

HEARING AID COMPATIBILITY

Applicant Name:

Samsung Electronics Co., Ltd.
129, Samsung-ro, Maetan dong,
Yeongtong-gu, Suwon-si
Gyeonggi-do 16677, Korea

Date of Testing:

04/20/2016

Test Site/Location:

PCTEST Lab, Columbia, MD, USA

Test Report Serial No.:

0Y1604190819.A3L

FCC ID:

A3LSMG935US

APPLICANT:

SAMSUNG ELECTRONICS CO., LTD.

Scope of Test:

RF Emissions Testing

Application Type:

Class II Permissive Change

FCC Rule Part(s):

CFR §20.19(b)

HAC Standard:

ANSI C63.19-2011

CTIA Test Plan for Hearing Aid Compatibility Rev 3.0, November 2013

EUT Type:

Portable Handset

Model(s):

SM-G935V, SM-G935A, SM-G935T, SM-G935R4, SM-G935P

Test Device Serial No.:

Pre-Production Sample [S/N: 73576]

Class II Permissive Change(s):

See FCC Change Document

Original Grant Date:

02/03/2016

C63.19-2011 HAC Category: M4 (RF EMISSIONS CATEGORY)

This report pertains only to the WLAN modes supported by the device. This wireless portable device has been shown to be hearing aid compatible for WLAN air interfaces, under the above rated category, specified in ANSI/IEEE Std. C63.19-2011 and has been tested in accordance with the specified measurement procedures. Test results reported herein relate only to the item(s) tested. Hearing-Aid Compatibility is based on the assumption that all production units will be designed electrically identical to the device tested in this report. North American Bands only.

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.


Randy Ortanez
President



FCC ID: A3LSMG935US		HAC (RF EMISSIONS) TEST REPORT		Reviewed by: Quality Manager
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1. INTRODUCTION

On July 10, 2003, the Federal Communications Commission (FCC) adopted new rules requiring wireless manufacturers and service providers to provide digital wireless phones that are compatible with hearing aids. The FCC has modified the exemption for wireless phones under the Hearing Aid Compatibility Act of 1998 (HAC Act) in WT Docket 01-309 RM-8658¹ to extend the benefits of wireless telecommunications to individuals with hearing disabilities. These benefits encompass business, social and emergency communications, which increase the value of the wireless network for everyone. An estimated more than 10% of the population in the United States show signs of hearing impairment and of that fraction, almost 80% use hearing aids. Approximately 500 million people worldwide suffer from hearing loss.

Compatibility Tests Involved:

The standard calls for wireless communications devices to be measured for:

- RF Electric-field emissions
- T-coil mode, magnetic-signal strength in the audio band
- T-coil mode, magnetic-signal frequency response through the audio band
- T-coil mode, magnetic-signal and noise articulation index

The hearing aid must be measured for:

- RF immunity in microphone mode
- RF immunity in T-coil mode

In the following tests and results, this report includes the evaluation for a wireless communications device.

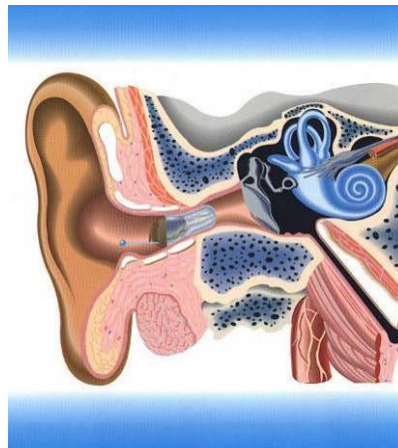


Figure 1-1 Hearing Aid *in-vitu*

¹ FCC Rule & Order, WT Docket 01-309 RM-8658

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3. EUT DESCRIPTION



FCC ID: A3LSMG935US
 Manufacturer: Samsung Electronics Co., Ltd.
 129, Samsung-ro, Maetan dong,
 Yeongtong-gu, Suwon-si
 Gyeonggi-do 16677, Korea
 Model(s): SM-G935V, SM-G935A, SM-G935T, SM-G935R4, SM-G935P
 Serial Number: 73576
 Antenna Configurations: Internal Antenna
 EUT Type: Portable Handset

Air-Interface	Band (MHz)	Type Transport	HAC Tested	Simultaneous But Not Tested	Voice over Digital Transport OTT Capability	WiFi Low Power	Additional GSM Power Reduction
GSM	850	VO	No ²	Yes: WiFi or BT	N/A	N/A	No
	1900	VO	No ²	Yes: WiFi or BT	N/A	N/A	No
	GPRS/EDGE	DT	No	Yes: WiFi	Yes	N/A	No
UMTS	850	VD	No ²	Yes: WiFi or BT	N/A	N/A	N/A
	1900	VD	No ²	Yes: WiFi or BT	N/A	N/A	N/A
	HSPA	DT	No	Yes: WiFi or BT	Yes	N/A	N/A
CDMA	835	VO	No ²	Yes: WiFi or BT	N/A	N/A	N/A
	1900	VO	No ²	Yes: WiFi or BT	N/A	N/A	N/A
	EVDO	DT	No	Yes: WiFi or BT	Yes	N/A	N/A
LTE (FDD)	780 (B13)	VD ³	No ²	Yes: WiFi or BT	Yes	N/A	N/A
	850 (B5)						
	1700 (B4)						
	1900 (B2)						
	2450						
WiFi	5200	VD	No ¹	Yes: CDMA, GSM, UMTS, or LTE	Yes	N/A	N/A
	5300						
	5500						
	5800						
	5800						
BT	2450	DT	No	Yes: CDMA, GSM Voice, UMTS, or LTE	N/A	N/A	N/A

Type Transport
 VO = Voice Only
 DT = Digital Data - Not intended for CMRS Service
 VD = CMRS and Data Transport

Notes:
 1. Evaluated for MIF and low-power exemption.
 2. CDMA, GSM, UMTS and LTE air interfaces are not within the scope of this test report. Please refer to the Original Certification Test Report.
 3. The 3GPP VoLTE CMRS service is defined by GSMA in PRD IR.92 for IP Voice Service and Digital Transport.

Table 3-1: SM-G935V HAC Air Interfaces

Air-Interface	Band (MHz)	Type Transport	HAC Tested	Simultaneous But Not Tested	Voice over Digital Transport OTT Capability	WiFi Low Power	Additional GSM Power Reduction
GSM	850	VO	No ²	Yes: WiFi or BT	N/A	N/A	No
	1900	VO	No ²	Yes: WiFi or BT	N/A	N/A	No
	GPRS/EDGE	DT	No	Yes: WiFi	Yes	N/A	No
UMTS	850	VD	No ²	Yes: WiFi or BT	N/A	N/A	N/A
	1700	VD	No ²	Yes: WiFi or BT	N/A	N/A	N/A
	1900	VD	No ²	Yes: WiFi or BT	N/A	N/A	N/A
LTE (FDD)	HSPA	DT	No	Yes: WiFi or BT	Yes	N/A	N/A
	700 (B12)	VD ³	No ²	Yes: WiFi or BT	Yes	N/A	N/A
	850 (B5)						
	1700 (B4)						
	1900 (B2)						
	2300 (B30)						
WiFi	2450	VD	No ¹	Yes: GSM, UMTS, or LTE	Yes	N/A	N/A
	5200						
	5300						
	5500						
	5800						
BT	2450	DT	No	Yes: GSM Voice, UMTS, or LTE	N/A	N/A	N/A

Type Transport
 VO = Voice Only
 DT = Digital Data - Not intended for CMRS Service
 VD = CMRS and Data Transport

Notes:
 1. Evaluated for MIF and low-power exemption.
 2. GSM, UMTS and LTE air interfaces are not within the scope of this test report. Please refer to the Original Certification Test Report.
 3. The 3GPP VoLTE CMRS service is defined by GSMA in PRD IR.92 for IP Voice Service and Digital Transport.

Table 3-2: SM-G935A HAC Air Interfaces

FCC ID: A3LSMG935US	PCTEST ENGINEERING LABORATORY, INC.	HAC (RF EMISSIONS) TEST REPORT		Reviewed by: Quality Manager
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Air-Interface	Band (MHz)	Type Transport	HAC Tested	Simultaneous But Not Tested	Voice over Digital Transport OTT Capability	WiFi Low Power	Additional GSM Power Reduction
GSM	850	VO	No ²	Yes: WIFI or BT	N/A	N/A	No
	1900	VO	No ²	Yes: WIFI or BT	N/A	N/A	No
	GPRS/EDGE	DT	No	Yes: WIFI	Yes	N/A	No
UMTS	850	VD	No ²	Yes: WIFI or BT	N/A	N/A	N/A
	1700	VD	No ²	Yes: WIFI or BT	N/A	N/A	N/A
	1900	VD	No ²	Yes: WIFI or BT	N/A	N/A	N/A
LTE (FDD)	700 (B12)	VD ²	No ²	Yes: WIFI or BT	Yes	N/A	N/A
	850 (B5)						
	1700 (B4)						
	1900 (B2)						
WIFI	2450	VD	No ¹	Yes: GSM, UMTS, or LTE	Yes	N/A	N/A
	5200						
	5300						
	5500						
	5800						
BT	2450	DT	No	Yes: GSM Voice, UMTS, or LTE	N/A	N/A	N/A
Type Transport VO = Voice Only DT = Digital Data - Not intended for CMRS Service VD = CMRS and Data Transport			Notes: 1. Evaluated for MIF and low-power exemption. 2. GSM, UMTS and LTE air interfaces are not within the scope of this test report. Please refer to the Original Certification Test Report. 3. The 3GPP VoLTE CMRS service is defined by GSMA in PRD IR.92 for IP Voice Service and Digital Transport.				

Table 3-3: SM-G935T HAC Air Interfaces

Air-Interface	Band (MHz)	Type Transport	HAC Tested	Simultaneous But Not Tested	Voice over Digital Transport OTT Capability	WiFi Low Power	Additional GSM Power Reduction
GSM	850	VO	No ¹	Yes: WIFI or BT	N/A	N/A	No
	1900	VO	No ¹	Yes: WIFI or BT	N/A	N/A	No
	GPRS/EDGE	DT	No	Yes: WIFI	Yes	N/A	No
UMTS	850	VD	No ¹	Yes: WIFI or BT	N/A	N/A	N/A
	1900	VD	No ¹	Yes: WIFI or BT	N/A	N/A	N/A
	HSPA	DT	No	Yes: WIFI or BT	Yes	N/A	N/A
CDMA	835	VO	No ¹	Yes: WIFI or BT	N/A	N/A	N/A
	1900	VO	No ¹	Yes: WIFI or BT	N/A	N/A	N/A
	EVDO	DT	No	Yes: WIFI or BT	Yes	N/A	N/A
LTE (FDD)	700 (B12)	DT	No	Yes: WIFI or BT	Yes	N/A	N/A
	780 (B13)						
	850 (B5)						
	1700 (B4)						
	1900 (B2)						
	1900 (B25)						
WIFI	2450	DT	No	Yes: CDMA, GSM, UMTS, or LTE	Yes	N/A	N/A
	5200						
	5300						
	5500						
	5800						
BT	2450	DT	No	Yes: CDMA, GSM Voice, UMTS, or LTE	N/A	N/A	N/A
Type Transport VO = Voice Only DT = Digital Data - Not intended for CMRS Service VD = CMRS and Data Transport			Notes: 1. CDMA, GSM, and UMTS air interfaces are not within the scope of this test report. Please refer to the Original Certification Test Report.				

Table 3-4: SM-G935R4 HAC Air Interfaces

Air-Interface	Band (MHz)	Type Transport	HAC Tested	Simultaneous But Not Tested	Voice over Digital Transport OTT Capability	WiFi Low Power	Additional GSM Power Reduction
GSM	850	VO	No ²	Yes: WIFI or BT	N/A	N/A	No
	1900	VO	No ²	Yes: WIFI or BT	N/A	N/A	No
	GPRS/EDGE	DT	No	Yes: WIFI	Yes	N/A	No
UMTS	850	VD	No ²	Yes: WIFI or BT	N/A	N/A	N/A
	1900	VD	No ²	Yes: WIFI or BT	N/A	N/A	N/A
	HSPA	DT	No	Yes: WIFI or BT	Yes	N/A	N/A
CDMA	835	VO	No ²	Yes: WIFI or BT	N/A	N/A	N/A
	1900	VO	No ²	Yes: WIFI or BT	N/A	N/A	N/A
	EVDO	DT	No	Yes: WIFI or BT	Yes	N/A	N/A
LTE (FDD)	700 (B12)	DT	No	Yes: WIFI or BT	Yes	N/A	N/A
	850 (B5)						
	1700 (B4)						
	1900 (B2)						
	850 (B26)						
	1900 (B25)						
LTE (TDD)	2600 (B41)	DT	No	Yes: WIFI or BT	Yes	N/A	N/A
WIFI	2450	VD	No ¹	Yes: CDMA, GSM, UMTS, or LTE	Yes	N/A	N/A
	5200						
	5300						
	5500						
	5800						
BT	2450	DT	No	Yes: CDMA, GSM Voice, UMTS, or LTE	N/A	N/A	N/A
Type Transport VO = Voice Only DT = Digital Data - Not intended for CMRS Service VD = CMRS and Data Transport			Notes: 1. Evaluated for MIF and low-power exemption. 2. CDMA, GSM, and UMTS air interfaces are not within the scope of this test report. Please refer to the Original Certification Test Report.				

Table 3-5: SM-G935P HAC Air Interfaces

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4. ANSI/IEEE C63.19 PERFORMANCE CATEGORIES

I. RF EMISSIONS

The ANSI Standard presents performance requirements for acceptable interoperability of hearing aids with wireless communications devices. When these parameters are met, a hearing aid operates acceptably in close proximity to a wireless communications device.

Category	Telephone RF Parameters
Near field Category	E-field emissions CW dB(V/m)
f < 960 MHz	
M1	50 to 55
M2	45 to 50
M3	40 to 45
M4	< 40
f > 960 MHz	
M1	40 to 45
M2	35 to 40
M3	30 to 35
M4	< 30
Table 4-1 WD near-field categories as defined in ANSI C63.19-2011	

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5. SYSTEM SPECIFICATIONS

ER3DV6 E-Field Probe Description

Construction:	One dipole parallel, two dipoles normal to probe axis Built-in shielding against static charges
Calibration:	In air from 100 MHz to 3.0 GHz (absolute accuracy $\pm 6.0\%$, $k=2$)
Frequency:	100 MHz to > 6 GHz; Linearity: ± 0.2 dB (100 MHz to 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 (M3 or better device readings fall well below diode compression point)
Linearity:	± 0.2 dB
Dimensions	Overall length: 330 mm (Tip: 16 mm) Tip diameter: 8 mm (Body: 12 mm) Distance from probe tip to dipole centers: 2.5 mm

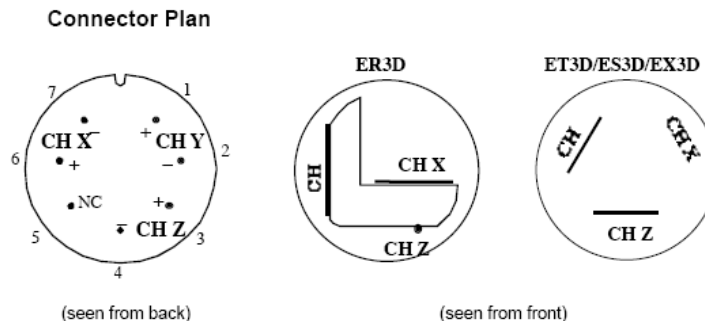


Figure 5-1
E-field Free-space
Probe

Probe Tip Description

HAC field measurements take place in the close near field with high gradients. Increasing the measuring distance from the source will generally decrease the measured field values (in case of the validation dipole approx. 10% per mm).

The electric field probes have an irregular internal geometry because it is physically not possible to have the 3 orthogonal sensors situated with the same center. The effect of the different sensor centers is accounted for in the HAC uncertainty budget ("sensor displacement"). Their geometric center is at 2.5mm from the tip, and the element ends are 1.1mm closer to the tip.



The antistatic shielding inside the probe is connected to the probe connector case.

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Instrumentation Chain

Equation 1

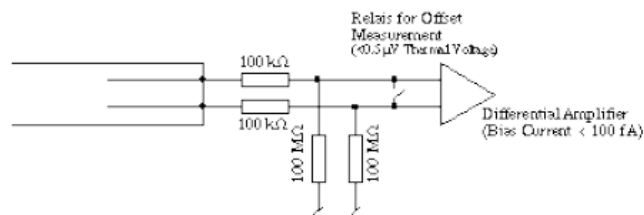
Conversion of Connector Voltage u_i to E-Field E_i

$$E_i = \sqrt{\frac{u_i + (u_i^2 \cdot CF)/(DCP)}{Norm_i \cdot ConvF}}$$

whereby

E_i : electric field in V/m
 u_i : voltage of channel i at the connector in μV
 $Norm_i$: sensitivity of channel i in $\mu V/(V/m)^2$
 $ConvF$: enhancement factor in liquid ($ConvF=1$ for Air)
 DCP : diode compression point in μV
 CF : signal crest factor (peak power/average power)

Conditions of Calibration



Please note:

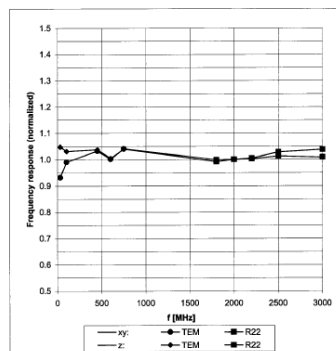
- a lower input impedance of the amplifier will result in different sensitivity factors $Norm_i$ and DCP
- larger bias currents will cause higher offset

Probe Response to Frequency

The E-field sensors have inherently a very flat frequency response. They are calibrated with a number of frequencies resulting in a common calibration factor, with the frequency behavior documented in the calibration certificate (See also below).

Frequency Response of E-Field

(TEM-Cell: if110 EXX, Waveguide R22)



Uncertainty of Frequency Response of E-field: $\pm 6.3\%$ ($k=2$)

Figure 5-2 E-Field Probe Frequency Response

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SPEAG Robotic System

E-field measurements are performed using the DASY5 automated dosimetric assessment system. The DASY5 is made by Schmid & Partner Engineering AG (SPEAG) in Zurich, Switzerland and consists of high precision robotics system (Staubli), robot controller, Intel CORE i7 computer, near-field probe, probe alignment sensor, and the HAC phantom. The robot is a six-axis industrial robot performing precise movements to position the probe to the location (points) of maximum electromagnetic field (EMF).



Figure 5-3
SPEAG Robotic System

System Hardware

A cell controller system contains the power supply, robot controller, teach pendant (Joystick), and a remote control used to drive the robot motors. The PC consists of the computer with operating system and RF Measurement Software DASY5 v52.8 (with HAC Extension), A/D interface card, monitor, mouse, and keyboard. The Staubli Robot is connected to the cell controller to allow software manipulation of the robot. A data acquisition electronic (DAE) circuit that performs the signal amplification, signal multiplexing, AD-conversion, offset measurements, mechanical surface detection, collision detection, etc. is connected to the Electro-optical coupler (EOC). The EOC performs the conversion from the optical into digital electric signal of the DAE and transfers data to the PC plug-in card.

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System Electronics

The DAE consists of a highly sensitive electrometer-grade preamplifier with auto-zeroing, a channel and gain-switching multiplexer, a fast 16 bit AD-converter and a command decoder and control logic unit. Transmission to the PC-card is accomplished through an optical downlink for data and status information and an optical uplink for commands and clock lines. The mechanical probe mounting device includes two different sensor systems for frontal and sidewise probe contacts. They are also used for mechanical surface detection and probe collision detection. The robot uses its own controller with a built in VME-bus computer.

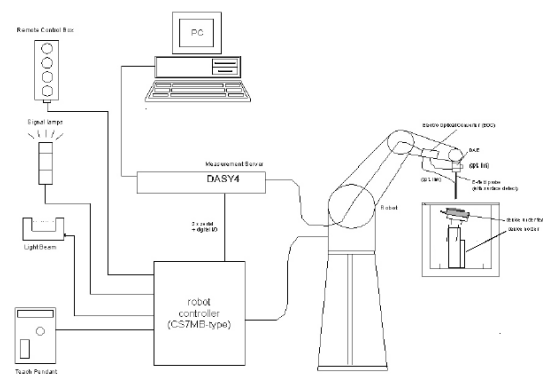


Figure 5-4
SPEAG Robotic System Diagram

DASY5 Instrumentation Chain

The first step of the evaluation is a linearization of the filtered input signal to account for the compression characteristics of the detector diode. The compensation depends on the input signal, the diode type and the DC-transmission factor from the diode to the evaluation electronics. If the exciting field is pulsed, the crest factor of the signal must be known to correctly compensate for peak power. The formula for each channel can be given as:

$$V_i = U_i + U_i^2 \cdot \frac{cf}{dcp_i}$$

- with

V_i

U_i

cf

dcp_i
- = compensated signal of channel i

= input signal of channel i

= crest factor of exciting field

= diode compression point
- (i = x, y, z)

(i = x, y, z)

(DASY parameter)

(DASY parameter)

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From the compensated input signals the primary field data for each channel can be evaluated:

$$E - \text{fieldprobes} : \quad E_i = \sqrt{\frac{V_i}{Norm_i \cdot ConvF}}$$

with V_i = compensated signal of channel i (i = x, y, z)
 $Norm_i$ = sensor sensitivity of channel i (i = x, y, z)
 $\mu V / (V/m)^2$ for E-field Probes
 $ConvF$ = sensitivity enhancement in solution
 E_i = electric field strength of channel i in V/m

The RSS value of the field components gives the total field strength (Hermitian magnitude):

$$E_{tot} = \sqrt{E_x^2 + E_y^2 + E_z^2}$$

The primary field data are used to calculate the derived field units.

The measurement/integration time per point, as specified by the system manufacturer is >500ms.

The signal response time is evaluated as the time required by the system to reach 90% of the expected final value after an on/off switch of the power source with an integration time of 500ms and a probe response time of <5 ms. In the current implementation, DASY5 waits longer than 100ms after having reached the grid point before starting a measurement, i.e., the response time uncertainty is negligible.

If the device under test does not emit a CW signal, the integration time applied to measure the electric field at a specific point may introduce additional uncertainties due to the discretization. The tolerances for the different systems had the worst-case of 2.6%.

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6. TEST PROCEDURE

I. RF EMISSIONS

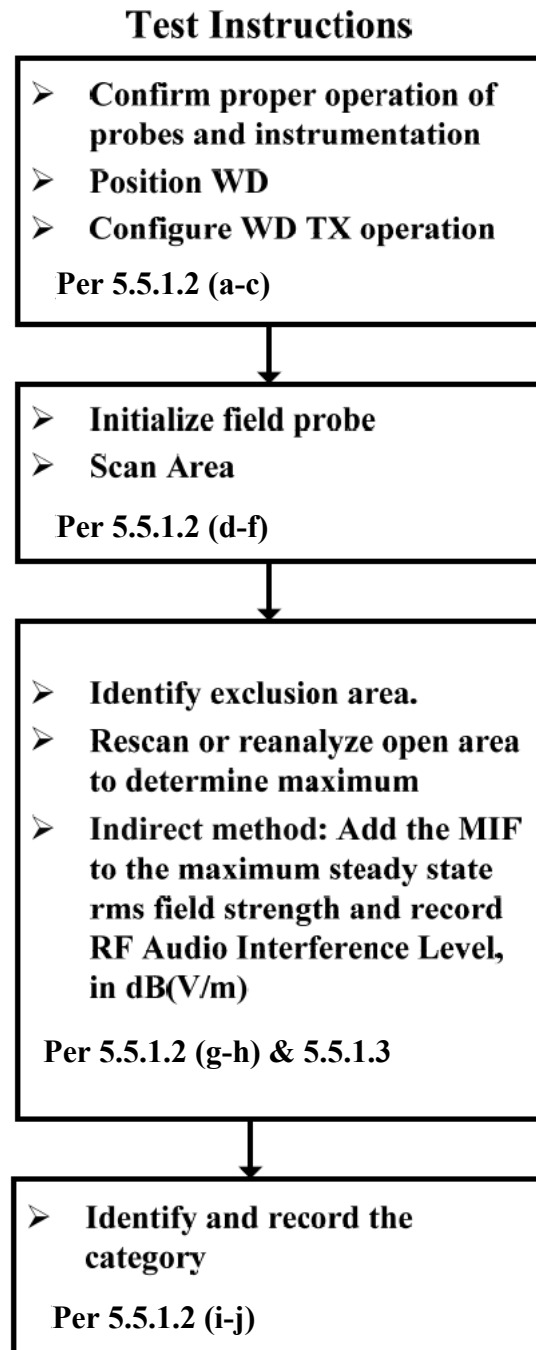


Figure 6-1 RF Emissions Flow Chart

FCC ID: A3LSMG935US	 PCTEST ENGINEERING LABORATORY, INC.	HAC (RF EMISSIONS) TEST REPORT		Reviewed by: Quality Manager
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Test Setup

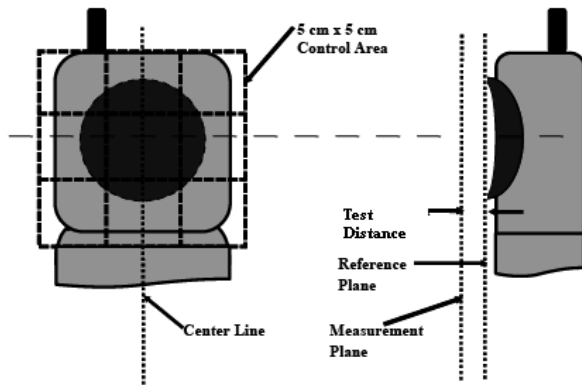


Figure 6-2

E-Field Emissions Test Setup Diagram (See Test Photographs for actual WD scan grid overlay)

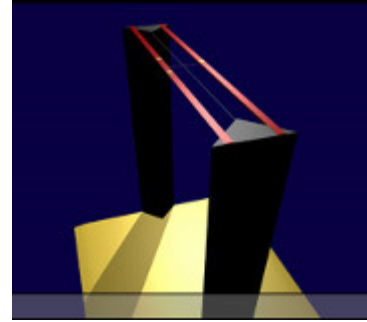


Figure 6-3
HAC Phantom

RF Emissions Test Procedure:

The following illustrate a typical RF emissions test scan over a wireless communications device:

1. Proper operation of the field probe, probe measurement system, other instrumentation, and the positioning system was confirmed.
2. WD is positioned in its intended test position, acoustic output point of the device perpendicular to the field probe.
3. The WD operation for maximum rated RF output power was configured and confirmed with the base station simulator, at the test channel and other normal operating parameters as intended for the test. The battery was ensured to be fully charged before each test.
4. The center sub-grid was centered over the center of the acoustic output (also audio band magnetic output, if applicable). The WD audio output was positioned tangent (as physically possible) to the measurement plane.
5. A surface calibration was performed before each setup change to ensure repeatable spacing and proper maintenance of the measurement plane using the HAC Phantom.
6. The measurement system measured the field strength at the reference location.
7. Measurements at 2mm or 5mm increments in the 5 x 5 cm region were performed at a distance 15 mm from the center point of the probe measurement element to the WD. A 360° rotation about the azimuth axis at the maximum interpolated position was measured. For the worst-case condition, the peak reading from this rotation was used in re-evaluating the HAC category.
8. The system performed a drift evaluation by measuring the field at the reference location. If the power drift deviated by more than 5%, the HAC test and drift measurements were repeated.

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7. MODULATION INTERFERENCE FACTOR

I. Measuring Modulation Interference Factors

For any specific fixed and repeatable modulated signal, a modulation interference factor (MIF, expressed in dB) may be determined that relates its interference potential to its steady-state RMS signal level or average power level. This factor is a function only of the audio-frequency amplitude modulation characteristics of the signal and is the same for field-strength and conducted power measurements. The MIF is valid only for a specific repeatable audio-frequency amplitude modulation characteristic; any change in modulation characteristic requires determination and application of a new MIF.

The MIF may be determined using a radiated RF field or a conducted RF signal:

- Using RF illumination or conducted coupling, apply the specific modulated signal in question to the measurement system at a level within its confirmed operating dynamic range.
- Measure the steady-state RMS level at the output of the fast probe or sensor.
- Measure the steady-state average level at the weighting output.
- Without changing the square-law detector or weighting system, and using RF illumination or conducted coupling, substitute for the specific modulated signal a 1 kHz, 80% amplitude modulated carrier at the same frequency and adjust its strength until the level at the weighting output equals the step c) measurement.
- Without changing the carrier level from step d), remove the 1 kHz modulation and again measure the steady-state RMS level indicated at the output of the fast probe or sensor.
- The MIF for the specific modulation characteristic is provided by the ratio of the step e) measurement to the step b) measurement, expressed in dB ($20 \times \log[(\text{step e})/(\text{step b})]$).

The following procedure was used to measure the MIF using the SPEAG Audio Interference Analyzer (AIA), Type No: SE UMS 170 CB, Serial No: 1010:

- The device was placed into a simulated call using a base station simulator or set to transmit using test software for a given mode.
- The device was then set to continuously transmit at maximum power.
- Using a coupler if needed, the device output signal was connected to the RF In port of the AIA, which was connected to a desktop computer. Alternatively, a radiated RF signal may be used with the AIA's built-in antenna.
- The MIF measurement procedure in the DASY software was run, and the resulting MIF value was recorded.
- Steps 1-4 were repeated for all CMRS air interfaces, frequency bands, and modulations.

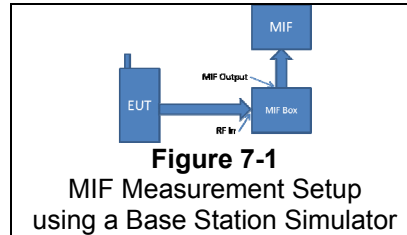
The modulation interference factors obtained were applied to readings taken of the actual wireless device in order to obtain an accurate audio interference level reading using the formula:

$$\text{Audio Interference Level [dB(V/m)]} = 20 * \log[\text{Raw Field Value (V/m)}] + \text{MIF (dB)}$$

Because the MIF value is output power independent, MIF values for a given mode should be constant across all devices; however, per C63.19-2011 §D.7, MIF values should be measured for each device being evaluated. The voice modes for this device have been investigated in this section of the report.

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II. MIF Measurement Block Diagrams



III. Measured Modulation Interference Factors:

Mode	802.11b MIF Measurements [dB]			
	Data Rate [Mbps]			
	1	2	5.5	11
802.11b	-16.46	-15.75	-11.43	-11.42

Table 7-1

802.11b (2.4GHz, SISO) Modulation Interference Factors^{1,2}

Mode	802.11g MIF Measurements [dB]							
	Data Rate [Mbps]							
	6	9	12	18	24	36	48	54
802.11g	-12.64	-12.30	-11.64	-10.97	-11.04	-11.39	-11.83	-12.61

Table 7-2

802.11g (2.4GHz, SISO) Modulation Interference Factors^{1,2}

Mode	802.11g MIF Measurements [dB]							
	Data Rate [Mbps]							
	12	18	24	36	48	72	96	108
802.11g	-12.52	-12.43	-11.89	-10.86	-10.68	-11.06	-11.52	-12.28

Table 7-3

802.11g (2.4GHz, MIMO) Modulation Interference Factors^{1,2}

Mode	802.11n (2.4GHz) MIF Measurements [dB]							
	Data Rate [Mbps]							
	6.5	13	19.5	26	39	52	58.5	65
802.11n	-13.10	-11.91	-11.34	-11.15	-11.44	-11.86	-12.20	-12.47

Table 7-4

802.11n (2.4GHz, SISO) Modulation Interference Factors^{1,2}

Mode	802.11n (2.4GHz) MIF Measurements [dB]							
	Data Rate [Mbps]							
	13	26	39	52	78	104	117	130
802.11n	-12.67	-11.48	-11.25	-10.70	-11.25	-11.55	-11.96	-12.15

Table 7-5

802.11n (2.4GHz, MIMO) Modulation Interference Factors^{1,2}

¹ Note: Measured MIF values may be lower than sample MIF values provided in ANSI C63.19-2011 Annex D.7 Table D.5 due to manufacturing variations for each device, however per Annex D.7, the sample MIF values of Table D.5 are not intended to substitute for measurements of actual devices under test and their respective operating modes.

² Note: WLAN MIF values were found to be independent of the transmit channel.

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Mode	802.11a MIF Measurements [dB]							
	Data Rate [Mbps]							
	6	9	12	18	24	36	48	54
802.11a	-13.22	-12.78	-12.18	-11.28	-11.21	-11.54	-12.01	-12.83

Table 7-6

802.11a (5GHz, 20MHz BW, SISO) Modulation Interference Factors^{1,2}

Mode	802.11a MIF Measurements [dB]							
	Data Rate [Mbps]							
	12	18	24	36	48	72	96	108
802.11a	-12.75	-12.35	-12.11	-11.16	-11.05	-11.51	-11.77	-12.67

Table 7-7

802.11a (5GHz, 20MHz BW, MIMO) Modulation Interference Factors^{1,2}

Mode	20MHz BW 802.11n (5GHz) MIF Measurements [dB]							
	Data Rate [Mbps]							
	6.5	13	19.5	26	39	52	58.5	65
802.11n	-13.26	-12.07	-11.53	-11.36	-11.62	-12.03	-12.39	-12.64

Table 7-8

802.11n (5GHz, 20MHz BW, SISO) Modulation Interference Factors^{1,2}

Mode	20MHz BW 802.11n (5GHz) MIF Measurements [dB]							
	Data Rate [Mbps]							
	13	26	36	52	78	104	117	130
802.11n	-12.99	-11.61	-11.13	-11.17	-11.21	-11.95	-11.97	-12.28

Table 7-9

802.11n (5GHz, 20MHz BW, MIMO) Modulation Interference Factors^{1,2}

Mode	20MHz BW 802.11ac (5GHz) MIF Measurements [dB]									
	Data Rate [Mbps]									
	6.5	13	19.5	26	39	52	58.5	65	78	
802.11ac	-13.33	-12.18	-11.48	-11.30	-11.54	-12.05	-12.25	-12.50	-12.87	

Table 7-10

802.11ac (5GHz, 20MHz BW, SISO) Modulation Interference Factors^{1,2}

Mode	20MHz BW 802.11ac (5GHz) MIF Measurements [dB]									
	Data Rate [Mbps]									
	13	26	36	52	78	104	117	130	156	
802.11ac	-11.95	-10.75	-11.42	-11.62	-12.43	-13.58	-13.67	-13.90	-14.68	

Table 7-11

802.11ac (5GHz, 20MHz BW, MIMO) Modulation Interference Factors^{1,2}

Mode	40MHz BW 802.11n (5GHz) MIF Measurements [dB]							
	Data Rate [Mbps]							
	13.5	27	40.5	54	81	108	121.5	135
802.11n	-11.32	-10.65	-11.04	-11.56	-12.80	-13.77	-14.20	-14.63

Table 7-12

802.11n (5GHz, 40MHz BW, SISO) Modulation Interference Factors^{1,2}

¹ Note: Measured MIF values may be lower than sample MIF values provided in ANSI C63.19-2011 Annex D.7 Table D.5 due to manufacturing variations for each device, however per Annex D.7, the sample MIF values of Table D.5 are not intended to substitute for measurements of actual devices under test and their respective operating modes.

² Note: WLAN MIF values were found to be independent of the transmit channel.

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Mode	40MHz BW 802.11n (5GHz) MIF Measurements [dB]							
	Data Rate [Mbps]							
	27	54	81	108	162	216	243	270
802.11n	-11.41	-10.66	-10.62	-11.19	-12.39	-13.36	-13.67	-14.70

Table 7-13

802.11n (5GHz, 40MHz BW, MIMO) Modulation Interference Factors^{1,2}

Mode	40MHz BW 802.11ac (5GHz) MIF Measurements [dB]									
	Data Rate [Mbps]									
	13.5	27	40.5	54	81	108	121.5	135	162	180
802.11ac	-11.30	-10.49	-10.94	-11.49	-12.69	-13.61	-13.98	-14.18	-14.63	-15.07

Table 7-14

802.11ac (5GHz, 40MHz BW, SISO) Modulation Interference Factors^{1,2}

Mode	40MHz BW 802.11ac (5GHz) MIF Measurements [dB]									
	Data Rate [Mbps]									
	27	54	81	108	162	216	243	270	324	360
802.11ac	-10.72	-11.04	-12.18	-12.93	-14.50	-15.72	-15.45	-15.10	-16.08	-15.68

Table 7-15

802.11ac (5GHz, 40MHz BW, MIMO) Modulation Interference Factors^{1,2}

Mode	80MHz BW 802.11ac (5GHz) MIF Measurements [dB]									
	Data Rate [Mbps]									
	29.3	58.5	87.8	117	175.5	234	263.3	292.5	351	390
802.11ac	-10.41	-11.31	-12.10	-12.79	-13.42	-15.22	-16.01	-16.22	-16.42	-16.85

Table 7-16

802.11ac (5GHz, 80MHz BW, SISO) Modulation Interference Factors^{1,2}

Mode	80MHz BW 802.11ac (5GHz) MIF Measurements [dB]									
	Data Rate [Mbps]									
	58.5	117	175.5	234	351	468	526.5	585	702	780
802.11ac	-11.83	-13.70	-14.47	-14.46	-16.14	-16.83	-15.11	-16.30	-15.32	-15.82

Table 7-17

802.11ac (5GHz, 80MHz BW, MIMO) Modulation Interference Factors^{1,2}

¹ Note: Measured MIF values may be lower than sample MIF values provided in ANSI C63.19-2011 Annex D.7 Table D.5 due to manufacturing variations for each device, however per Annex D.7, the sample MIF values of Table D.5 are not intended to substitute for measurements of actual devices under test and their respective operating modes.

² Note: WLAN MIF values were found to be independent of the transmit channel.

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8. RF CONDUCTED POWER MEASUREMENTS

I. Procedures Used to Establish RF Signal for HAC Testing

The handset was placed into a simulated call using a base station simulator in a shielded chamber. Such test signals offer a consistent means for testing HAC and are recommended for evaluating HAC. Measurements were taken with a fully charged battery. In order to verify that the device was tested and maintained at full power, this was configured with the base station simulator.

II. HAC Measurement Conditions

Output Power Verification

Maximum output power is verified on the High, Middle and Low channels for all applicable air interfaces. See Table 8-1 for air interface specific settings of transmit power parameters.

Air Interface:	Parameter Name:	Parameter Set To:
WLAN	PLS	Mfr Specified

Table 8-1
Power Control Parameters and Settings by Air Interface

III. Setup Used to Measure RF Conducted Powers

Power measurements were performed using a power meter and power sensor.

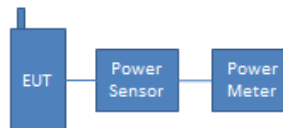


Figure 8-1
Power Measurement Setup

IV. WLAN Conducted Powers

Table 8-2
IEEE 802.11b/g/n (2.4GHz, SISO) Average RF Power

Freq [MHz]	Channel	2.4GHz Conducted Power [dBm]		
		IEEE Transmission Mode		
		802.11b	802.11g	802.11n
2412	1	19.95	16.95	16.93
2437	6	20.19	17.10	16.61
2462	11	19.32	16.72	16.53

Table 8-3
IEEE 802.11g/n (2.4GHz, MIMO) Average RF Power

Freq [MHz]	Channel	2.4GHz Conducted Power [dBm]	
		802.11g	802.11a
2412	1	20.22	20.15
2437	6	20.64	20.36
2462	11	20.54	20.48

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Table 8-4
IEEE 802.11a/n/ac (5GHz, 20MHz BW, SISO) Average RF Power

Freq [MHz]	Channel	5GHz (20MHz) Conducted Power [dBm]		
		IEEE Transmission Mode		
		802.11a	802.11n	802.11ac
5180	36	16.02	16.82	16.47
5200	40	16.89	16.79	17.26
5220	44	16.83	16.75	17.18
5240	48	16.79	16.52	17.06
5260	52	16.75	16.59	17.33
5280	56	16.56	16.39	17.33
5300	60	16.64	16.41	17.24
5320	64	16.58	17.35	17.29
5500	100	16.40	16.99	16.97
5600	120	17.24	16.98	16.94
5620	124	17.21	17.12	17.01
5720	144	17.38	17.20	17.11
5745	149	16.67	17.40	17.35
5785	157	16.74	17.33	17.32
5825	165	16.82	17.48	17.29

Table 8-5
IEEE 802.11a/n/ac (5GHz, 20MHz BW, MIMO) Average RF Power

Freq [MHz]	Channel	5GHz (20MHz) Conducted Power [dBm]		
		802.11a	802.11n	802.11ac
5180	36	19.43	19.69	19.60
5200	40	19.88	19.74	19.98
5220	44	19.94	19.77	19.95
5240	48	19.80	19.64	19.91
5260	52	19.79	19.65	20.00
5280	56	19.73	19.62	20.09
5300	60	19.85	19.68	20.04
5320	64	19.82	20.13	20.11
5500	100	19.72	19.97	19.99
5600	120	20.20	19.99	20.04
5620	124	20.16	20.09	20.07
5720	144	20.28	20.11	20.12
5745	149	19.94	20.24	20.24
5785	157	20.00	20.20	20.16
5825	165	19.98	20.24	20.11

Table 8-6
IEEE 802.11n/ac (5GHz, 40MHz BW, SISO) Average RF Power

Freq [MHz]	Channel	5GHz (40MHz) Conducted Power [dBm]	
		IEEE Transmission Mode	
		802.11n	802.11ac
5190	38	14.54	14.60
5230	46	15.49	15.49
5270	54	15.48	15.44
5310	62	15.40	15.30
5510	102	14.93	14.93
5590	118	15.00	14.97
5630	126	14.96	14.94
5710	142	15.18	15.14
5755	151	15.48	15.43
5795	159	14.61	14.53

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Table 8-7
IEEE 802.11n/ac (5GHz, 40MHz BW, MIMO) Average RF Power

Freq [MHz]	Channel	5GHz (40MHz) Conducted Power [dBm]	
		802.11n	802.11ac
5190	38	17.57	17.58
5230	46	18.08	18.06
5270	54	18.10	18.05
5310	62	18.02	18.01
5510	102	17.95	17.94
5590	118	18.00	17.98
5630	126	18.01	17.95
5710	142	18.08	18.10
5755	151	18.18	18.13
5795	159	17.74	17.64

Table 8-8
IEEE 802.11ac (5GHz, 80MHz BW, SISO) Average RF Power

5GHz (80MHz) Conducted Power [dBm]		
Freq [MHz]	Channel	IEEE Transmission Mode
		802.11ac
5210	42	13.13
5290	58	12.90
5530	106	12.76
5610	122	12.73
5690	138	12.84
5775	155	13.02

Table 8-9
IEEE 802.11ac (5GHz, 80MHz BW, MIMO) Average RF Power

5GHz (80MHz) Conducted Power [dBm]		
Freq [MHz]	Channel	IEEE Transmission Mode
		802.11ac
5210	42	15.84
5290	58	15.73
5530	106	15.72
5610	122	15.63
5690	138	15.71
5775	155	15.81

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9. JUSTIFICATION OF HELD TO EAR MODES TESTED

I. Analysis of RF Air Interface Technologies

- a. According to the April 2013 TCB workshop slides, OTT data services are outside the current definition of a managed CMRS service and are currently not required to be evaluated.
- b. No associated T-coil measurements for VoIP over WIFI CMRS have been made in accordance with the guidance issued by OET in KDB publication 285076 D02 T-Coil testing for CMRS IP.
- c. An analysis was performed, following the guidance of §4.3 and §4.4 of the ANSI standard, of the RF air interface technologies being evaluated. The factors that will affect the RF interference potential were evaluated, and the worst case operating modes were identified and used in the evaluation. A WD's interference potential is a function both of the WD's average near-field field strength and of the signal's audio-frequency amplitude modulation characteristics. Per §4.4, RF air interface technologies that have low power have been found to produce sufficiently low RF interference potential, so it is possible to exempt them from the product testing specified in Clause 5 of the ANSI standard. An RF air interface technology of a device is exempt from testing when its average antenna input power plus its MIF is $\leq 17\text{dBm}$ for all of its operating modes. RF air interface technologies exempted from testing in this manner are automatically assigned an M4 rating to be used in determining the overall rating for the WD.

The worst case MIF plus the worst case average antenna input power for all modes are investigated below to determine the testing requirements for this device.

II. Individual Mode Evaluations

Air Interface	Maximum Average Power (dBm)	Worst Case MIF (dB)	Total (Power + MIF, dB)	C63.19 Testing Required
2.4GHz WLAN	20.64	-10.68	9.96	No
5GHz WLAN	20.28	-10.41	9.87	No

Table 9-1
Max Power + MIF calculations
for Low Power Exemptions

III. Low-Power Exemption Conclusions

Per ANSI C63.19-2011, RF Emissions testing is exempt for all WLAN modes.

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10. EQUIPMENT LIST

Manufacturer	Model	Description	Cal Date	Cal Interval	Cal Due	Serial Number
Anritsu	ML2496A	Power Meter	2/28/2016	Annual	2/28/2017	1306009
Anritsu	MA2411B	Pulse Power Sensor	8/3/2015	Annual	8/3/2016	1126066
Anritsu	MA24106A	USB Power Sensor	5/29/2015	Annual	5/29/2016	1248508
Mini-Circuits	BW-N6W5+	6dB Attenuator	N/A	CBT*	N/A	1139
Pasternack	NC-100	Torque Wrench	11/6/2015	Biennial	11/6/2017	N/A
Pasternack	PE2237-20	Bidirectional Coupler	N/A	CBT*	N/A	N/A
SPEAG	AIA	Audio Interference Analyzer	N/A	CBT*	N/A	1010

Table 10-1
Equipment List

Calibration traceable to the National Institute of Standards and Technology (NIST).

***Note: CBT (Calibrated Before Testing).** Prior to testing, the measurement paths containing a cable, 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.

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11. MEASUREMENT UNCERTAINTY

Wireless Communications Device Near-Field Measurement							
Uncertainty Estimation							
Uncertainty Component	Data (dB)	Data Type	Prob. Dist.	Divisor	Ci (E)	Unc. (dB)	Notes/Comments
Measurement System							
RF System Reflections	0.50	Tolerance	N	1.00	1	0.50	* Refl. < -20 dB
Field Probe Calibration	0.21	Tolerance	N	1.00	1	0.21	
Field Probe Isotropy	0.01	Tolerance	N	1.00	1	0.01	
Field Probe Frequency Response	0.135	Tolerance	N	1.00	1	0.14	
Field Probe Linearity	0.013	Tolerance	N	1.00	1	0.01	
Modulation Interference Factor	0.20	Tolerance	R	1.73	1	0.12	Applicable for M-rating testing
Boundary Effects	0.105	Accuracy	R	1.73	1	0.06	*
Probe Positioning Accuracy	0.20	Accuracy	R	1.73	1	0.12	*
Probe Positioner	0.050	Accuracy	R	1.73	1	0.03	*
Extrapolation/Interpolation	0.045	Tolerance	R	1.73	1	0.03	*
Resolution to 2mm error	0.21	Tolerance	N	1.00	1	0.21	
System Detection Limit	0.05	Tolerance	R	1.73	1	0.03	*
Readout Electronics	0.015	Tolerance	N	1.00	1	0.02	*
Integration Time	0.11	Tolerance	R	1.73	1	0.06	*
Response Time	0.033	Tolerance	R	1.73	1	0.02	*
Phantom Thickness	0.10	Tolerance	R	1.73	1	0.06	*
System Repeatability (Field x 2=power)	0.17	Tolerance	N	1.00	1	0.17	*
Test Sample Related							
Device Positioning Vertical	0.2	Tolerance	R	1.73	1	0.12	*
Device Positioning Lateral	0.045	Tolerance	R	1.73	1	0.03	*
Device Holder and Phantom	0.1	Tolerance	R	1.73	1	0.06	*
Power Drift	0.21	Tolerance	R	1.73	1	0.12	
Combined Standard Uncertainty (k=1)						0.66	16.3%
Expanded Uncertainty [95% confidence]						1.31	32.6%
Expanded Uncertainty [95% confidence] on Field						0.66	16.3%

Table 11-1
Uncertainty Estimation Table

Notes:

1. Test equipments are calibrated according to techniques outlined in NIS81, NIS3003 and NIST Tech Note 1297. All equipments have traceability according to NIST. Measurement Uncertainties are defined in further detail in NIS 81 and NIST Tech Note 1297 and UKAS M3003.
2. * Uncertainty specifications from Schmidt & Partner Engineering AG (not site specific)

Measurement uncertainty reflects the quality and accuracy of a measured result as compared to the true value. Such statements are generally required when stating results of measurements so that it is clear to the intended audience that the results may differ when reproduced by different facilities. Measurement results vary due to the measurement uncertainty of the instrumentation, measurement technique, and test engineer. Most uncertainties are calculated using the tolerances of the instrumentation used in the measurement, the measurement setup variability, and the technique used in performing the test. While not generally included, the variability of the equipment under test also figures into the overall measurement uncertainty. Another component of the overall uncertainty is based on the variability of repeated measurements (so-called Type A uncertainty). This may mean that the Hearing Aid immunity tests may have to be repeated by taking down the test setup and resetting it up so that there are a statistically significant number of repeat measurements to identify the measurement uncertainty. By combining the repeat measurement results with that of the instrumentation chain using the technique contained in NIS 81 and NIS 3003, the overall measurement uncertainty was estimated.

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12. CONCLUSION

The measurements taken in accordance with the procedures provided in the CTIA Test Plan for Hearing Aid Compatibility Rev 3.0, November 2013, indicate that the wireless communications device complies with the HAC limits specified in the ANSI C63.19 Standard and FCC WT Docket No. 01-309 RM-8658 for the WLAN air interfaces tested. Precise laboratory measures were taken to assure repeatability of the tests. The tested device complies with the requirements in respect to all parameters specific to the test. The test results and statements relate only to the item(s) tested.

Please note that the M-rating for this equipment only represents the field interference possible against a hypothetical and typical hearing aid. The measurement system and techniques presented in this evaluation are proposed in the ANSI standard as a means of best approximating wireless device compatibility with a hearing-aid. The literature is under continual re-construction.

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