK, 15 kHz)	-15.07

A PMR calibrated probe is linearized for the selected waveform over the full dynamic range within the uncertainty specified in its calibration certificate. E-field probes have a bandwidth <10 kHz and can therefore not evaluate the RF envelope in the full audio band. DASY52 is therefore using the "indirect" measurement method according to ANSI C63.19 which is the primary method. These near field probes read the averaged E-field measurement. Especially for the new high peak-to-average (PAR) signal types, the probes shall be linearized by PMR calibration in order to not overestimate the field reading.

The MIF measurement uncertainty is estimated as follows, for modulation frequencies from slotted waveforms with fundamental frequency and at least 2 harmonics within 10 kHz:

- 0.2 dB for MIF -7 to +5 dB,
- 0.5 dB for MIF -13 to +11 dB
- 1 dB for MIF > -20 dB

10. HAC RF Emissions Test Procedure

The following are step-by-step test procedures.

- a) Confirm proper operation of the field probe, probe measurement system and other instrumentation and the positioning system.
- b) Position the WD in its intended test position.
- c) Set the WD to transmit a fixed and repeatable combination of signal power and modulation characteristic that is representative of the worst case (highest interference potential) encountered in normal use. Transiently occurring start-up, changeover, or termination conditions, or other operations likely to occur less than 1% of the time during normal operation, may be excluded from consideration.
- d) The center sub-grid shall be centered on the T-Coil mode perpendicular measurement point or the acoustic output, as appropriate. Locate the field probe at the initial test position in the 50 mm by 50 mm grid, which is contained in the measurement plane, refer to illustrated in Figure 1. If the field alignment method is used, align the probe for maximum field reception.
- e) Record the reading at the output of the measurement system
- f) Scan the entire 50 mm by 50 mm region in equally spaced increments and record the reading at each measurement point. The distance between measurement points shall be sufficient to assure the identification of the maximum reading.
- g) Identify the five contiguous sub-grids around the center sub-grid whose maximum reading is the lowest of all available choices. This eliminates the three sub-grids with the maximum readings. Thus, the six areas to be used to determine the WD's highest emissions are identified.
- h) Identify the maximum reading within the non-excluded sub-grids identified in step g).
- i) Convert the highest field reading within identified in step h) to RF audio interference level, in V/m, by taking the square root of the reading and then dividing it by the measurement system transfer function, established in 5.5.1.1 Convert this result to dB(V/m) by taking the base-10 logarithm and multiplying by 20.

Indirect measurement method

Replacing step i), the RF audio interference level in dB (V/m) is obtained by adding the MIF (in dB) to the maximum steady-state rms field-strength reading, in dB (V/m), from step h). Use this result to determine the category rating

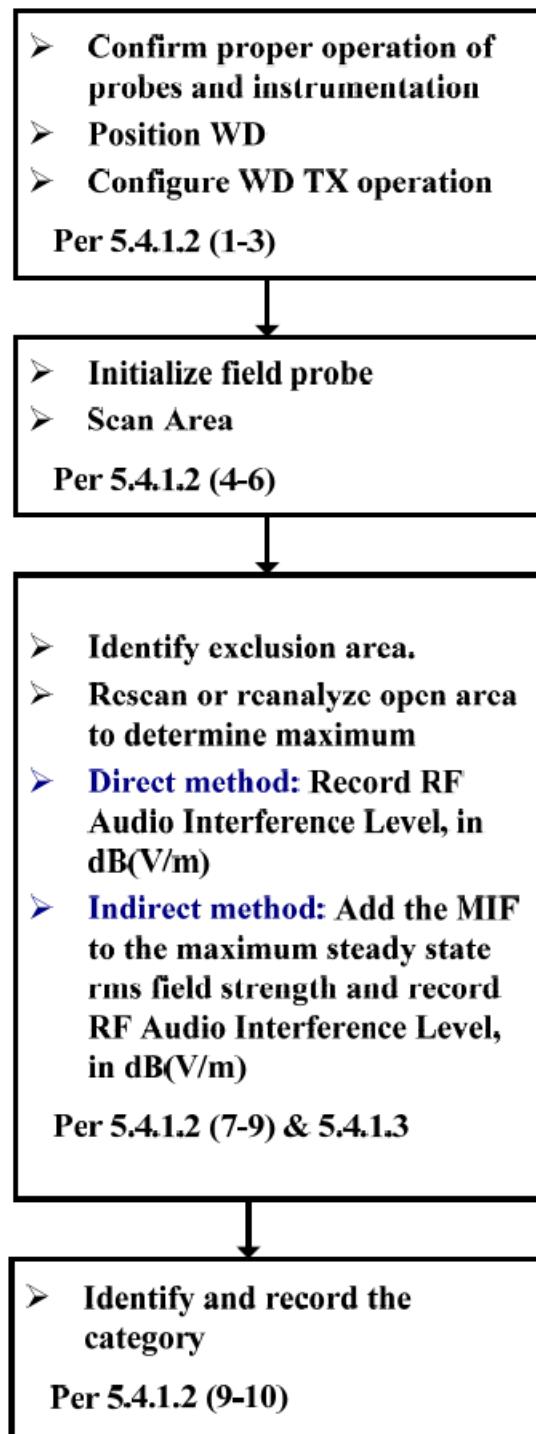
- j) Compare this RF audio interference level with the categories in Clause 8 (ANSI C63.19) and record the resulting WD category rating
- k) For the T-Coil mode M-rating assessment, determine whether the chosen perpendicular measurement point is contained in an included sub-grid of the first scan. If so, then a second scan is not necessary. The first scan and resultant category rating may be used for the T-Coil mode M rating.

Otherwise, repeat step a) through step i), with the grid shifted so that it is centered on the perpendicular measurement point. Record the WD category rating.



Figure 1 - WD reference and plane for RF emission measurements

Test flowchart Per ANSI-63.19-2011



11. RF Emissions Measurement Criteria

WD RF audio interference level categories in logarithmic units

Emission Categories	E-field emissions	
	< 960 MHz	> 960 MHz
Category M1	50 to 55 dB (V/m)	40 to 45 dB (V/m)
Category M2	45 to 50 dB (V/m)	35 to 40 dB (V/m)
Category M3	40 to 45 dB (V/m)	30 to 35 dB (V/m)
Category M4	<40 dB (V/m)	<30 dB (V/m)

12. HAC (RF Emissions) Test Results

MIF values were not tested by a probe or as specified in the standards but are based on analysis provided by SPEAG for the following User Identifiers and air interfaces.

The data included in this report are for the worst case operating modes. Refer to Appendix D and G for the MIF values that represent the worst case operation modes.

Refer to Section 7 Evaluation for Low-power Exemption. RF Emission testing for this device is required only for GSM, CDMA, LTE-TDD, 5G NR (FR1), Wi-Fi and Bluetooth. All other applicable air-interfaces are exempt from testing in accordance with C63.19 Clause 4.4 and are rated M4.

12.1. ANT 1

Air-Interface	Ch. No.	Freq. (MHz)	Results* (dB V/m)	Results plus 0.2dB uncertainty (dB V/m)	Margin (dB)	M-Rating	Plots Page #
GSM850	128	824.40	34.78	34.98	5.02	M4	1
	190	836.60	35.59	35.79	4.21	M4	2
	251	848.60	35.34	35.54	4.46	M4	3
GSM1900	512	1850.20	25.06	25.26	4.74	M4	4
	661	1880.00	23.96	24.16	5.84	M4	5
	810	1909.80	25.25	25.45	4.55	M4	6
CDMA2000 BC0	1013	824.70	24.60	24.80	15.20	M4	7
	384	836.60	23.42	23.62	16.38	M4	8
	777	848.31	23.95	24.15	15.85	M4	9
CDMA2000 BC1	25	1851.25	17.56	17.76	12.24	M4	10
	600	1880.00	18.33	18.53	11.47	M4	11
	1175	1908.75	18.24	18.44	11.56	M4	12
CDMA2000 BC10	450	817.30	23.82	24.02	15.98	M4	13
	560	820.00	23.38	23.58	16.42	M4	14
	670	822.75	23.75	23.95	16.05	M4	15
LTE-TDD Band 41	39750	2506.00	19.44	19.64	10.36	M4	16
	40185	2549.50	20.64	20.84	9.16	M4	17
	40620	2593.00	21.79	21.99	8.01	M4	18
	41055	2636.50	22.27	22.47	7.53	M4	19
	41490	2680.00	22.07	22.27	7.73	M4	20
LTE-TDD Band 41 Power Class 2 [27pwr]	39750	2506.00	20.65	20.85	9.15	M4	21
	40185	2549.50	21.64	21.84	8.16	M4	22
	40620	2593.00	23.05	23.25	6.75	M4	23
	41055	2636.50	23.42	23.62	6.38	M4	24
	41490	2680.00	23.09	23.29	6.71	M4	25

Note(s):

*: Measured Audio Interference level in dB (V/m): indirect method (max rms field strength Plus MIF)

12.2. ANT 2

Air-Interface	Ch. No.	Freq. (MHz)	Results* (dB V/m)	Results plus 0.2dB uncertainty (dB V/m)	Margin (dB)	M-Rating	Plots Page #
GSM850	128	824.40	40.05	40.25	4.75	M3	26
	190	836.60	39.78	39.98	0.02	M4	27
	251	848.60	40.01	40.21	4.79	M3	28
GSM1900	512	1850.20	33.31	33.51	1.49	M3	29
	661	1880.00	32.98	33.18	1.82	M3	30
	810	1909.80	32.25	32.45	2.55	M3	31
CDMA2000 BC0	1013	824.70	33.18	33.38	6.62	M4	32
	384	836.60	33.45	33.65	6.35	M4	33
	777	848.31	33.43	33.63	6.37	M4	34
CDMA2000 BC1	25	1851.25	28.67	28.87	1.13	M4	35
	600	1880.00	28.21	28.41	1.59	M4	36
	1175	1908.75	27.41	27.61	2.39	M4	37
CDMA2000 BC10	450	817.30	32.90	33.10	6.90	M4	38
	560	820.00	33.05	33.25	6.75	M4	39
	670	822.75	33.17	33.37	6.63	M4	40
LTE-TDD Band 41	39750	2506.00	28.62	28.82	1.18	M4	41
	40185	2549.50	29.63	29.83	0.17	M4	42
	40620	2593.00	30.67	30.87	4.13	M3	43
	41055	2636.50	30.63	30.83	4.17	M3	44
	41490	2680.00	29.72	29.92	0.08	M4	45

Note(s):

*: Measured Audio Interference level in dB (V/m): indirect method (max rms field strength Plus MIF)

12.3. ANT 3

Air-Interface	Ch. No.	Freq. (MHz)	Results* (dB V/m)	Results plus 0.2dB uncertainty (dB V/m)	Margin (dB)	M-Rating	Plots Page #
GSM1900	512	1850.20	27.24	27.44	2.56	M4	46
	661	1880.00	27.43	27.63	2.37	M4	47
	810	1909.80	26.85	27.05	2.95	M4	48
LTE-TDD Band 41	39750	2506.00	23.07	23.27	6.73	M4	49
	40185	2549.50	23.18	23.38	6.62	M4	50
	40620	2593.00	23.64	23.84	6.16	M4	51
	41055	2636.50	24.01	24.21	5.79	M4	52
	41490	2680.00	24.77	24.97	5.03	M4	53
LTE-TDD Band 41 Power Class 2 [27pwr]	39750	2506.00	21.76	21.96	8.04	M4	54
	40185	2549.50	22.31	22.51	7.49	M4	55
	40620	2593.00	24.48	24.68	5.32	M4	56
	41055	2636.50	24.17	24.37	5.63	M4	57
	41490	2680.00	24.57	24.77	5.23	M4	58
802.11b	2	2417.00	16.90	17.10	12.90	M4	59
	6	2437.00	16.40	16.60	13.40	M4	60
	11	2462.00	16.48	16.68	13.32	M4	61
802.11g	3	2422.00	18.52	18.72	11.28	M4	62
	6	2437.00	18.18	18.38	11.62	M4	63
	9	2452.00	18.58	18.78	11.22	M4	64

Note(s):

*: Measured Audio Interference level in dB (V/m): indirect method (max rms field strength Plus MIF)

12.4. ANT 4

Air-Interface	Ch. No.	Freq. (MHz)	Results* (dB V/m)	Results plus 0.2dB uncertainty (dB V/m)	Margin (dB)	M-Rating	Plots Page #
GSM1900	512	1850.20	29.79	29.99	0.01	M4	65
	661	1880.00	29.62	29.82	0.18	M4	66
	810	1909.80	29.92	30.12	4.88	M3	67
LTE-TDD Band 41	39750	2506.00	23.88	24.08	5.92	M4	68
	40185	2549.50	23.34	23.54	6.46	M4	69
	40620	2593.00	22.57	22.77	7.23	M4	70
	41055	2636.50	22.66	22.86	7.14	M4	71
	41490	2680.00	22.19	22.39	7.61	M4	72
LTE-TDD Band 48	55340	3560.00	24.40	24.60	5.40	M4	73
	55773	3603.30	24.58	24.78	5.22	M4	74
	56207	3646.70	23.85	24.05	5.95	M4	75
	56640	3690.00	23.18	23.38	6.62	M4	76
802.11b	2	2417.00	18.42	18.62	11.38	M4	77
	6	2437.00	16.40	16.60	13.40	M4	78
	11	2462.00	17.12	17.32	12.68	M4	79
802.11g	3	2422.00	19.49	19.69	10.31	M4	80
	6	2437.00	17.78	17.98	12.02	M4	81
	9	2452.00	19.04	19.24	10.76	M4	82

Note(s):

*: Measured Audio Interference level in dB (V/m): indirect method (max rms field strength Plus MIF)

12.5. ANT 5

Air-Interface	Ch. No.	Freq. (MHz)	Results* (dB V/m)	Results plus 0.2dB uncertainty (dB V/m)	Margin (dB)	M-Rating	Plots Page #
802.11a (5.2 GHz)	40	5200.00	7.16	7.36	22.64	M4	83
	44	5220.00	7.03	7.23	22.77	M4	84
	48	5240.00	6.44	6.64	23.36	M4	85
802.11a (5.3 GHz)	52	5260.00	9.13	9.33	20.67	M4	86
	56	5280.00	8.54	8.74	21.26	M4	87
	60	5300.00	9.73	9.93	20.07	M4	88
802.11a (5.5 GHz)	104	5520.00	9.35	9.55	20.45	M4	89
	124	5620.00	6.96	7.16	22.84	M4	90
	144	5720.00	9.24	9.44	20.56	M4	91
802.11a (5.8 GHz)	149	5745.00	7.40	7.60	22.40	M4	92
	157	5785.00	7.85	8.05	21.95	M4	93
	165	5825.00	10.19	10.39	19.61	M4	94

Note(s):

*: Measured Audio Interference level in dB (V/m): indirect method (max rms field strength Plus MIF)

12.6. ANT 7

Air-Interface	Ch. No.	Freq. (MHz)	Results* (dB V/m)	Results plus 0.2dB uncertainty (dB V/m)	Margin (dB)	M-Rating	Plots Page #
LTE-TDD Band 48	55340	3560.00	15.97	16.17	13.83	M4	95
	55773	3603.30	16.06	16.26	13.74	M4	96
	56207	3646.70	15.41	15.61	14.39	M4	97
	56640	3690.00	15.57	15.77	14.23	M4	98

Note(s):

*: Measured Audio Interference level in dB (V/m): indirect method (max rms field strength Plus MIF)

12.7. ANT 8

Air-Interface	Ch. No.	Freq. (MHz)	Results* (dB V/m)	Results plus 0.2dB uncertainty (dB V/m)	Margin (dB)	M-Rating	Plots Page #
LTE-TDD Band 48	55340	3560.00	28.71	28.91	1.09	M4	99
	55773	3603.30	29.56	29.76	0.24	M4	100
	56207	3646.70	29.74	29.94	0.06	M4	101
	56640	3690.00	29.58	29.78	0.22	M4	102

Note(s):

*: Measured Audio Interference level in dB (V/m): indirect method (max rms field strength Plus MIF)

12.8. ANT 9

Air-Interface	Ch. No.	Freq. (MHz)	Results* (dB V/m)	Results plus 0.2dB uncertainty (dB V/m)	Margin (dB)	M-Rating	Plots Page #
LTE-TDD Band 48	55340	3560.00	16.60	16.80	13.20	M4	103
	55773	3603.30	15.98	16.18	13.82	M4	104
	56207	3646.70	15.56	15.76	14.24	M4	105
	56640	3690.00	14.86	15.06	14.94	M4	106

Note(s):

*: Measured Audio Interference level in dB (V/m): indirect method (max rms field strength Plus MIF)

12.9. Worst Case RF Emission Test Plot

Test Laboratory: UL Verification Services Inc. SAR Lab 2

Date/Time: 6/23/2021 4:13:32 PM

HAC-RF Emission

Communication System: UID 10021 - CAA, GSM-FDD (TDMA, GMSK); Frequency: 1850.2 MHz; Duty Cycle: 1:8.6896

Phantom section: RF Section

DASY5 Configuration:

- Probe: EF3DV3 - SN4028; ConvF(1, 1, 1) @ 1850.2 MHz; Calibrated: 7/22/2020
- Sensor-Surface: (Fix Surface)
- Electronics: DAE4 Sn1377; Calibrated: 9/10/2020
- Phantom: HAC Test Arch with AMCC; Type: SD HAC P01 BB
- Measurement SW: DASY52, Version 52.10 (4); SEMCAD X Version 14.6.14 (7483)

GSM1900 E-Field measurement/Voice_ch 512/Hearing Aid Compatibility Test

(101x101x1): Interpolated grid: dx=0.5000 mm, dy=0.5000 mm

Device Reference Point: 0, 0, -6.3 mm

Reference Value = 33.24 V/m; Power Drift = 0.02 dB

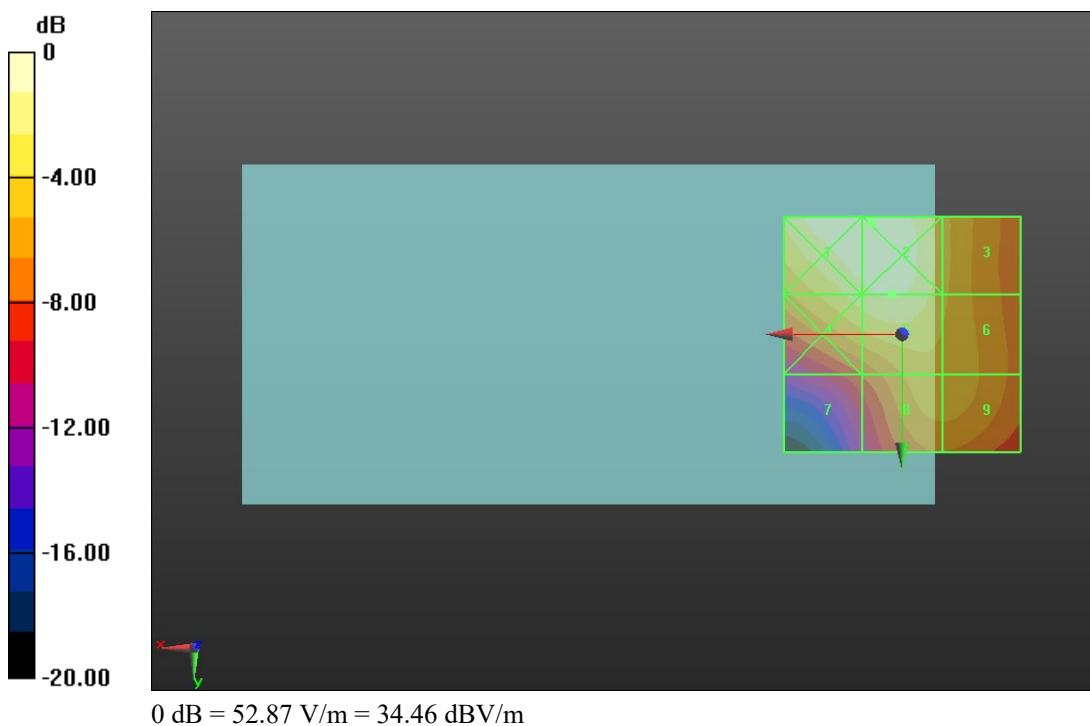
Applied MIF = 3.63 dB

RF audio interference level = 33.31 dBV/m

Emission category: M3

MIF scaled E-field

Grid 1 M3 34.44 dBV/m	Grid 2 M3 34.46 dBV/m	Grid 3 M3 31.1 dBV/m
Grid 4 M3 32.61 dBV/m	Grid 5 M3 33.31 dBV/m	Grid 6 M3 30.87 dBV/m
Grid 7 M4 26.58 dBV/m	Grid 8 M3 30.13 dBV/m	Grid 9 M3 30.11 dBV/m



Appendices

Refer to separated files for the following appendixes

Appendix A: RF-E Setup Photo

Appendix B: RF-E System Validation Plots

Appendix C: RF-E Test Plots

Appendix D: RF-E MIF Attestation Letter

Appendix E: RF-E Probe Certificates

Appendix F: RF-E Dipole Certificates

Appendix G: RF-E UID Specifications

END OF REPORT