HAC RF EMISSIONS TEST REPORT

FCC 47 CFR § 20.19
ANSI C63.19-2011

For
SMARTPHONE

FCC ID: BCG-E3305A
Model Name: A2160, A2216, and A2217

Report Number: 12607346-S4V2
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NVLAP LAB CODE 200065-0

Revision History

Rev.	Date	Revisions	Revised By
V1	8/2/2019	Initial Issue	--
V2	8/17/2019	1. Section 6.1: Updated table 2. Section 7.4: Updated W-CDMA B4, LTE B4/30/66 power 3. Section 12.4: re-measured LTE B48 4. Appendix B and C updated	Devin Chang

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1. Attestation of Test Results

Applicant Name	APPLE, INC.
FCC ID	BCG-E3305A
Model Name	A2160, A2216, and A2217
Difference in Model Name	Model A2216, A2217 is electrically identical to Model A2160. Three model numbers are allocated for marketing and logistic purposes only.
Applicable Standards	FCC 47 CFR § 20.19 ANSI C63.19-2011
HAC Rating	M3
Date Tested	6/22/2019 to 6/29/2019
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.

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 NVLAP, 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.	Chakrit Thammanavarat Senior Test Engineer UL Verification Services Inc.

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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 abd FCC Published procedure

KDB 285076 D01 HAC Guidance v05
KDB 285076 D03 HAC FAQ v01
TCB workshop updates

3. Facilities and Accreditation

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

47266 Benicia Street	47266 Benicia Street
SAR Lab 7	SAR Lab 8

UL Verification Services Inc. is accredited by NVLAP, Laboratory Code 200065-0.

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	R &S	SMB100A	180968-gX	2/14/2020
Power Sensor	R &S	NRP18A	100995-hs	2/15/2020
Data Acquisition Electronics (SAR 7)	SPEAG	DAE4	1352	11/6/2019
Data Acquisition Electronics (SAR 8)	SPEAG	DAE4	1540	2/18/2020
E-Field Probe[1]	SPEAG	EF3DV3	4041	3/22/2020
Calibration Dipole	SPEAG	CD835V3	1175	5/16/2020
Calibration Dipole	SPEAG	CD1880V3	1159	5/16/2020
Calibration Dipole	SPEAG	CD2450V3	1014	2/19/2020
Calibration Dipole[3]	SPEAG	CD2600V3	1008	7/10/2019
Calibration Dipole	SPEAG	CD2600V3	1014	8/22/2019
Calibration Dipole[2]	SPEAG	CD3500V3	1006	5/2/2020
Calibration Dipole	SPEAG	CD5500V3	1008	5/14/2020
Radio Communication Tester	R &S	CMW 500	132910-cp	2/18/2020

Notes:

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.

2: In accordance with KDB 865664 §3.2.2 reference dipoles need only be returned to the system manufacturer for calibration every three years. The dipole target, impedance and return loss must be checked at least yearly by the test laboratory and compared to the calibration certificate. If any of these parameters deviate by more than that permitted by KDB 865664 then the dipole shall be withdrawn from use and return to the manufacturer for immediate re-calibration. Refer to Appendix E of this report for both the calibration certificates and the in-house checks (where appropriate).

3: Equipment not used past calibration due date.

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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**

Notesfor table
1. N - Nomal
2. R - Rectangular
3. Div. - Divisor used to obtain standard uncertainty
4. Ci - is te sensitivity coefficient

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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 ±6.0%, k=2) ISO/IEC 17025 calibration service 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

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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:

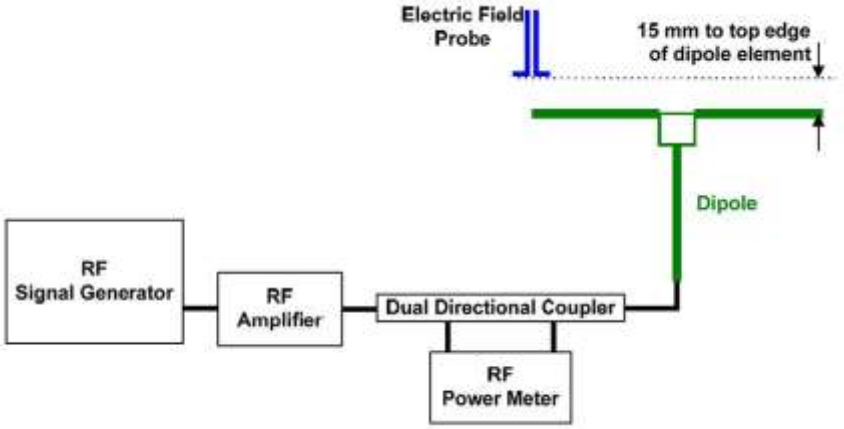
Place a dipole antenna meeting the requirements given in ANSI C63.19 in the normally occupied by the WD.

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



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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 (V/m)	above low end (V/m)				
8	6/22/2019	CD835V3_SN:1175_(835 MHz)	5/16/2020	99.03	122.70	110.87	105.80	4.79	1
8	6/22/2019	CD1880V3_SN:1159_(1880 MHz)	5/16/2020	79.33	84.47	81.90	86.20	-4.99	2
8	6/22/2019	CD2600V3_SN:1008_(2600 MHz)	7/10/2019	83.84	79.39	81.62	86.20	-5.32	3
8	6/22/2019	CD2450V3_SN:1014_(2450 MHz)	2/19/2020	91.94	94.33	93.14	85.20	9.31	4
8	6/22/2019	CD5500V3_SN:1008_(5500 MHz)	5/14/2020	106.60		106.60	99.10	7.57	5
7	6/28/2019	CD1880V3_SN:1159_(1880 MHz)	5/16/2020	92.55	96.65	94.60	86.20	9.74	6
7	6/28/2019	CD2600V3_SN:1014_(2600 MHz)	8/22/2019	94.39	96.51	95.45	87.20	9.46	7
7	6/28/2019	CD3500V3_SN:1006_(3500 MHz)	5/2/2020	87.90	88.44	88.17	85.10	3.61	8
7	8/17/2019	CD3500V3_SN:1006_(3500 MHz)	5/2/2020	87.62	88.22	87.92	85.10	3.31	9

Notes:

1) Delta (Deviation) % = 100 * (Measured value minus Target value) divided by the Target value. Deltas within ±25% 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.

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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(Max tune-up limit) plus its **MIF is ≤17 dBm** for any of its operating modes. If a device supports multiple RF air interfaces, each RF air interface shall be evaluated individually.

Power measurements were performed in accordance to the device's two power modes, Mode A and Mode B for each antenna. Mode A power is used when the device is used against the user's head or away from the body. Mode B power is used when the device is used in a Body-worn configuration by the user.
The selection between antennas ANT1, ANT2, ANT3, ANT4, ANT5, and ANT6 in the application is based on RSSI based antenna selection. The full details of power selections are described in the operational description.

7.1. ANT1

Air-Interface	Average Antenna Input Power (dBm)	Worst Case MIF (dB)	Input Power plus its MIF (dBm)	HAC Tested
GSM850	33.25	3.63	36.88	Yes
GSM1900	31.75	3.63	35.38	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	25.70	3.26	28.96	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 14	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	28.70	-1.44	27.26	Yes
LTE Band 48	25.70	-1.44	24.26	Yes
LTE Band 66	25.70	-9.76	15.94	No
LTE Band 71	25.70	-9.76	15.94	No
LTE CA_5B[1]	25.00	-9.76	15.24	No
LTE CA_7C[1]	25.00	-9.76	15.24	No
LTE CA_41C PC3[1]	25.00	-1.44	23.56	No
LTE CA_41C PC2[1]	27.00	-1.44	25.56	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.

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7.2. ANT2

Air-Interface	Average Antenna Input Power (dBm)	Worst Case MIF (dB)	Input Power plus its MIF (dBm)	HAC Tested
GSM850	31.75	3.63	35.38	Yes
GSM1900	29.25	3.63	32.88	Yes
W-CDMA Band II	20.50	-27.23	-6.73	No
W-CDMA Band IV	22.00	-27.23	-5.23	No
W-CDMA Band V	24.50	-27.23	-2.73	No
CDMA BC0	24.50	3.26	27.76	Yes
CDMA BC1	20.50	3.26	23.76	Yes
CDMA BC10	24.50	3.26	27.76	Yes
LTE Band 2	20.50	-9.76	10.74	No
LTE Band 4	22.00	-9.76	12.24	No
LTE Band 5	24.50	-9.76	14.74	No
LTE Band 7	18.75	-9.76	8.99	No
LTE Band 12	24.50	-9.76	14.74	No
LTE Band 13	24.50	-9.76	14.74	No
LTE Band 14	24.50	-9.76	14.74	No
LTE Band 17	24.50	-9.76	14.74	No
LTE Band 25	20.50	-9.76	10.74	No
LTE Band 26	24.50	-9.76	14.74	No
LTE Band 30	21.00	-9.76	11.24	No
LTE Band 41 PC3	20.00	-1.44	18.56	Yes
LTE Band 41 PC2[2]	20.00	-1.44	18.56	No
LTE Band 66	22.00	-9.76	12.24	No
LTE Band 71	24.50	-9.76	14.74	No
LTE CA_5B[1]	23.50	-9.76	13.74	No
LTE CA_7C[1]	18.75	-9.76	8.99	No
LTE CA_41C PC3[1]	20.00	-1.44	18.56	No
LTE CA_41C PC2[1]	20.00	-1.44	18.56	No

Notes:

1. Testing for ULCA is not required because it uses same Tx band, modulations, and output power is equal or less than non-CA modes.
2. LTE band 41 PC2 testing is not required because PC2 has the same power limit but a lower duty cycle than PC3.

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7.3. ANT3

Air-Interface	Average Antenna Input Power (dBm)	Worst Case MIF (dB)	Input Power plus its MIF (dBm)	HAC Tested
GSM1900	32.00	3.63	35.63	Yes
W-CDMA Band II	25.00	-27.23	-2.23	No
W-CDMA Band IV	25.00	-27.23	-2.23	No
LTE Band 2	25.00	-9.76	15.24	No
LTE Band 4	25.00	-9.76	15.24	No
LTE Band 7	25.00	-9.76	15.24	No
LTE Band 25	25.00	-9.76	15.24	No
LTE Band 30	24.50	-9.76	14.74	No
LTE Band 41 PC3	25.50	-1.44	24.06	Yes
LTE Band 41 PC2	28.00	-1.44	26.56	Yes
LTE Band 48	25.50	-1.44	24.06	Yes
LTE Band 66	25.00	-9.76	15.24	No
LTE CA_7C[1]	24.50	-9.76	14.74	No
LTE CA_41C PC3[1]	24.50	-1.44	23.06	No
LTE CA_41C PC2[1]	26.50	-1.44	25.06	No
802.11b	21.50	-2.02	19.48	Yes
802.11g/n/ac	21.50	0.12	21.62	Yes
802.11ax	21.50	-5.58	15.92	No

Notes:

1. LTE band 41 PC2 testing is not required because PC2 has the same power limit but a lower duty cycle than PC3.

7.4. ANT4

Air-Interface	Average Antenna Input Power (dBm)	Worst Case MIF (dB)	Input Power plus its MIF (dBm)	HAC Tested
GSM1900	28.00	3.63	31.63	Yes
W-CDMA Band II	18.75	-27.23	-8.48	No
W-CDMA Band IV	21.00	-27.23	-6.23	No
LTE Band 2	18.75	-9.76	8.99	No
LTE Band 4	21.00	-9.76	11.24	No
LTE Band 7	17.00	-9.76	7.24	No
LTE Band 25	18.75	-9.76	8.99	No
LTE Band 30	17.50	-9.76	7.74	No
LTE Band 41 PC3	19.25	-1.44	17.81	Yes
LTE Band 41 PC2[2]	19.25	-1.44	17.81	No
LTE Band 48	22.50	-1.44	21.06	Yes
LTE Band 66	21.00	-9.76	11.24	No
LTE CA_7C[1]	17.00	-9.76	7.24	No
LTE CA_41C PC3[1]	19.25	-1.44	17.81	No
LTE CA_41C PC2[1]	19.25	-1.44	17.81	No
802.11b	17.00	-2.02	14.98	No
802.11g/n/ac	17.00	0.12	17.12	Yes
802.11ax	17.00	-5.58	11.42	No

Notes:

1. Testing for ULCA is not required because it uses same Tx band, modulations, and output power is equal or less than non-CA modes.
2. LTE band 41 PC2 testing is not required because PC2 has the same power limit but a lower duty cycle than PC3.

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7.5. ANT5

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

7.6. ANT6

Air-Interface	Average Antenna Input Power (dBm)	Worst Case MIF (dB)	Input Power plus its MIF (dBm)	HAC Tested
LTE Band 48	22.50	-1.44	21.06	Yes
802.11a/n/ac (U-NII-1)	21.50	-3.15	18.35	Yes
802.11a/n/ac (U-NII-2A)	20.75	-3.15	17.6	Yes
802.11a/n/ac (U-NII-2C)	21.50	-3.15	18.35	Yes
802.11a/n/ac (U-NII-3)	21.50	-3.15	18.35	Yes
802.11ax (U-NII-1)	21.50	-5.58	15.92	No
802.11ax (U-NII-2A)	20.75	-5.58	15.17	No
802.11ax (U-NII-2C)	21.50	-5.58	15.92	No
802.11ax (U-NII-3)	21.50	-5.58	15.92	No

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8. Device Under Test

The Apple iPhone is a smartphone with multimedia functions (music, application support, and video), cellular GSM, GPRS, EGPRS, UMTS, LTE, TD-SCDMA, CDMA, IEEE 802.11a/b/g/n/ac/ax, Bluetooth, Ultra-Wide band, GPS and NFC. All models support at least one UICC based SIM. The second SIM, if present, is either UICC based pSIM (physical SIM) or e-SIM (electronic SIM). The device has a built-in inductive charging receiver. The rechargeable battery is also not user accessible.

ANT1 (all WWAN bands) - located at the lower of the device.

ANT2 (all WWAN bands except for LTE Band 48) - located at the upper of the device.

ANT3 (all WWAN bands above 1700 MHz and Wi-Fi 2.4 GHz and Bluetooth) – located at lower left corner of the device. CDMA BC1 is not supported by this antenna.

ANT4 (all WWAN bands above 1700 MHz and Wi-Fi 2.4 GHz and Bluetooth) – located at upper right corner of the device. CDMA BC1 is not supported by this antenna.

ANT5 (Wi-Fi 5 GHz Bands) – located at lower left corner of the device.

ANT6 (LTE Band 48 and Wi-Fi 5 GHz Bands) – located at upper left corner of the device.

Normal operation	Held to head
Back Cover	The Back Cover is not removable

8.1. 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	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)					
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	No	WWAN, Wi-Fi 5GHz	NA	N/A

Type
VO: Legacy Cellular Voice Service
DT: Digital Transport only (no voice)
VD: IP Voice Service over Digital Transport
CMRS: Commercial Mobile Radio Service

Note:
1. Evaluated for MIF and low power exemption.

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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). 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, 1/8th 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
10178-CAF	LTE-FDD (SC-FDMA, 1 RB, 5 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
10030-CAA	IEEE 802.15.1 Bluetooth (GFSK, DH1)	1.02
10671-AAA	IEEE 802.11ax (20MHz, MCS0, 90pc duty cycle)	-5.58

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.

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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*

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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.

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Figure 1 - WD reference and plane for RF emission measurements

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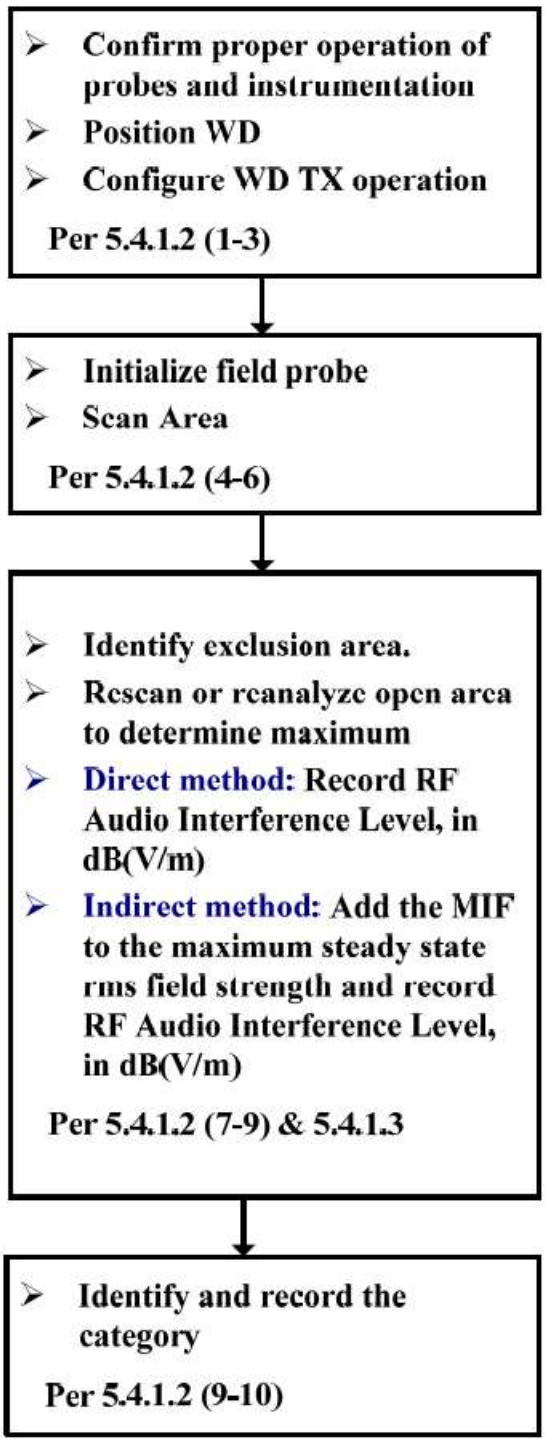
Test flowchart Per ANSI-63.19-2011



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11. RF Emissions Measurement Criteria

WD RF audio interference level caterories 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)

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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 vales 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 voice modes, LTE-TDD, 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. ANT1

Air-Interface	Ch. No.	Freq. (MHz)	Results* (dB V/m)	Results plus 0.2dB uncertaninty (dB V/m)	Margin (dB)	M-Rating	Plots Page #
GSM850	128	824.2	28.91	29.11	10.89	M4	1
	190	836.6	29.10	29.30	10.70	M4	2
	251	848.8	30.26	30.46	9.54	M4	3
GSM1900	512	1850.2	26.57	26.77	3.23	M4	4
	661	1880	27.60	27.80	2.20	M4	5
	810	1909.8	29.15	29.35	0.65	M4	6
CDMA2000 BC0	1013	824.7	25.60	25.80	14.20	M4	7
	384	836.52	27.44	27.64	12.36	M4	8
	777	848.31	28.40	28.60	11.40	M4	9
CDMA2000 BC1	25	1851.25	24.28	24.48	5.52	M4	10
	600	1880	24.59	24.79	5.21	M4	11
	1175	1908.75	24.69	24.89	5.11	M4	12
CDMA2000 BC10	450	817.3	29.05	29.25	10.75	M4	13
	560	820	28.93	29.13	10.87	M4	14
	670	822.75	29.20	29.40	10.60	M4	15
LTE-TDD Band 41 Power Class 3	39750	2506	23.12	23.32	6.68	M4	16
	40185	2549.5	22.57	22.77	7.23	M4	17
	40620	2593	23.16	23.36	6.64	M4	18
	41055	2636.5	22.45	22.65	7.35	M4	19
	41490	2680	20.93	21.13	8.87	M4	20
LTE-TDD Band 41 Power Class 2	39750	2506	23.64	23.84	6.16	M4	21
	40185	2549.5	22.80	23.00	7.00	M4	22
	40620	2593	23.08	23.28	6.72	M4	23
	41055	2636.5	22.51	22.71	7.29	M4	24
	41490	2680	19.69	19.89	10.11	M4	25
LTE-TDD Band 48	55340	3560	23.38	23.58	6.42	M4	26
	55773	3603.3	22.43	22.63	7.37	M4	27
	56207	3646.7	22.76	22.96	7.04	M4	28
	56640	3690	22.46	22.66	7.34	M4	29

Note(s):

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

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12.2. ANT2

Air-Interface	Ch. No.	Freq. (MHz)	Results* (dB V/m)	Results plus 0.2dB uncertaninty (dB V/m)	Margin (dB)	M-Rating	Plots Page #
GSM850	128	824.2	36.48	36.68	3.32	M4	30
	190	836.6	36.56	36.76	3.24	M4	31
	251	848.8	39.24	39.44	0.56	M4	32
GSM1900	512	1850.2	30.77	30.97	4.03	M3	33
	661	1880	30.47	30.67	4.33	M3	34
	810	1909.8	29.75	29.95	0.05	M4	35
CDMA2000 BC0	1013	824.7	29.67	29.87	10.13	M4	36
	384	836.6	30.25	30.45	9.55	M4	37
	777	848.31	31.49	31.69	8.31	M4	38
CDMA2000 BC1	25	1851.25	25.41	25.61	4.39	M4	39
	600	1880	24.50	24.70	5.30	M4	40
	1175	1908.75	23.22	23.42	6.58	M4	41
CDMA2000 BC10	450	817.3	29.25	29.45	10.55	M4	42
	560	820	29.56	29.76	10.24	M4	43
	670	822.75	29.77	29.97	10.03	M4	44
LTE-TDD Band 41 Power Class 3	39750	2506	22.91	23.11	6.89	M4	45
	40185	2549.5	22.53	22.73	7.27	M4	46
	40620	2593	21.77	21.97	8.03	M4	47
	41055	2636.5	20.40	20.60	9.40	M4	48
	41490	2680	20.17	20.37	9.63	M4	49

Note(s):

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

12.3. ANT3

Air-Interface	Ch. No.	Freq. (MHz)	Results* (dB V/m)	Results plus 0.2dB uncertaninty (dB V/m)	Margin (dB)	M-Rating	Plots Page #
GSM1900	512	1850.20	31.43	31.63	3.37	M3	50
	661	1880.00	31.15	31.35	3.65	M3	51
	810	1909.80	31.54	31.74	3.26	M3	52
LTE-TDD Band 41 Power Class 3	39750	2506.00	19.09	19.29	10.71	M4	53
	40185	2549.50	21.30	21.50	8.50	M4	54
	40620	2593.00	20.98	21.18	8.82	M4	55
	41055	2636.50	19.14	19.34	10.66	M4	56
	41490	2680.00	19.15	19.35	10.65	M4	57
LTE-TDD Band 41 Power Class 2	39750	2506.00	18.93	19.13	10.87	M4	58
	40185	2549.50	20.93	21.13	8.87	M4	59
	40620	2593.00	20.78	20.98	9.02	M4	60
	41055	2636.50	19.09	19.29	10.71	M4	61
	41490	2680.00	19.25	19.45	10.55	M4	62
LTE-TDD Band 48	55340	3560	20.71	20.91	9.09	M4	63
	55773	3603.3	20.31	25.58	4.42	M4	64
	56207	3646.7	21.90	22.10	7.90	M4	65
	56640	3690	22.12	22.32	7.68	M4	66
802.11b	2	2417.00	25.38	25.58	4.42	M4	67
	6	2437.00	24.12	24.32	5.68	M4	68
	11	2462.00	23.71	23.91	6.09	M4	69
802.11g	3	2422.00	26.67	26.87	3.13	M4	70
	6	2437.00	25.93	26.13	3.87	M4	71
	9	2452.00	26.58	26.78	3.22	M4	72

Note(s):

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

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12.4. ANT4

Air-Interface	Ch. No.	Freq. (MHz)	Results* (dB V/m)	Results plus 0.2dB uncertaninty (dB V/m)	Margin (dB)	M-Rating	Plots Page #
GSM1900	512	1850.20	31.15	31.35	3.65	M3	73
	661	1880.00	31.58	31.78	3.22	M3	74
	810	1909.80	31.77	31.97	3.03	M3	75
LTE-TDD Band 41 Power Class 3	39750	2506.00	22.27	22.47	7.53	M4	76
	40185	2549.50	21.34	21.54	8.46	M4	77
	40620	2593.00	20.87	21.07	8.93	M4	78
	41055	2636.50	20.12	20.32	9.68	M4	79
	41490	2680.00	19.44	19.64	10.36	M4	80
LTE-TDD Band 41 Power Class 2	39750	2506.00	20.97	21.17	8.83	M4	81
	40185	2549.50	19.74	19.94	10.06	M4	82
	40620	2593.00	19.45	19.65	10.35	M4	83
	41055	2636.50	19.24	19.44	10.56	M4	84
	41490	2680.00	17.80	18.00	12.00	M4	85
LTE-TDD Band 48	55340	3560.00	20.76	20.96	9.04	M4	86
	55773	3603.30	25.18	25.38	4.62	M4	87
	56207	3646.70	25.46	25.66	4.34	M4	88
	56640	3690.00	22.24	22.44	7.56	M4	89
802.11b	2	2417.00	32.24	32.44	2.56	M3	90
	6	2437.00	30.93	31.13	3.87	M3	91
	11	2462.00	32.06	32.26	2.74	M3	92
802.11g	3	2422.00	34.57	34.77	0.23	M3	93
	6	2437.00	32.65	32.85	2.15	M3	94
	9	2452.00	32.62	32.82	2.18	M3	95

Note(s):

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

12.5. ANT5

Air-Interface	Ch. No.	Freq. (MHz)	Results* (dB V/m)	Results plus 0.2dB uncertaninty (dB V/m)	Margin (dB)	M-Rating	Plots Page #
802.11a (5.2 GHz)	40	5200	15.09	15.29	14.71	M4	96
	44	5220	13.20	13.40	16.60	M4	97
	48	5240	14.70	14.90	15.10	M4	98
802.11a (5.3 GHz)	52	5260	13.64	13.84	16.16	M4	99
	56	5280	14.23	14.43	15.57	M4	100
	60	5300	14.25	14.45	15.55	M4	101
802.11a (5.5 GHz)	104	5520	13.98	14.18	15.82	M4	102
	124	5620	14.27	14.47	15.53	M4	103
	144	5720	15.55	15.75	14.25	M4	104
802.11a (5.8 GHz)	149	5745	15.37	15.57	14.43	M4	105
	157	5785	16.19	16.39	13.61	M4	106
	165	5825	17.11	17.31	12.69	M4	107

Note(s):

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

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12.6. ANT6

Air-Interface	Ch. No.	Freq. (MHz)	Results* (dB V/m)	Results plus 0.2dB uncertaninty (dB V/m)	Margin (dB)	M-Rating	Plots Page #
LTE-TDD Band 48	55340	3560.00	21.32	21.52	8.48	M4	108
	55773	3603.30	22.51	22.71	7.29	M4	109
	56207	3646.70	22.27	22.47	7.53	M4	110
	56640	3690.00	22.10	22.30	7.70	M4	111
802.11a (5.2 GHz)	40	5200	23.46	23.66	6.34	M4	112
	44	5220	24.15	24.35	5.65	M4	113
	48	5240	24.81	25.01	4.99	M4	114
802.11a (5.3 GHz)	52	5260	25.88	26.08	3.92	M4	115
	56	5280	26.21	26.41	3.59	M4	116
	60	5300	26.07	26.27	3.73	M4	117
802.11a (5.5 GHz)	104	5520	27.52	27.72	2.28	M4	118
	124	5620	27.05	27.25	2.75	M4	119
	144	5720	26.33	26.53	3.47	M4	120
802.11a (5.8 GHz)	149	5745	25.99	26.19	3.81	M4	121
	157	5785	25.44	25.64	4.36	M4	122
	165	5825	24.64	24.84	5.16	M4	123

Note(s):

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

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12.7. Worst Case RF Emission Test Plot

Test Laboratory: UL Verification Services Inc. SAR Lab 8 Date: 6/24/2019

HAC-RF Emission

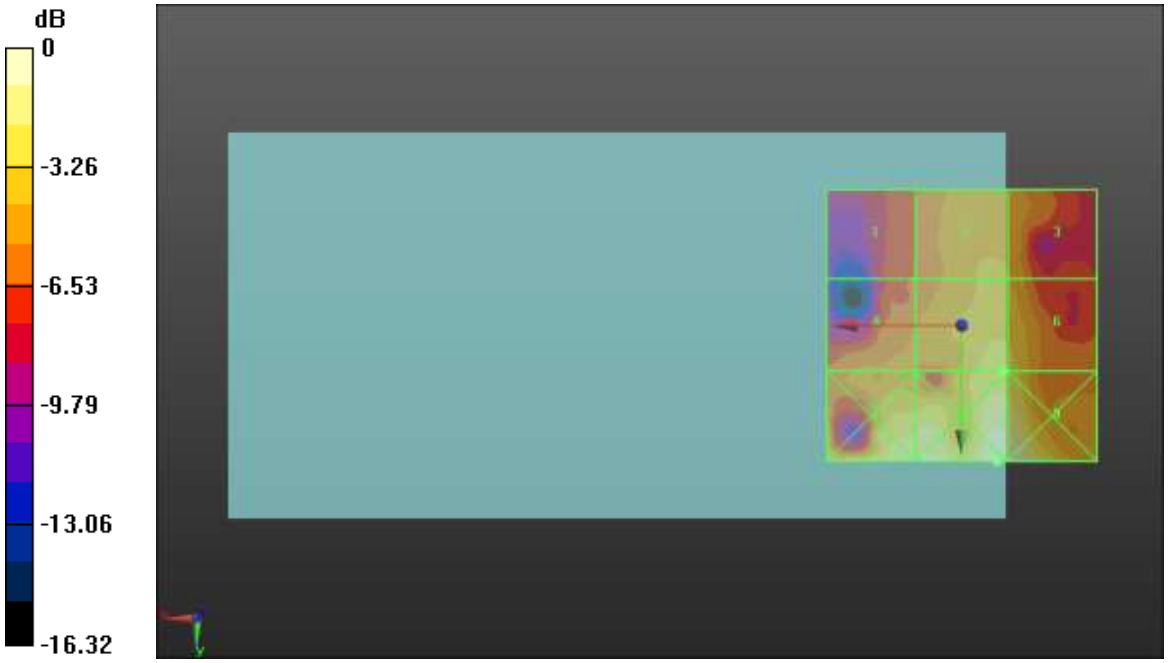
Communication System: UID 10077 - CAB, IEEE 802.11g WiFi 2.4 GHz (DSSS/OFDM, 54 Mbps); Frequency: 2422 MHz; Duty Cycle: 1:12.5893
Phantom section: RF Section
DASY5 Configuration:
- Probe: EF3DV3 - SN4041; ConvF(1, 1, 1); Calibrated: 3/22/2019;
- Sensor-Surface: (Fix Surface)
- Electronics: DAE4 Sn1540; Calibrated: 2/18/2019
- Phantom: HAC Test Arch with AMCC; Type: SD HAC P01 BB
- Measurement SW: DASY52, Version 52.8 (7);SEMCAD X Version 14.6.10 (7164)

802.11g E-Field measurement/IEEE 802.11g_OFDM 54 Mbps_ch 3/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 = 66.09 V/m; Power Drift = -0.03 dB
Applied MIF = 0.12 dB
RF audio interference level = 34.57 dBV/m
Emission category: M3

MIF scaled E-field

Grid 1 **M3** **30.97 dBV/m**	Grid 2 **M3** **33.11 dBV/m**	Grid 3 **M3** **33.03 dBV/m**
Grid 4 **M3** **32.3 dBV/m**	Grid 5 **M3** **34.57 dBV/m**	Grid 6 **M3** **34.48 dBV/m**
Grid 7 **M2** **36.34 dBV/m**	Grid 8 **M2** **37.26 dBV/m**	Grid 9 **M2** **37.01 dBV/m**



0 dB = 72.93 V/m = 37.26 dBV/m

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Appendixes

Refer to separated files for the following appendixes

Appendix A: HAC RF Emission Setup Photo

Appendix B: System Validation Plots

Appendix C: HAC RF Emission Test Plots

Appendix D: MIF Attestation Letter

Appendix E: Probe Calibration Certificates

Appendix F: Dipole Calibration Certificates

Appendix G: UID Specifications

END OF REPORT

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