



**HAC T-COIL SIGNAL TEST REPORT**

**FCC 47 CFR § 20.19  
ANSI C63.19-2011**

*For*

**GSM/WCDMA/LTE Phone + BT/BLE, DTS/UNII a/b/g/n/ac, ANT+ and NFC**

**MODEL NUMBER : SM-G889A**

**FCC ID: A3LSMG889A**

**REPORT NUMBER: 4788768228-S3V1**

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*Prepared for*

**SAMSUNG ELECTRONICS CO., LTD.  
129 SAMSUNG-RO, YEONGTONG-GU, SUWON-SI,  
GYEONGGI-DO, 16677, KOREA**

*Prepared by*

**UL Korea, Ltd.**

**26th floor, 152, Teheran-ro, Gangnam-gu Seoul, 06236, Korea**

**Suwon Test Site: UL Korea, Ltd. Suwon Laboratory  
218 Maeyeong-ro, Yeongtong-gu,  
Suwon-si, Gyeonggi-do, 16675, Korea  
TEL: (031) 337-9902  
FAX: (031) 213-5433**



**TL-637**

**Revision History**

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# 1. Attestation of Test Results

Applicant Name	SAMSUNG ELECTRONICS CO.,LTD.
FCC ID	A3LSMG889A
Model Name	SM-G889A
Applicable Standards	FCC 47 CFR § 20.19 ANSI C63.19-2011
HAC Rating	T4
Date Tested	3/8/2019 to 4/2/2019 and 5/8/2019 to 4/10/2019
Test Results	Pass

UL Korea, Ltd. tested the above equipment in accordance with the requirements set forth in the above standards. All indications of Pass/Fail in this report are opinions expressed by UL Korea, Ltd. based on interpretations and/or observations of test results. Measurement Uncertainties were not taken into account and are published for informational purposes only. The test results show that the equipment tested is capable of demonstrating compliance with the requirements as documented in this report.

**Note:** The results documented in this report apply only to the tested sample, under the conditions and modes of operation as described herein. This document may not be altered or revised in any way unless done so by UL Korea, Ltd. and all revisions are duly noted in the revisions section. Any alteration of this document not carried out by UL Korea, Ltd. 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 IAS, any agency of the Federal Government, or any agency of any government.

Approved & Released By: 	Prepared By: 
Justin Park Lead Test Engineer UL Korea, Ltd. Suwon Laboratory	Eunji Choi Associate Test Engineer UL Korea, Ltd. Suwon Laboratory

## 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 v05  
 KDB 285076 D02 T-Coil testing for CMRS IP v03  
 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

Suwon
SAR 2 Room (HAC)

UL Korea, Ltd. is accredited by IAS, Laboratory Code TL-637.

The full scope of accreditation can be viewed at <http://www.iasonline.org/PDF/TL/TL-637.pdf>.

## 4. Calibration and Uncertainty

### 4.1. Measuring Instrument Calibration

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

Name of Equipment	Manufacturer	Type/Model	Serial No.	Cal. Due Date
ABM Probe	SPEAG	AM1DV3	3137	11-20-2019
Data Acquisition Electronics	SPEAG	DAE4	1447	03-15-2019
Radio Communication Tester	R & S	CMW 500	150314	08-09-2019
Support Device	Samsung	SM-G955N	R39J40DPK3D	N/A
DAC	Sound Devices	USBPre 2	HB1218172005	N/A
AP	Cisco	Air-CAP3702I-A-K9	FTX1902S5JZ	N/A
Series Wireless Controller	Cisco	WLAN 2500 Series Controller	PSZ173000ZG	N/A
Switch	Netgear	ProSafe 5 Port Gigabit Switch GS105v5	3TL1865A1173B	N/A

## 4.2. Measurement Uncertainty

### Measurement Uncertainty for Audio Band Magnetic Measurement

Error Description	Uncertainty values (±%)	Probe Dist.	Div.	c <sub>i</sub>		Std. Unc.	
				ABM1	ABM2	ABM1 (±%)	ABM2 (±%)
<b>Probe Sensitivity</b>							
Reference level	3.0	N	1	1	1	3.0	3.0
AMCC geometry	0.4	R	√3	1	1	0.2	0.2
AMCC current	1.0	R	√3	1	1	0.6	0.6
Probe positioning during calibration	0.1	R	√3	1	1	0.1	0.1
Noise contribution	0.7	R	√3	0.0143	1	0.0	0.4
Frequency slope	5.9	R	√3	0.1	1.00	0.3	3.5
<b>Probe System</b>							
Repeatability / drift	1.0	R	√3	1	1	0.6	0.6
Linearity / Dynamic range	0.6	R	√3	1	1	0.4	0.4
Acoustic noise	1.0	R	√3	0.1	1	0.1	0.6
Probe angle	2.3	R	√3	1	1	1.4	1.4
Spectral processing	0.9	R	√3	1	1	0.5	0.5
Integration time	0.6	N	1	1	5	0.6	3.0
Field disturbance	0.2	R	√3	1	1	0.1	0.1
<b>Test Signal</b>							
Reference signal spectral response	0.6	R	√3	0	1	0.0	0.4
<b>Positioning</b>							
Probe positioning	1.9	R	√3	1	1	1.1	1.1
Phantom positioning	0.9	R	√3	1	1	0.5	0.5
EUT positioning	1.9	R	√3	1	1	1.1	1.1
<b>External Contributions</b>							
RF interference	0.0	R	√3	1	0.3	0.0	0.0
Test signal variation	2.0	R	√3	1	1	1.2	1.2
<b>Combined Std. Uncertainty (ABM field)</b>						4.1	6.1
<b>Expanded Std. Uncertainty (%)</b>						8.1	12.3
Notes for table							
1. N - Normal							
2. R - Rectangular							
3. Div. - Divisor used to obtain standard uncertainty							

## 5. Test Procedures for all Technologies

ANSI C63.19-2011, Section 7

This document describes the procedures used to measure the ABM (T-Coil) performance of the WD. In addition to measuring the absolute signal levels, the A-weighted magnitude of the unintended signal shall also be determined. In order to assure that the required signal quality is measured, the measurement of the intended signal and the measurement of the unintended signal must be made at the same location for all measurement positions. In addition, the RF field strength at each measurement location must be at or below that required for the assigned category.

Measurements shall not include undesired properties from the WD's RF field; therefore, use of a coaxial connection to a base station simulator or non-radiating load may be necessary. However, even then with a coaxial connection to a base station simulator or non-radiating load there may still be RF leakage from the WD, which may interfere with the desired measurement. Pre-measurement checks should be made to avoid this possibility. All measurements shall be done with the WD operating on battery power with an appropriate normal speech audio signal input level given in Table 7.1. If the device display can be turned off during a phone call then that may be done during the measurement as well.

Measurements shall be performed at two locations specified in A.3, with the correct probe orientation for a particular location, in a multistage sequence by first measuring the field intensity of the desired T-Coil signal (ABM1) that is useful to a hearing aid T-Coil. The undesired magnetic components (ABM2) must be measured at the same location as the desired ABM or T-Coil signal (ABM1), and the ratio of desired to undesired ABM signals must be calculated. For the perpendicular field location, only the ABM1 frequency response shall be determined in a third measurement stage. The flow chart in Figure 7.3 illustrates this three-stage, two orientation process.

The following steps summarize the basic test flow for determining ABM1<sup>1</sup> and ABM2<sup>2</sup>. These steps assume that a sine wave or narrowband 1/3 octave signal can be used for the measurement of ABM1.

- a. A validation of the test setup and instrumentation may be performed using a TMFS or Helmholtz coil. Measure the emissions and confirm that they are within the specified tolerance.
- b. Position the WD in the test setup and connect the WD RF connector to a base station simulator or a non-radiating load as shown in Figure 7.1 or Figure 7.2. Confirm that equipment that requires calibration has been calibrated, and that the noise level meets the requirements given in 7.3.1.
- c. The drive level to the WD is set such that the reference input level specified in Table 7.1 is input to the base station simulator (or manufacturer's test mode equivalent) in the 1 kHz, 1/3 octave band. This drive level shall be used for the T-Coil signal test (ABM1) at  $f = 1$  kHz. Either a sine wave at 1025 Hz or a voice-like signal, band-limited to the 1 kHz 1/3 octave, as defined in 7.4.2, shall be used for the reference audio signal. If interference is found at 1025 Hz an alternative nearby reference audio signal frequency may be used.<sup>46</sup> The same drive level will be used for the ABM1 frequency response measurements at each 1/3 octave band center frequency. The WD volume control may be set at any level up to maximum, provided that a signal at any frequency at maximum modulation would not result in clipping or signal overload.
- d. Determine the magnetic measurement locations for the WD device (A.3), if not already specified by the manufacturer, as described in 7.4.4.1.1 and 7.4.4.2.

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<sup>1</sup> **Audio Band Magnetic signal - desired (ABM1):** Measured quantity of the desired magnetic signal

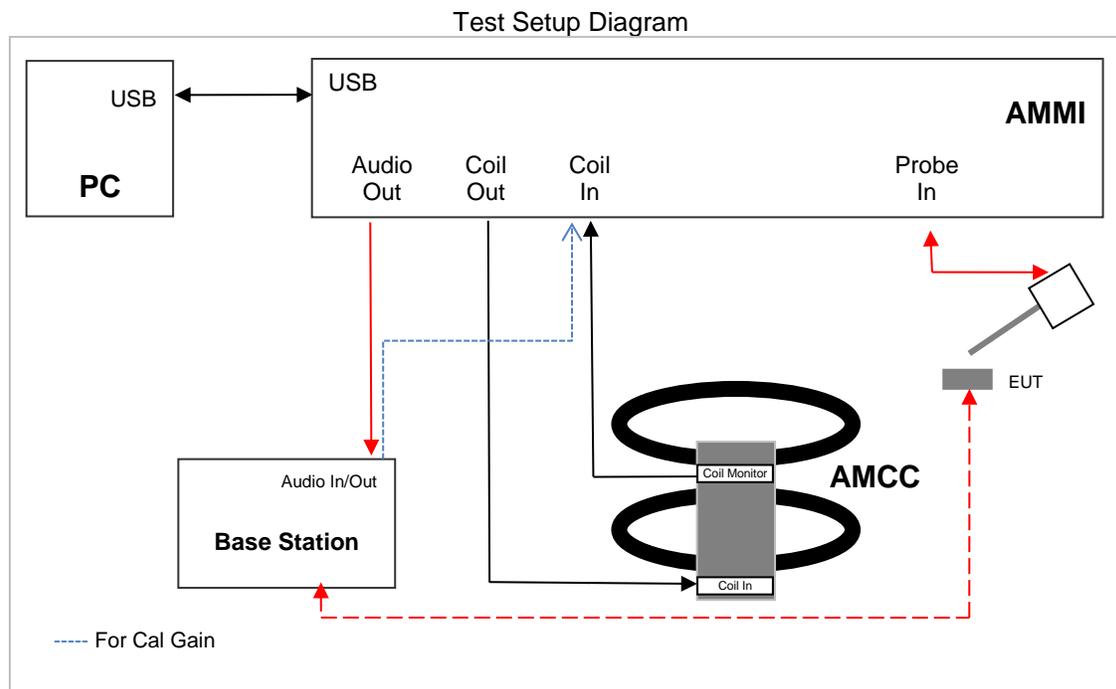
<sup>2</sup> **Audio Band Magnetic signal - undesired (ABM2):** Measured quantity of the undesired magnetic signal, such as interference from battery current and similar non-signal elements.

- e. At each measurement location, measure and record the desired T-Coil magnetic signals (ABM1 at  $f_i$ ) as described in 7.4.4.2 in each individual ISO 266-1975 R10 standard 1/3 octave band. The desired audio band input frequency ( $f_i$ ) shall be centered in each 1/3 octave band maintaining the same drive level as determined in item c) and the reading taken for that band.

Equivalent methods of determining the frequency response may also be employed, such as fast Fourier transform (FFT) analysis using noise excitation or input-output comparison using simulated speech. The full-band integrated or half-band integrated probe output, as specified in D.9, may be used, as long as the appropriate calibration curve is applied to the measured result, so as to yield an accurate measurement of the field magnitude. (The resulting measurement shall be an accurate measurement in dB A/m.)

All measurements of the desired signal shall be shown to be of the desired signal and not of an undesired signal. This may be shown by turning the desired signal ON and OFF with the probe measuring the same location. If the scanning method is used the scans shall show that all measurement points selected for the ABM1 measurement meet the ambient and test system noise criteria in 7.3.1.

- f. At the measurement location for each orientation, measure and record the undesired broadband audio magnetic signal (ABM2) as specified in 7.4.4.4 with no audio signal applied (or digital zero applied, if appropriate) using A-weighting and the half-band integrator. Calculate the ratio of the desired to undesired signal strength (i.e., signal quality).
- g. Obtain the data from the postprocessor, SEMCAD, and determine the category that properly classifies the signal quality based on Table 8.5.

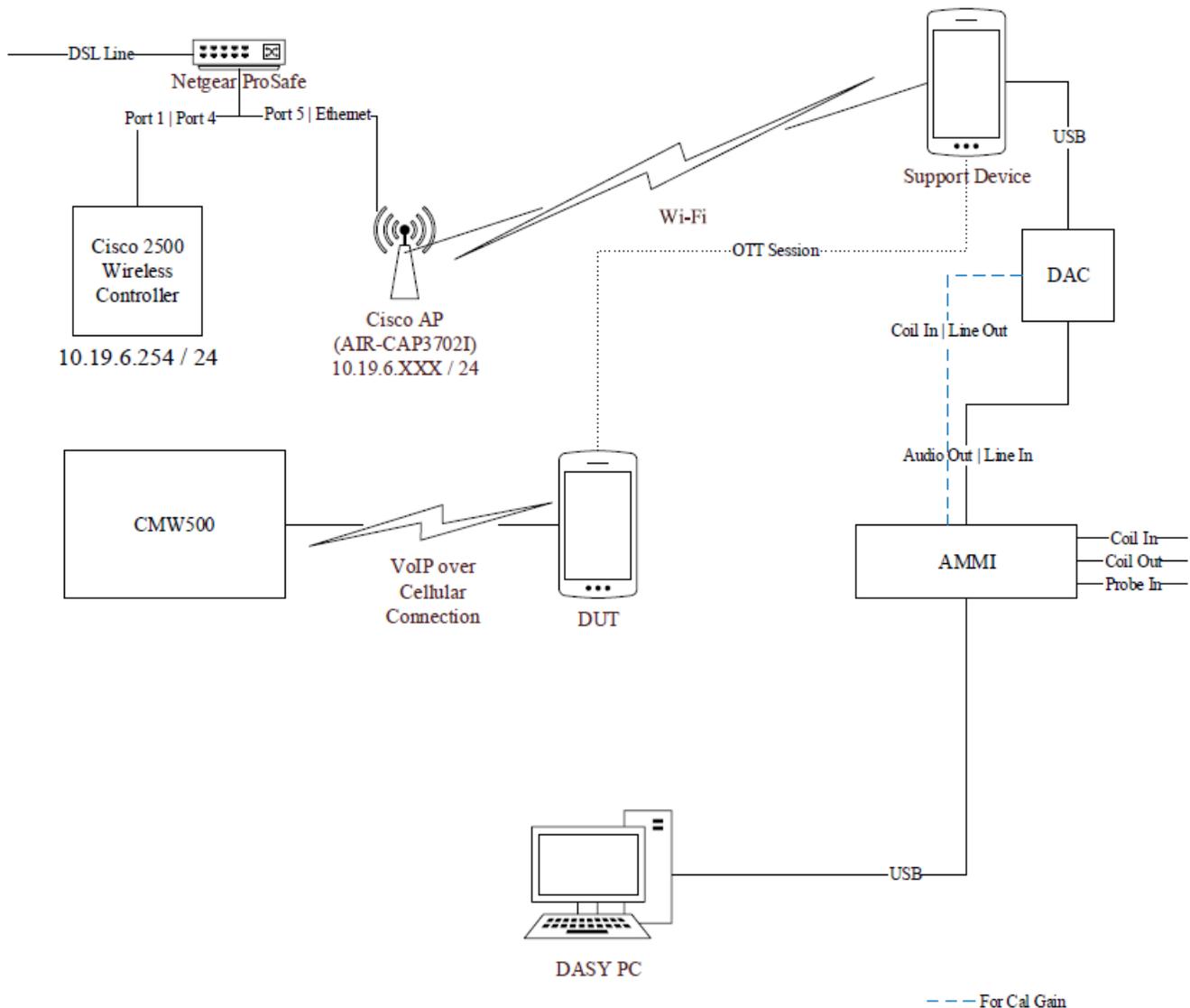


### 5.1. Over the Top (OTT)

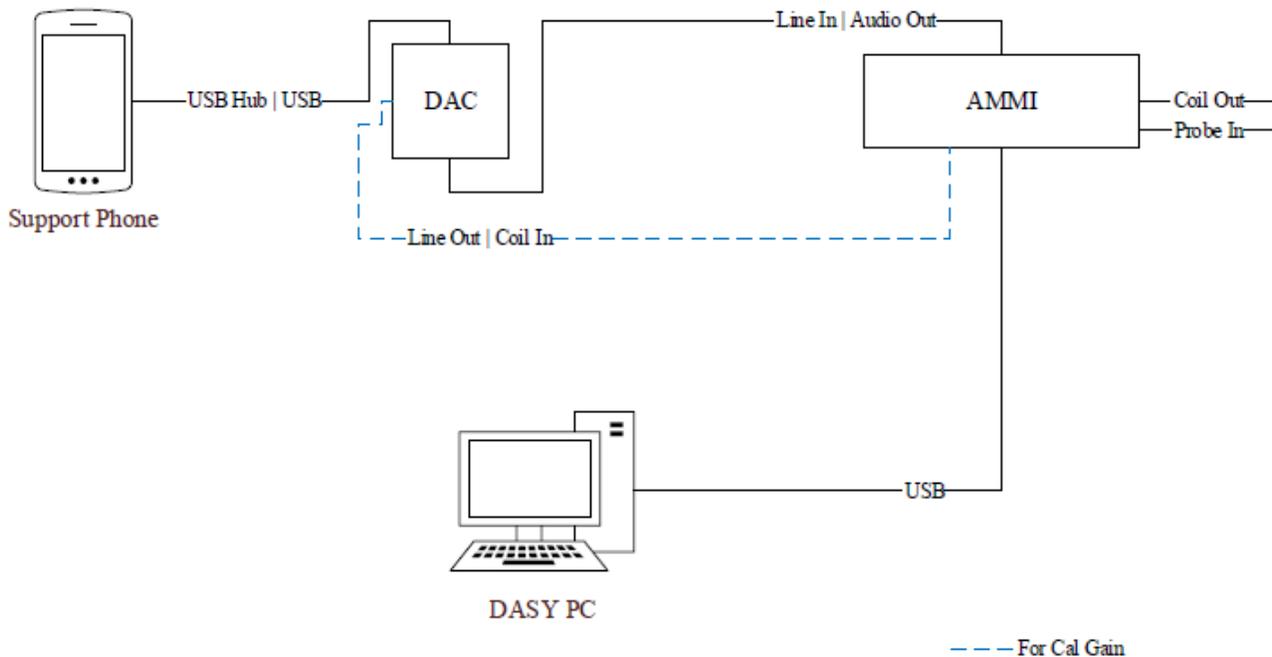
The test procedure for OTT testing is identical to the section above, except for how the signal is sent to the DUT, as outlined in the diagram below.

The AMMI is connected to an external ADC (Analog to Digital Converter) and the ADC is connected to the Support Device via USB. The Support Device and the DUT is connected to the Internet via Wi-Fi. Using the DUT's OTT application, a VoIP call is established with the Support Device. The test signal is sent from the DASY PC to the AMMI, from the AMMI to the ADC, from the ADC to the Support Device, and finally to the DUT. To exercise the license antenna, the DUT was simultaneously connected to an external AP and to a mobile base station. This is essentially the manufacturer's test mode method (C63.19 2011 §7.3.3) (C63.19 2007 §6.2.3) but with the audio wired signal injection replaced by the Wi-Fi connection.

Test Setup configuration for EGPRS, HSUPA and LTE



Test Setup configuration for Wi-Fi



## 6. Audio Level and Gain Measurements

### GSM

No correction gain factors were measured for GSM due to the Rohde & Schwarz CMW500, hosting a calibrated audio board. Refer to the below table for the gains used to measure GSM.

Signal Type	Audio Level [dBm0]	Gain [dB]	Gain [linear]
Voice 1 kHz	-16.00	27.72	<b>24.32</b>
Voice 300 - 3 kHz	-16.00	33.57	<b>47.70</b>

### W-CDMA

No correction gain factors were measured for W-CDMA due to the Rohde & Schwarz CMW500, hosting a calibrated audio board. Refer to the below table for the gains used to measure W-CDMA.

Signal Type	Audio Level [dBm0]	Gain [dB]	Gain [linear]
Voice 1 kHz	-16.00	27.72	<b>24.32</b>
Voice 300 - 3 kHz	-16.00	33.57	<b>47.70</b>

### VoLTE

No correction gain factors were measured for VoLTE due to the Rohde & Schwarz CMW500, hosting a calibrated audio board. Refer to the below table for the gains used to measure VoLTE.

The following software/firmware was used to simulate the VoLTE server for testing:

Firmware	License Keys	Software Name
V3.7.30 for LTE	KS500	LTE FDD R8 SIG BASIC
	KS550	LTE TDD R8 SIG BASIC
V3.7.20 for Audio	KA100	IP APPL ENABLING IPv4
	KA150	IP APPL ENABLING IPv4
	KAA20	IP APPL IMS BASIC
	KM050	DATA APPL MEAS

Signal Type	Audio Level [dBm0]	Gain [dB]	Gain [linear]
Voice 1 kHz	-16.00	27.72	<b>24.32</b>
Voice 300 - 3 kHz	-16.00	33.57	<b>47.70</b>

**VoWi-Fi**

No correction gain factors were measured for VoWi-Fi due to the Rohde & Schwarz CMW500, hosting a calibrated audio board. Refer to the below table for the gains used to measure VoWi-Fi.

Firmware	License Keys	Software Name
V3.7.50 for WLAN	KS650	WLAN A/B/G SIG BASIC
	KS651	WLAN N SIG BASIC
	KS656	WLAN IEEE 802.11ac
V3.7.20 for Audio	KA100	IP APPL ENABLING IPv4
	KA150	IP APPL ENABLING IPv4
	KAA20	IP APPL IMS BASIC
	KM050	DATA APPL MEAS

Signal Type	Audio Level [dBm0]	Gain [dB]	Gain [linear]
Voice 1 kHz	-20.00	23.72	<b>15.35</b>
Voice 300 - 3 kHz	-20.00	29.57	<b>30.09</b>

**Over the Top (OTT)**

For EDGE, HSPA, LTE, and Wi-Fi, the linear gain levels listed below were used. The results below are based on a reference input level of -20 dBm0. Granted, the C63.19-2011 interpretation for T-coil audio levels for LTE states that an input reference level of -16 dBm0 should be used, we, the test lab, opted for -20 dBm0 for LTE due to it being a more conservative input reference level.

The adjusted gain measurements are based on an external Analogue to Digital Converter (ADC), where the signal is sent from the AMMI to the ADC, then to the DUT via Wi-Fi.

To calibrate the ADC, three .wav audio files (sine wave, 1 kHz voice, and 300 to 3 kHz voice) are sent from the DASY5 PC to the AMMI, then to the ADC. The Helmholtz resonator measures the field strength, which represents the AMMI to ADC input sensitivity. After determining the input sensitivity, the adjusted linear gain values can then be calculated.

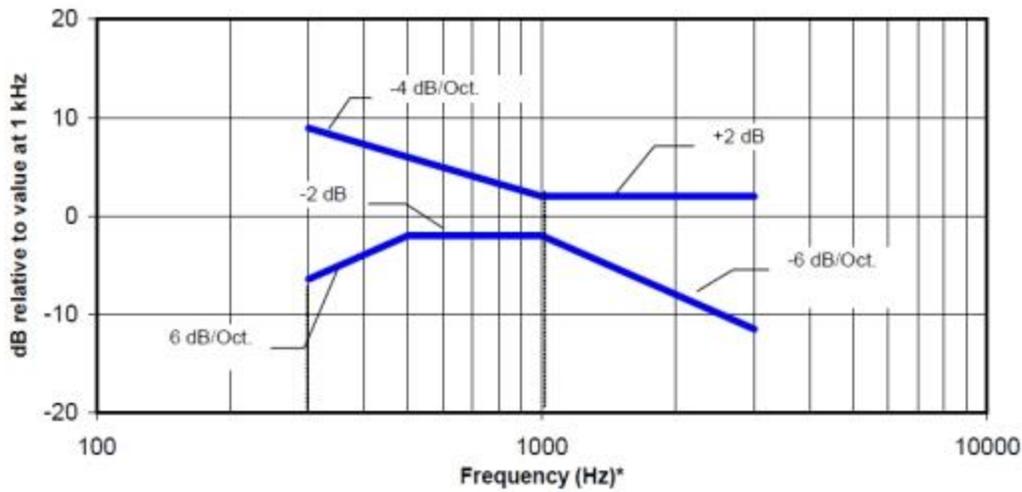
Signal Type	Audio Level [dBm0]	Gain [dB]	Gain [linear]
Voice 1 kHz	-20.00	26.22	<b>20.46</b>
Voice 300 - 3 kHz	-20.00	32.06	<b>40.07</b>

## 7. T-coil Measurement Criteria

### 7.1. Frequency Response

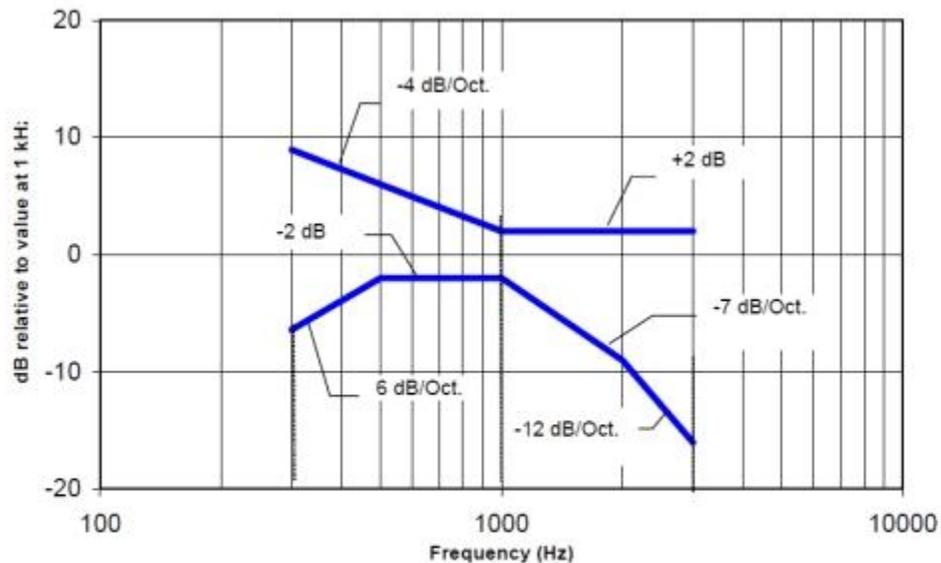
The frequency response of the axial component of the magnetic field, measured in 1/3 octave bands, shall follow the response curve, over the frequency range 300 Hz to 3000 Hz.

Figure 8.1 and Figure 8.2 provide the boundaries for the specified frequency. These response curves are for true field strength measurements of the T-Coil signal. Thus the 6 dB/octave probe response has been corrected from the raw readings.



NOTE—The frequency response is between 300 Hz and 3000 Hz.

**Figure 8.1—Magnetic field frequency response for WDs with field strength  $\leq -15$  dB (A/m) at 1 kHz**



NOTE—The frequency response is between 300 Hz and 3000 Hz.

**Figure 8.2—Magnetic field frequency response for WDs with a field that exceeds  $-15$  dB(A/m) at 1 kHz**

## 7.2. Signal to Noise

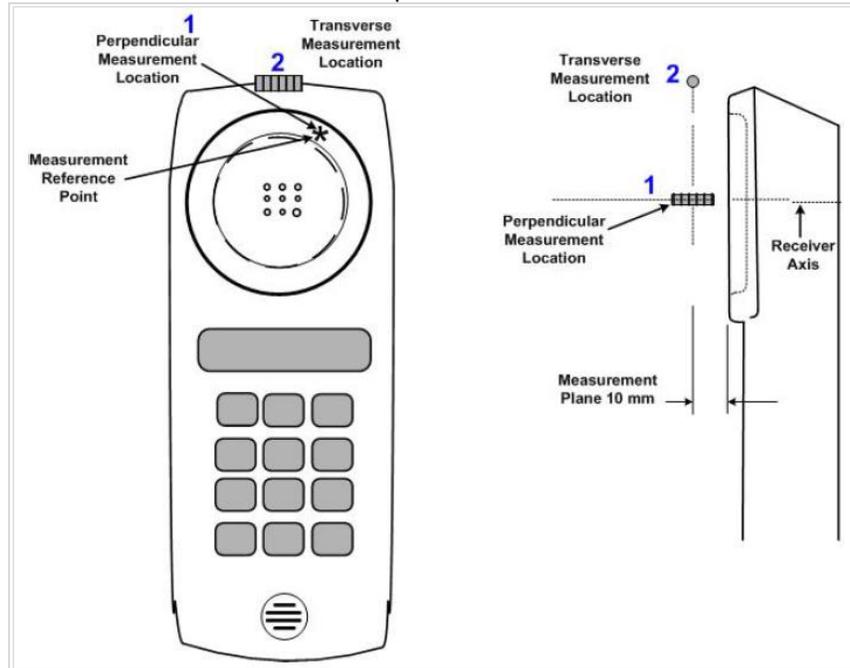
This specifies the signal-to-noise quality requirement for the intended T-Coil signal from a WD. The worst signal to noise of the two T-Coil signal measurements, as determined in Clause 7, shall be used to determine the T-Coil mode category per Table 8.5.

Only the RF immunity of the hearing aid is measured in T-Coil mode. It is assumed that a hearing aid can have no immunity to an interference signal in the audio band, which is the intended reception band for this mode. So, the only criterion that can be measured is the RF immunity in T-Coil Mode. This is measured using the same procedure as for the audio coupling mode and at the same levels as specified in 6.4.

**Table 8.5—T-Coil signal-to-noise categories**

Category	Telephone parameters WD signal quality [(signal + noise)-to-noise ratio in decibels]
Category T1	0 dB to 10 dB
Category T2	10 dB to 20 dB
Category T3	20 dB to 30 dB
Category T4	>30 dB

Measurement locations and reference plane to be used for the T-coil measurements



### 8. Device Under Test

Normal operation	Held to head				
Back Cover	Normal Battery Cover				
Test sample information	<table border="0" style="width: 100%;"> <tr> <td style="text-align: center;"><b>S/N</b></td> <td style="text-align: center;"><b>Notes</b></td> </tr> <tr> <td style="text-align: center;">R38M109WB1R</td> <td style="text-align: center;">T-coil Test</td> </tr> </table>	<b>S/N</b>	<b>Notes</b>	R38M109WB1R	T-coil Test
<b>S/N</b>	<b>Notes</b>				
R38M109WB1R	T-coil Test				

#### 8.1. Air Interfaces and Operating Mode

Air Interface	Bands (MHz)	Type	C63.19 Tested	Simultaneous Transmitter	OTT Testing Required? Name of Voice Service	Audio Codecs Evaluated
GSM	850	VO	Yes	Wi-Fi and BT	NA	EFR
	1900					
	GPRS/EDGE	VD	Yes	Wi-Fi and BT	Yes Google Duo <sup>2</sup>	OPUS
W-CDMA (UMTS)	850 (V)	VO	Yes	Wi-Fi and BT	NA	AMR-NB & AMR-WB
	1700 (IV)					
	1900 (II)	VD	Yes	Wi-Fi and BT	Yes Google Duo <sup>2</sup>	OPUS
HSPA						
LTE - FDD	700 (B12/14)	VD	Yes	Wi-Fi and BT	Yes <sup>1</sup> Google Duo <sup>2</sup>	AMR-NB, AMR-WB and OPUS
	850 (B5)					
	1700 (B4/66)					
	1900 (B2)					
	2300 (B30)					
	2600 (B7)					
LTE - TDD	2300 (B40)	VD	Yes	Wi-Fi and BT	Yes <sup>1</sup> Google Duo <sup>2</sup>	AMR-NB, AMR-WB and OPUS
	2500 (B38/41)					
Wi-Fi	2450	VD	Yes	WWAN and Wi-Fi 5GHz	Yes Wi-Fi calling Google Duo <sup>2</sup>	AMR-NB, AMR-WB and OPUS
	5200 (U-NII-1)			WWAN, Wi-Fi 2.4GHz and BT		
	5300 (U-NII-2A)					
	5500 (U-NII-2C)					
	5800 (U-NII-3)					
BT	2450	DT	NA	WWAN and Wi-Fi 5GHz	NA	NA

Type VO: Legacy Cellular Voice Service DT: Digital Transport only (no voice) VD: IP Voice Service over Digital Transport BT: Bluetooth	Note: 1. Ref Lev in accordance with the July 2012 VoLTE interpretatio 2. Ref Lev -20 dBm0
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## 9. HAC (T-coil) Test Results

### 9.1. Antenna Investigation

The testing was performed at the worst case of VoWi-Fi SNR on the WiFi Ant1 and WiFi Ant2 for WLAN to confirm that there were no unexpected variations between the antennas, a difference of 3dB was used as the threshold.

Mode:	Channel and Frequency	Data Rate	Antenna	Orientation	ABM1 dB(A/m)	ABM2 dB(A/m)	Ambient Noise dB(A/m)	Freq. Response (dB)	ABM SNR (dB)	T-Rating	Delta (WiFi Ant1 v. Ant2)
802.11a Voice Codec : AMR-NB 12.2 kbit/s	CH.40 5200 MHz	64QAM 54 Mbps	WiFi Ant1	z (Axial)	0.66	-5.25	-50.89	1.71	<b>33.30</b>	T4	-0.88
				y (Transverse)	-9.09	-15.41	-50.90		38.82	T4	
			WiFi Ant2	z (Axial)	0.41	-4.05	-50.89	1.82	34.18	T4	
				y (Transverse)	-10.01	-12.90	-50.90		36.88	T4	

### 9.2. Codec Investigation

An investigation between the various codec configurations (Low/High bit rates for Narrowband, Wideband) and specific parameters are documented (ABM1, ABM2, S+N/N, frequency response) to determine the worst-case bit rates for each voice service type. The table below compares the varying codec configurations. A codec investigation was performed on one band of each GSM, W-CDMA, LTE FDD/TDD.

The highlighted results below were determined to be the worst case codec configuration(s) for GSM, W-CDMA and LTE.

Codec Investigation				
Codec State	AMR-NB (kbit/s)		Orientation	Band/ Channel
	FR V1	HR V1		
ABM1 (dB/m)	-4.14	-2.78	z (Axial)	GSM 850 CH.190
ABM2 (dBA/m)	-8.38	-10.78		
S+N/N (dB)	<b>39.30</b>	41.21		
Freq. Resposne (dB)	2.00	1.98		

Codec Investigation						
Codec State	AMR-NB (kbit/s)		AMR-WB (kbit/s)		Orientation	Band/ Bandwidth/ Channel
	4.75	12.2	6.6	23.85		
ABM1 (dB/m)	-4.53	-4.41	-3.47	-2.92	z (Axial)	WCDMA Band IV Rel.99 CH.1413
ABM2 (dBA/m)	-24.04	-15.11	-20.53	-20.67		
S+N/N (dB)	43.04	43.28	<b>42.30</b>	42.92		
Freq. Resposne (dB)	2.00	1.20	1.63	1.98		
ABM1 (dB/m)	-6.80	-4.76	-4.10	-5.06	z (Axial)	LTE Band 2 CH.18900 20 MHz BW QPSK RB 1/0
ABM2 (dBA/m)	-22.27	-22.04	-19.49	-19.40		
S+N/N (dB)	40.10	40.61	<b>39.95</b>	40.48		
Freq. Resposne (dB)	1.40	1.04	1.96	1.78		
ABM1 (dB/m)	-2.33	-1.92	-0.17	0.90	z (Axial)	LTE Band 41 CH.40620 20 MHz BW QPSK RB 1/0
ABM2 (dBA/m)	-16.11	-14.41	-16.15	-16.15		
S+N/N (dB)	<b>41.28</b>	41.56	42.06	42.96		
Freq. Resposne (dB)	2.00	1.10	2.00	2.00		

### 9.3. Air Interface Investigation

Use the worst-case codec test and document a limited set of bands/modulations/channels/bandwidth. Observe the effect of changing the band and bandwidth to ensure that there are no unexpected variations.

#### GSM / W-CDMA (UMTS)

Mode:	Channel and Frequency	Orientation	ABM1 dB(A/m)	ABM2 dB(A/m)	Ambient Noise dB(A/m)	Freq. Response (dB)	ABM SNR (dB)	T-Rating
GSM 850 Voice Coder Speech Codec: FR V1	CH.190 836.6 MHz	z (Axial)	-4.14	-8.38	-51.13	2.00	39.30	T4
		y (Transversal)	-12.27	-9.77	-51.11		34.96	T4
GSM 1900 Voice Coder Speech Codec: FR V1	CH.512 1850.2 MHz	z (Axial)	-3.74	-7.31	-50.90	1.58	38.60	T4
		y (Transversal)	-12.83	-9.16	-50.93		<b>34.48</b>	T4
	CH.661 1880.0 MHz	z (Axial)	-3.89	-7.78	-50.90	1.14	38.54	T4
		y (Transversal)	-13.04	-9.60	-50.93		34.64	T4
	CH.810 1909.8 MHz	z (Axial)	-3.71	-9.21	-50.90	1.35	39.17	T4
		y (Transversal)	-12.79	-10.89	-50.93		35.15	T4
W-CDMA Band IV Voice Wideband AMR Codec: 6.6 kbit/s	CH.1312 1712.4 MHz	z (Axial)	-4.53	-20.43	-50.91	1.91	41.09	T4
		y (Transversal)	-13.04	-25.16	-50.93		37.02	T4
	CH.1413 1732.6 MHz	z (Axial)	-3.47	-20.53	-50.91	1.63	42.30	T4
		y (Transversal)	-12.96	-27.35	-50.93		37.05	T4
	CH.1513 1752.6 MHz	z (Axial)	-4.37	-18.75	-50.91	2.00	41.29	T4
		y (Transversal)	-13.57	-24.33	-50.93		<b>36.48</b>	T4
W-CDMA Band II Voice Wideband AMR Codec: 6.6 kbit/s	CH.9400 1880.0 MHz	z (Axial)	-3.55	-20.41	-50.91	2.00	42.45	T4
		y (Transversal)	-12.30	-25.12	-50.93		37.76	T4
W-CDMA Band V Voice Wideband AMR Codec: 6.6 kbit/s	CH.4183 836.6 MHz	z (Axial)	-4.25	-20.50	-50.91	1.48	41.77	T4
		y (Transversal)	-13.39	-27.07	-50.93		37.20	T4

### Air Interface Investigation (Continued)

LTE - FDD

Mode:	Channel and Frequency	Bandwidth	Bandwidth / Modulation	RB configuration	Orientation	ABM1 dB(A/m)	ABM2 dB(A/m)	Ambient Noise dB(A/m)	Freq. Response (dB)	ABM SNR (dB)	T-Rating	
LTE Band 2 Voice Wideband AMR Codec: 6.6 kbit/s	CH.18900 1880 MHz	20MHz	QPSK	1/0	z (Axial)	-4.10	-19.49	-51.01	1.96	39.95	T4	
					y (Transversal)	-12.73	-16.93	-51.04		36.37	T4	
				1/49	z (Axial)	-3.77	-18.68	-51.01	2.00	39.33	T4	
					y (Transversal)	-13.04	-25.01	-51.04		36.75	T4	
				1/99	z (Axial)	-3.57	-18.21	-51.01	1.85	39.54	T4	
					y (Transversal)	-12.54	-24.92	-51.04		36.60	T4	
				50/0	z (Axial)	-4.06	-16.63	-51.01	1.76	38.29	T4	
					y (Transversal)	-13.36	-19.77	-51.04		36.42	T4	
				50/24	z (Axial)	-3.79	-17.91	-51.01	2.00	39.33	T4	
					y (Transversal)	-12.82	-25.22	-51.04		36.89	T4	
				50/50	z (Axial)	-5.27	-18.66	-51.01	2.00	38.06	T4	
					y (Transversal)	-13.81	-25.19	-51.04		36.38	T4	
				100/0	z (Axial)	-4.20	-16.97	-51.01	2.00	39.07	T4	
					y (Transversal)	-13.10	-25.28	-51.04		36.59	T4	
				16QAM	1/0	z (Axial)	-4.08	-18.17	-51.01	1.77	38.13	T4
						y (Transversal)	-13.28	-19.24	-51.04		35.66	T4
		64QAM	1/0	z (Axial)	-3.65	-19.33	-50.97	2.00	39.57	T4		
				y (Transversal)	-12.20	-20.89	-50.95		37.01	T4		
		15 MHz	1/0	z (Axial)	-4.61	-16.44	-50.97	2.00	39.47	T4		
				y (Transversal)	-12.32	-20.30	-50.95		37.47	T4		
		10 MHz	1/0	z (Axial)	-3.60	-19.98	-50.97	2.00	40.55	T4		
				y (Transversal)	-12.62	-19.16	-50.95		36.89	T4		
		5 MHz	1/0	z (Axial)	-3.57	-11.79	-50.97	2.00	40.19	T4		
				y (Transversal)	-12.73	-23.66	-50.95		36.46	T4		
		3 MHz	1/0	z (Axial)	-4.02	-18.34	-50.97	1.94	39.56	T4		
				y (Transversal)	-12.90	-25.87	-50.95		36.62	T4		
		1.4 MHz	1/0	z (Axial)	-4.09	-19.69	-50.97	2.00	40.83	T4		
				y (Transversal)	-12.84	-18.33	-50.95		36.74	T4		

### Air Interface Investigation (Continued)

#### LTE - FDD

Mode:	Channel and Frequency	Bandwidth	Bandwidth / Modulation	RB configuration	Orientation	ABM1 dB(A/m)	ABM2 dB(A/m)	Ambient Noise dB(A/m)	Freq. Response (dB)	ABM SNR (dB)	T-Rating
LTE Band 5 Voice Wideband AMR Codec: 6.6 kbit/s	CH.20525 836.5 MHz	10 MHz	16QAM	1/0	z (Axial)	-4.87	-19.26	-50.97	2.00	38.53	T4
					y (Transversal)	-13.66	-20.60	-50.95		36.11	T4
LTE Band 7 Voice Wideband AMR Codec: 6.6 kbit/s	CH.21100 2535 MHz	20 MHz	16QAM	1/0	z (Axial)	-5.40	-14.45	-50.97	1.68	36.85	T4
					y (Transversal)	-13.01	-22.87	-50.95		36.27	T4
LTE Band 12 Voice Wideband AMR Codec: 6.6 kbit/s	CH.23060 704 MHz	10 MHz	16QAM	1/0	z (Axial)	-4.87	-18.86	-50.97	1.98	38.37	T4
					y (Transversal)	-13.75	-25.44	-50.95		35.06	T4
	CH.23095 707.5 MHz			1/0	z (Axial)	-4.32	-17.57	-50.97	1.90	38.70	T4
					y (Transversal)	-13.74	-23.80	-50.95		35.37	T4
	CH.23130 711 MHz			1/0	z (Axial)	-5.13	-18.98	-50.97	2.00	37.91	T4
					y (Transversal)	-13.64	-25.38	-50.95		35.39	T4
LTE Band 30 Voice Wideband AMR Codec: 6.6 kbit/s	CH.27710 2310 MHz	10 MHz	16QAM	1/0	z (Axial)	-5.08	-19.35	-50.97	2.00	38.23	T4
					y (Transversal)	-13.66	-25.79	-50.95		35.54	T4
LTE Band 66 Voice Wideband AMR Codec: 6.6 kbit/s	CH.20525 836.5 MHz	20 MHz	16QAM	1/0	z (Axial)	-4.56	-14.77	-50.97	1.80	38.11	T4
					y (Transversal)	-13.98	-24.61	-50.95		35.45	T4

### Air Interface Investigation (Continued)

LTE - TDD

Mode:	Channel and Frequency	Bandwidth	Bandwidth / Modulation	RB configuration	Orientation	ABM1 dB(A/m)	ABM2 dB(A/m)	Ambient Noise dB(A/m)	Freq. Response (dB)	ABM SNR (dB)	T-Rating	
LTE Band 40 Voice NB AMR Codec: 4.75 kbit/s	CH.38750 2310 MHz	10MHz	QPSK	1/0	z (Axial)	3.43	-13.18	-50.54	1.28	45.48	T4	
					y (Transversal)	-6.21	-22.13	-50.63		41.19	T4	
LTE Band 41 Voice NB AMR Codec: 4.75 kbit/s	CH.40620 2593 MHz	20MHz	QPSK	1/0	z (Axial)	-2.33	-16.11	-50.85	2.00	41.28	T4	
					y (Transversal)	-13.63	-21.64	-50.90		<b>34.84</b>	T4	
				1/49	z (Axial)	-2.58	-15.90	-50.85	1.56	40.75	T4	
					y (Transversal)	-12.29	-22.62	-50.90		36.22	T4	
				1/99	z (Axial)	-2.82	-14.95	-50.85	2.00	39.56	T4	
					y (Transversal)	-12.92	-23.55	-50.90		35.82	T4	
				50/0	z (Axial)	-3.41	-17.49	-50.85	1.20	40.68	T4	
					y (Transversal)	-12.55	-25.82	-50.90		35.66	T4	
				50/24	z (Axial)	-3.49	-17.21	-50.85	2.00	40.38	T4	
					y (Transversal)	-12.20	-25.47	-50.90		35.68	T4	
				50/50	z (Axial)	-3.21	-16.93	-50.85	1.18	40.52	T4	
					y (Transversal)	-12.38	-25.07	-50.90		35.78	T4	
				100/0	z (Axial)	-3.26	-17.31	-50.85	1.22	40.68	T4	
					y (Transversal)	-12.31	-25.34	-50.90		35.77	T4	
				16QAM	1/0	z (Axial)	-3.57	-17.30	-50.85	1.12	40.45	T4
						y (Transversal)	-13.03	-24.59	-50.90		35.27	T4
				64QAM	1/0	z (Axial)	-3.95	-18.26	-50.85	1.89	40.51	T4
						y (Transversal)	-13.52	-16.11	-50.90		35.17	T4
		15 MHz	1/0	z (Axial)	-3.57	-16.83	-50.85	1.56	40.27	T4		
				y (Transversal)	-3.57	-24.13	-50.90		35.10	T4		
		10 MHz	1/0	z (Axial)	-3.42	-16.09	-50.85	1.43	40.56	T4		
				y (Transversal)	-12.93	-21.25	-50.90		35.28	T4		
		5 MHz	1/0	z (Axial)	-3.48	-15.54	-50.85	2.00	39.88	T4		
				y (Transversal)	-12.41	-23.48	-50.90		35.11	T4		
CH.39750 2506 MHz	20 MHz	QPSK	1/0	z (Axial)	-2.57	-14.37	-50.91	1.87	40.50	T4		
				y (Transversal)	-11.77	-20.54	-50.93		36.22	T4		
CH.40185 2549.5 MHz	20 MHz	QPSK	1/0	z (Axial)	-2.63	-14.28	-50.91	1.13	40.42	T4		
				y (Transversal)	-12.64	-23.18	-50.93		35.41	T4		
CH.41055 2636.5 MHz	20 MHz	QPSK	1/0	z (Axial)	-2.86	-13.32	-50.91	1.34	39.30	T4		
				y (Transversal)	-12.64	-22.12	-50.93		35.25	T4		
CH.41490 2680 MHz	20 MHz	QPSK	1/0	z (Axial)	-3.55	-18.26	-50.91	2.00	40.85	T4		
				y (Transversal)	-12.61	-25.91	-50.93		35.07	T4		

### 9.4. VoWi-Fi Codec Investigation

An investigation between the various codec configurations (Low/High bit rates for Narrowband, Wideband) and specific parameters are documented (ABM1, ABM2, S+N/N, frequency response) to determine the worst-case bit rates for each voice service type. The table below compares the varying codec configurations. A codec investigation was performed for each Wi-Fi 2.4GHz and 5GHz. The highlighted results below were determined to be the worst case codec configuration(s) for Wi-Fi 2.4GHz and 5GHz

Codec Investigation						
Codec State	AMR-NB (kbit/s)		AMR-WB (kbit/s)		Orientation	Band/ BandWidth/ Channel
	4.75	12.2	6.6	23.85		
ABM1 (dB/m)	0.50	0.75	0.79	1.00	z (Axial)	802.11b CH.6 2412 MHz DSSS 1 Mbps
ABM2 (dBA/m)	-9.70	-7.55	-9.20	-9.26		
S+N/N (dB)	33.65	<b>33.44</b>	35.32	35.63		
Freq. Resposne (dB)	2.00	1.82	2.00	1.82		
ABM1 (dB/m)	0.13	0.87	0.53	1.11	z (Axial)	802.11a CH.40 5200 MHz BPSK 6 Mbps
ABM2 (dBA/m)	-6.31	-8.31	-7.68	-6.38		
S+N/N (dB)	35.49	<b>34.73</b>	35.75	35.03		
Freq. Resposne (dB)	2.00	1.92	2.00	2.00		

### 9.5. VoWi-Fi Air Interface Investigation

Using the data from §9.4, further testing was performed on the remaining 802.11 modes. The objective of these measurements is to ensure that changing the modulation, bandwidth, and data rate, whilst using the worst case codec configuration measured in §9.4, yields no unexpected variations.

Mode:	Channel and Frequency	Bandwidth	Bandwidth / Modulation	Orientation	ABM1 dB(A/m)	ABM2 dB(A/m)	Ambient Noise dB(A/m)	Freq. Response (dB)	ABM SNR (dB)	T-Rating
802.11b codec: AMR-NB 12.2 kbit/s	CH.6 2437 MHz	20 MHz	DSSS 1 Mbps	z (Axial)	0.75	-7.55	-51.35	1.82	<b>33.44</b>	T4
				y (Transversal)	-11.05	-13.75	-51.41		37.06	T4
			CCK 5.5 Mbps	z (Axial)	1.33	-7.86	-51.35	1.64	35.62	T4
				y (Transversal)	-8.57	-12.65	-51.41		39.04	T4
CCK 11 Mbps	z (Axial)	1.25	-10.77	-51.35	2.00	36.71	T4			
	y (Transversal)	-11.28	-15.15	-51.41		37.65	T4			
802.11g codec: AMR-NB 12.2 kbit/s	CH.6 2437 MHz	20 MHz	64QAM 54 Mbps	z (Axial)	1.22	-7.68	-51.35	1.81	34.00	T4
				y (Transversal)	-8.92	-14.27	-51.41		37.78	T4
802.11n HT20 codec: AMR-NB 12.2 kbit/s	CH.6 2437 MHz	20 MHz	MCS 7 65 Mbps	z (Axial)	1.10	-8.84	-51.35	1.95	35.78	T4
				y (Transversal)	-9.06	-15.55	-51.41		38.61	T4

### VoWi-Fi Air Interface Investigation (Continued)

Mode:	Channel and Frequency	Bandwidth	Bandwidth / Modulation	Orientation	ABM1 dB(A/m)	ABM2 dB(A/m)	Ambient Noise dB(A/m)	Freq. Response (dB)	ABM SNR (dB)	T-Rating
802.11a codec: AMR-NB 12.2 kbit/s	CH.40 5200 MHz	20 MHz	BPSK 6 Mbps	z (Axial)	0.87	-8.31	-51.13	1.92	34.73	T4
				y (Transversal)	-9.40	-14.03	-51.11		37.16	T4
			QPSK 18 Mbps	z (Axial)	0.40	-9.73	-51.13	1.92	35.66	T4
				y (Transversal)	-10.09	-15.56	-51.11		37.53	T4
			64QAM 54 Mbps	z (Axial)	0.66	-5.25	-51.13	1.71	<b>33.30</b>	T4
				y (Transversal)	-9.09	-15.41	-51.11		38.82	T4
802.11n HT20 codec: AMR-NB 12.2 kbit/s	CH.40 5200 MHz	20 MHz	MCS 0 6.5 Mbps	z (Axial)	-0.64	-8.14	-51.13	1.78	34.60	T4
				y (Transversal)	-9.99	-15.68	-51.11		36.36	T4
			MCS 3 26 Mbps	z (Axial)	-0.12	-8.98	-51.13	1.92	34.81	T4
				y (Transversal)	-9.38	-13.10	-51.11		37.83	T4
			MCS 7 65 Mbps	z (Axial)	1.45	-5.26	-51.13	1.75	34.34	T4
				y (Transversal)	-9.85	-14.13	-51.11		37.75	T4
802.11n HT40 codec: AMR-NB 12.2 kbit/s	CH.38 5190 MHz	40 MHz	MCS 0 13.5 Mbps	z (Axial)	1.23	-7.07	-51.13	1.99	34.74	T4
				y (Transversal)	-9.45	-13.50	-51.11		37.61	T4
			MCS 3 54 Mbps	z (Axial)	-0.49	-10.68	-51.13	1.86	35.36	T4
				y (Transversal)	-9.26	-16.28	-51.11		38.74	T4
			MCS 7 135 Mbps	z (Axial)	1.25	-9.88	-51.13	1.86	36.90	T4
				y (Transversal)	-9.21	-13.86	-51.11		37.93	T4

**VoWi-Fi Air Interface Investigation (Continued)**

Mode:	Channel and Frequency	Bandwidth	Bandwidth / Modulation	Orientation	ABM1 dB(A/m)	ABM2 dB(A/m)	Ambient Noise dB(A/m)	Freq. Response (dB)	ABM SNR (dB)	T-Rating
802.11ac VHT20 codec: AMR-NB 12.2 kbit/s	CH.40 5200 MHz	20 MHz	MCS 0 6.5 Mbps	z (Axial)	0.71	-5.71	-51.13	1.71	35.91	T4
				y (Transversal)	-10.38	-12.41	-51.11		38.23	T4
			MCS 4 39 Mbps	z (Axial)	1.08	-6.25	-51.13	1.81	33.48	T4
				y (Transversal)	-8.86	-13.56	-51.11		38.82	T4
			MCS 8 78 Mbps	z (Axial)	1.04	-10.29	-51.13	1.68	33.85	T4
				y (Transversal)	-8.43	-13.21	-51.11		39.28	T4
802.11ac VHT40 codec: AMR-NB 12.2 kbit/s	CH.38 5190 MHz	40 MHz	MCS 0 13.5 Mbps	z (Axial)	1.05	-9.82	-51.35	1.88	35.70	T4
				y (Transversal)	-9.16	-15.41	-51.41		38.79	T4
			MCS 4 108 Mbps	z (Axial)	1.08	-7.77	-51.35	1.61	36.07	T4
				y (Transversal)	-9.39	-13.65	-51.41		38.11	T4
			MCS 9 180 Mbps	z (Axial)	0.38	-7.67	-51.35	1.95	35.81	T4
				y (Transversal)	-9.72	-16.36	-51.41		38.53	T4
802.11ac VHT80 codec: AMR-NB 12.2 kbit/s	CH.42 5210 MHz	80 MHz	MCS 0 29.3 Mbps	z (Axial)	0.52	-6.82	-51.35	1.83	35.35	T4
				y (Transversal)	-9.57	-16.16	-51.41		38.18	T4
			MCS 4 175.5 Mbps	z (Axial)	1.02	-7.70	-51.35	1.81	36.13	T4
				y (Transversal)	-9.08	-13.93	-51.41		38.37	T4
			MCS 9 390 Mbps	z (Axial)	0.88	-9.49	-51.35	1.78	35.58	T4
				y (Transversal)	-9.27	-15.98	-51.41		38.37	T4
802.11a codec: AMR-NB 12.2 kbit/s	CH.56 5280 MHz	20 MHz	64QAM 54 Mbps	z (Axial)	0.57	-5.32	-51.35	1.94	34.14	T4
	y (Transversal)			-10.05	-14.30	-51.41		37.87	T4	
	CH.116 5580 MHz			z (Axial)	0.80	-5.44	-51.35	1.78	35.99	T4
	y (Transversal)			-9.63	-13.41	-51.41		38.41	T4	
	CH.157 5785 MHz			z (Axial)	0.74	-9.16	-51.35	1.79	35.78	T4
	y (Transversal)			-9.47	-13.25	-51.41		38.40	T4	
	CH.36 5180 MHz			z (Axial)	1.17	-5.04	-51.35	1.91	34.55	T4
	y (Transversal)			-8.73	-13.44	-51.41		38.00	T4	
CH.48 5240 MHz	z (Axial)	1.68	-4.72	-51.35	1.83	37.00	T4			
y (Transversal)	-8.94	-12.86	-51.41		38.05	T4				

## 9.6. OTT Codec Investigation

The DUT's nested OTT application supports range of codec bit rate 6 – 64 kbit/s, thus an investigation between the various codec configurations (6/64 as Low/High bit rates) and specific parameters are documented (ABM1, ABM2, S+N/N, frequency response) to determine the worst-case bit rates for each service type. The table below compares the varying codec configurations.

Codec Investigation				
Codec State	codec bit rate (kbit/s)		Orientation	Band/ BandWidth/ Channel
	6	64		
ABM1 (dB/m)	-4.29	-4.35	z (Axial)	GSM 850 EDGE 2 slots CH.190 836.6 MHz
ABM2 (dBA/m)	-13.40	-15.96		
S+N/N (dB)	<b>37.76</b>	38.03		
Freq. Resposne (dB)	1.73	1.19		
ABM1 (dB/m)	-1.18	-1.11	z (Axial)	WCDMA Band IV HSUPA subtest 1 CH.1413 1732.6 MHz
ABM2 (dBA/m)	-15.76	-16.90		
S+N/N (dB)	<b>44.59</b>	44.62		
Freq. Resposne (dB)	2.00	2.00		
ABM1 (dB/m)	-2.79	-2.97	z (Axial)	LTE Band 2 20 MHz 16QAM RB 1/0 CH.18900 1880MHz
ABM2 (dBA/m)	-8.85	-12.94		
S+N/N (dB)	41.58	<b>40.92</b>		
Freq. Resposne (dB)	1.97	2.00		
ABM1 (dB/m)	-4.30	-3.90	z (Axial)	LTE Band 41 20 MHz QPSK RB 1/0 CH.40620 2593 MHz
ABM2 (dBA/m)	-9.84	-17.28		
S+N/N (dB)	<b>38.61</b>	39.43		
Freq. Resposne (dB)	1.94	1.80		
ABM1 (dB/m)	-4.54	-3.79	z (Axial)	802.11g CH.6 2437 MHz 64QAM 54Mbps
ABM2 (dBA/m)	-16.93	-14.66		
S+N/N (dB)	39.72	<b>39.12</b>		
Freq. Resposne (dB)	2.00	2.00		
ABM1 (dB/m)	-3.50	-4.68	z (Axial)	802.11a CH.40 5200 MHz 64QAM 54 Mbps
ABM2 (dBA/m)	-16.41	-11.24		
S+N/N (dB)	<b>38.27</b>	38.39		
Freq. Resposne (dB)	1.97	1.80		

## 9.7. OTT Air Interface Investigation

Mode:	Channel and Frequency	Orientation	ABM1 dB(A/m)	ABM2 dB(A/m)	Ambient Noise dB(A/m)	Freq. Response (dB)	ABM SNR (dB)	T-Rating
GSM850 EDGE 2 slots Duo Codec: 6 kbit/s	CH.128 824.4 MHz	z (Axial)	-5.44	-13.23	-51.00	1.79	37.61	T4
		y (Transversal)	-14.11	-14.66	-51.01		34.50	T4
	CH.190 836.6 MHz	z (Axial)	-4.29	-13.40	-51.00	1.73	37.76	T4
		y (Transversal)	-13.75	-15.47	-51.01		34.95	T4
	CH.251 848.8 MHz	z (Axial)	-5.25	-14.30	-51.00	1.80	38.05	T4
		y (Transversal)	-14.07	-16.09	-51.01		34.91	T4
GSM1900 EDGE 2 slots Duo Codec: 6 kbit/s	CH.661 1880.0 MHz	z (Axial)	-4.92	-13.76	-51.00	2.00	37.80	T4
		y (Transversal)	-11.47	-14.25	-51.01		36.27	T4
WCDMA Band II HSUPA subtest1 Duo Codec: 6 kbit/s	CH.9262 1852.4 MHz	z (Axial)	-2.30	-18.88	-51.00	2.00	42.90	T4
		y (Transversal)	-10.64	-27.15	-51.01		39.16	T4
	CH.9400 1880.0 MHz	z (Axial)	-1.34	-20.67	-51.00	1.89	44.39	T4
		y (Transversal)	-12.71	-26.89	-51.01		37.50	T4
	CH.9538 1907.6 MHz	z (Axial)	-1.67	-19.15	-51.00	1.89	44.02	T4
		y (Transversal)	-10.45	-27.07	-51.01		39.32	T4
WCDMA Band IV HSUPA subtest1 Duo Codec: 6 kbit/s	CH.1413 1732.6 MHz	z (Axial)	-1.18	-15.76	-51.00	2.00	44.59	T4
		y (Transversal)	-10.73	-20.18	-51.01		39.24	T4
WCDMA Band V HSUPA subtest1 Duo Codec: 6 kbit/s	CH.4183 836.6 MHz	z (Axial)	-2.55	-15.65	-51.00	1.97	40.37	T4
		y (Transversal)	-10.44	-21.17	-51.01		38.77	T4

## OTT Air Interface Investigation (Continued)

Mode:	Channel and Frequency	Bandwidth/ Data Rate	Orientation	ABM1 dB(A/m)	ABM2 dB(A/m)	Ambient Noise dB(A/m)	Freq. Response (dB)	ABM SNR (dB)	T-Rating
LTE Band 2 16QAM RB 1/0 Duo Codec: 64 kbit/s	CH.18900 1880.0 MHz	20 MHz	z (Axial)	-2.97	-12.94	-51.00	2.00	40.92	T4
			y (Transversal)	-12.21	-23.87	-51.01		37.11	T4
LTE Band 5 16QAM RB 1/0 Duo Codec: 64 kbit/s	CH.20525 836.5 MHz	10 MHz	z (Axial)	-2.79	-15.27	-51.00	2.00	38.52	T4
			y (Transversal)	-12.71	-16.81	-51.01		36.73	T4
LTE Band 7 16QAM RB 1/0 Duo Codec: 64 kbit/s	CH.21100 2535.0 MHz	20MHz	z (Axial)	-2.86	-18.13	-51.00	2.00	40.28	T4
			y (Transversal)	-12.47	-21.87	-51.01		36.74	T4
LTE Band 12 16QAM RB 1/0 Duo Codec: 64 kbit/s	CH.23095 707.5 MHz	10 MHz	z (Axial)	-3.20	-18.41	-51.00	2.00	40.59	T4
			y (Transversal)	-12.84	-26.01	-51.01		36.47	T4
LTE Band 30 16QAM RB 1/0 Duo Codec: 64 kbit/s	CH.27710 2310.0 MHz	10 MHz	z (Axial)	-2.07	-19.64	-51.00	2.00	42.33	T4
			y (Transversal)	-11.33	-25.81	-51.01		37.84	T4
LTE Band 66 16QAM RB 1/0 Duo Codec: 64 kbit/s	CH.132072 1720.0 MHz	20 MHz	z (Axial)	-3.22	-18.91	-51.00	2.00	39.94	T4
			y (Transversal)	-13.19	-23.04	-51.01		36.52	T4
	CH.132322 1745.0 MHz	20 MHz	z (Axial)	-2.77	-9.73	-51.00	1.97	39.78	T4
			y (Transversal)	-12.94	-19.94	-51.01		36.34	T4
	CH.132572 1770.0 MHz	20 MHz	z (Axial)	-3.37	-19.13	-51.00	2.00	40.04	T4
			y (Transversal)	-12.27	-25.29	-51.01		36.92	T4
LTE Band 40 QPSK RB 1/0 Duo Codec: 6 kbit/s	CH.38750 2310.0 MHz	10 MHz	z (Axial)	-5.20	-12.10	-50.97	1.96	36.29	T4
			y (Transversal)	-12.67	-10.89	-50.99		35.13	T4
LTE Band 41 QPSK RB 1/0 Duo Codec: 6 kbit/s	CH.39750 2506.0 MHz	20 MHz	z (Axial)	-2.63	-4.49	-50.90	2.00	38.82	T4
			y (Transversal)	-12.28	-22.69	-50.93		34.48	T4
	CH.40185 2549.5 MHz	20 MHz	z (Axial)	-2.96	-13.77	-50.90	2.00	38.34	T4
			y (Transversal)	-12.93	-22.51	-50.93		34.13	T4
	CH.40620 2593.0 MHz	20 MHz	z (Axial)	-4.30	-9.84	-50.90	1.94	38.61	T4
			y (Transversal)	-13.55	-18.20	-50.93		33.14	T4
	CH.41055 2636.5 MHz	20 MHz	z (Axial)	-3.82	-12.82	-50.90	2.00	36.88	T4
			y (Transversal)	-12.69	-21.65	-50.93		34.18	T4
	CH.41490 2680.0 MHz	20 MHz	z (Axial)	-3.01	-10.81	-50.90	2.00	38.06	T4
			y (Transversal)	-13.05	-21.64	-50.93		33.90	T4
802.11b Duo Codec: 64 kbit/s	CH.6 2437 MHz	20 MHz DSSS 1 Mbps	z (Axial)	-3.79	-14.66	-50.90	2.00	39.12	T4
			y (Transversal)	-12.99	-23.63	-50.93		36.39	T4
802.11a Duo Codec: 6 kbit/s	CH.40 5200 MHz	20MHz 64QAM 54 Mbps	z (Axial)	-3.50	-16.41	-50.90	1.97	38.27	T4
			y (Transversal)	-13.45	-18.07	-50.93		36.25	T4
	CH.56 5280 MHz	20MHz 64QAM 54 Mbps	z (Axial)	-4.76	-17.31	-50.90	1.89	40.09	T4
			y (Transversal)	-12.76	-22.28	-50.93		38.45	T4
	CH.116 5580 MHz	20MHz 64QAM 54 Mbps	z (Axial)	-2.68	-14.33	-50.90	1.93	39.96	T4
			y (Transversal)	-11.84	-23.12	-50.93		37.59	T4
	CH.157 5785 MHz	20MHz 64QAM 54 Mbps	z (Axial)	-3.75	-16.84	-50.90	1.91	39.01	T4
			y (Transversal)	-12.85	-23.06	-50.93		36.71	T4

### 9.8. HAC (T-coil) Test Results

Mode:	Channel and Frequency	Bandwidth	Bandwidth / Modulation	RB configuration	Orientation	ABM1 dB(A/m)	ABM2 dB(A/m)	Ambient Noise dB(A/m)	Freq. Response (dB)	ABM SNR (dB)	T-Rating	Plot Page #
GSM 850 Voice Coder Speech Codec: FR V1	CH.190 836.6 MHz	N/A	N/A	N/A	z (Axial)	-4.14	-8.38	-51.13	2.00	39.30	T4	1,2
					y (Transversal)	-12.27	-9.77	-51.11		34.96	T4	3
GSM 1900 Voice Coder Speech Codec: FR V1	CH.512 1850.2 MHz				z (Axial)	-3.74	-7.31	-50.90	1.58	38.60	T4	4,5
					y (Transversal)	-12.83	-9.16	-50.93		34.48	T4	6
W-CDMA Band IV Voice Wideband AMR Codec: 6.6 kbit/s	CH.1513 1752.6 MHz				z (Axial)	-4.37	-18.75	-50.91	2.00	41.29	T4	7,8
					y (Transversal)	-13.57	-24.33	-50.93		36.48	T4	9
W-CDMA Band II Voice Wideband AMR Codec: 6.6 kbit/s	CH.9400 1880.0 MHz				z (Axial)	-3.55	-20.41	-50.91	2.00	42.45	T4	10,11
					y (Transversal)	-12.30	-25.12	-50.93		37.76	T4	12
W-CDMA Band V Voice Wideband AMR Codec: 6.6 kbit/s	CH.4183 836.6 MHz				z (Axial)	-4.25	-20.50	-50.91	1.48	41.77	T4	13,14
					y (Transversal)	-13.39	-27.07	-50.93		37.20	T4	15
LTE Band 2 Voice Wideband AMR Codec: 6.6 kbit/s	CH.18900 1880 MHz				z (Axial)	-4.08	-18.17	-51.01	1.77	38.13	T4	16,17
					y (Transversal)	-13.28	-19.24	-51.04		35.66	T4	18
LTE Band 5 Voice Wideband AMR Codec: 6.6 kbit/s	CH.20525 836.5 MHz	z (Axial)	-4.87	-19.26	-50.97	2.00	38.53	T4	19,20			
		y (Transversal)	-13.66	-20.60	-50.95		36.11	T4	21			
LTE Band 7 Voice Wideband AMR Codec: 6.6 kbit/s	CH.21100 2535 MHz	z (Axial)	-5.40	-14.45	-50.97	1.68	36.85	T4	22,23			
		y (Transversal)	-13.01	-22.87	-50.95		36.27	T4	24			
LTE Band 12 Voice Wideband AMR Codec: 6.6 kbit/s	CH.23060 704 MHz	z (Axial)	-4.87	-18.86	-50.97	1.98	38.37	T4	25,26			
		y (Transversal)	-13.75	-25.44	-50.95		35.06	T4	27			
LTE Band 30 Voice Wideband AMR Codec: 6.6 kbit/s	CH.27710 2310 MHz	z (Axial)	-5.08	-19.35	-50.97	2.00	38.23	T4	28,29			
		y (Transversal)	-13.66	-25.79	-50.95		35.54	T4	30			
LTE Band 66 Voice Wideband AMR Codec: 6.6 kbit/s	CH.20525 836.5 MHz	z (Axial)	-4.56	-14.77	-50.97	1.80	38.11	T4	31,32			
		y (Transversal)	-13.98	-24.61	-50.95		35.45	T4	33			
LTE Band 40 Voice NB AMR Codec: 4.75 kbit/s	CH.38750 2310 MHz	z (Axial)	3.43	-13.18	-50.54	1.28	45.48	T4	34,35			
		y (Transversal)	-6.21	-22.13	-50.63		41.19	T4	36			
LTE Band 41 Voice NB AMR Codec: 4.75 kbit/s	CH.40620 2593 MHz	z (Axial)	-2.33	-16.11	-50.85	2.00	41.28	T4	37,38			
		y (Transversal)	-13.63	-21.64	-50.90		34.84	T4	39			
802.11b codec: AMR-NB 12.2 kbit/s	CH.6 2437 MHz	z (Axial)	0.75	-7.55	-51.35	1.82	33.44	T4	40,41			
		y (Transversal)	-11.05	-13.75	-51.41		37.06	T4	42			
802.11a codec: AMR-NB 12.2 kbit/s	CH.40 5200 MHz	z (Axial)	0.66	-5.25	-51.13	1.71	<b>33.30</b>	T4	43,44			
		y (Transversal)	-9.09	-15.41	-51.11		38.82	T4	45			
	CH.56 5280 MHz	z (Axial)	0.57	-5.32	-51.35	1.94	34.14	T4	46,47			
		y (Transversal)	-10.05	-14.30	-51.41		37.87	T4	48			
	CH.116 5580 MHz	z (Axial)	0.80	-5.44	-51.35	1.78	35.99	T4	49,50			
		y (Transversal)	-9.63	-13.41	-51.41		38.41	T4	51			
CH.157 5785 MHz	z (Axial)	0.74	-9.16	-51.35	1.79	35.78	T4	52,53				
	y (Transversal)	-9.47	-13.25	-51.41		38.40	T4	54				

**Note:**

The radial longitudinal (x axis) measurements are no longer required per ANSI C63.19

### HAC (T-coil) Test Results (Continued)

Mode:	Channel and Frequency	Bandwidth/ Data Rate	Orientation	ABM1 dB(A/m)	ABM2 dB(A/m)	Ambient Noise dB(A/m)	Freq. Response (dB)	ABM SNR (dB)	T-Rating	Plot Page #
GSM850 EDGE 2 slots Duo Codec: 6 kbit/s	CH.128 824.4 MHz		z (Axial)	-5.44	-13.23	-51.00	1.79	37.61	T4	55,56
			y (Transversal)	-14.11	-14.66	-51.01		34.50	T4	57
GSM1900 EDGE 2 slots Duo Codec: 6 kbit/s	CH.661 1880.0 MHz		z (Axial)	-4.92	-13.76	-51.00	2.00	37.80	T4	58,59
			y (Transversal)	-11.47	-14.25	-51.01		36.27	T4	60
WCDMA Band II HSUPA subtest1 Duo Codec: 6 kbit/s	CH.9400 1880.0 MHz		z (Axial)	-1.34	-20.67	-51.00	1.89	44.39	T4	61,62
			y (Transversal)	-12.71	-26.89	-51.01		37.50	T4	63
WCDMA Band IV HSUPA subtest1 Duo Codec: 6 kbit/s	CH.1413 1732.6 MHz		z (Axial)	-1.18	-15.76	-51.00	2.00	44.59	T4	64,65
			y (Transversal)	-10.73	-20.18	-51.01		39.24	T4	66
WCDMA Band V HSUPA subtest1 Duo Codec: 6 kbit/s	CH.4183 836.6 MHz		z (Axial)	-2.55	-15.65	-51.00	1.97	40.37	T4	67,68
			y (Transversal)	-10.44	-21.17	-51.01		38.77	T4	69
LTE Band 2 16QAM RB 1/0 Duo Codec: 64 kbit/s	CH.18900 1880.0 MHz	20 MHz	z (Axial)	-2.97	-12.94	-51.00	2.00	40.92	T4	70,71
			y (Transversal)	-12.21	-23.87	-51.01		37.11	T4	72
LTE Band 5 16QAM RB 1/0 Duo Codec: 64 kbit/s	CH.20525 836.5 MHz	10 MHz	z (Axial)	-2.79	-15.27	-51.00	2.00	38.52	T4	73,74
			y (Transversal)	-12.71	-16.81	-51.01		36.73	T4	75
LTE Band 7 16QAM RB 1/0 Duo Codec: 64 kbit/s	CH.21100 2535.0 MHz	20MHz	z (Axial)	-2.86	-18.13	-51.00	2.00	40.28	T4	76,77
			y (Transversal)	-12.47	-21.87	-51.01		36.74	T4	78
LTE Band 12 16QAM RB 1/0 Duo Codec: 64 kbit/s	CH.23095 707.5 MHz	10 MHz	z (Axial)	-3.20	-18.41	-51.00	2.00	40.59	T4	79,80
			y (Transversal)	-12.84	-26.01	-51.01		36.47	T4	81
LTE Band 30 16QAM RB 1/0 Duo Codec: 64 kbit/s	CH.27710 2310.0 MHz	10 MHz	z (Axial)	-2.07	-19.64	-51.00	2.00	42.33	T4	82,83
			y (Transversal)	-11.33	-25.81	-51.01		37.84	T4	84
LTE Band 66 16QAM RB 1/0 Duo Codec: 64 kbit/s	CH.132322 1745.0 MHz	20 MHz	z (Axial)	-2.77	-9.73	-51.00	1.97	39.78	T4	85,86
			y (Transversal)	-12.94	-19.94	-51.01		36.34	T4	87
LTE Band 40 QPSK RB 1/0 Duo Codec: 6 kbit/s	CH.38750 2310.0 MHz	10 MHz	z (Axial)	-5.20	-12.10	-50.97	1.96	36.29	T4	88,89
			y (Transversal)	-12.67	-10.89	-50.99		35.13	T4	90
LTE Band 41 QPSK RB 1/0 Duo Codec: 6 kbit/s	CH.40620 2593.0 MHz	20 MHz	z (Axial)	-4.30	-9.84	-50.90	1.94	38.61	T4	91,92
			y (Transversal)	-13.55	-18.20	-50.93		33.14	T4	93
802.11b Duo Codec: 64 kbit/s	CH.6 2437 MHz	20 MHz DSSS 1 Mbps	z (Axial)	-3.79	-14.66	-50.90	2.00	39.12	T4	94,95
			y (Transversal)	-12.99	-23.63	-50.93		36.39	T4	96
802.11a Duo Codec: 6 kbit/s	CH.40 5200 MHz	20MHz 64QAM 54 Mbps	z (Axial)	-3.50	-16.41	-50.90	1.97	38.27	T4	97,98
			y (Transversal)	-13.45	-18.07	-50.93		36.25	T4	99
	CH.56 5280 MHz	20MHz 64QAM 54 Mbps	z (Axial)	-4.76	-17.31	-50.90	1.89	40.09	T4	100,101
			y (Transversal)	-12.76	-22.28	-50.93		38.45	T4	102
	CH.116 5580 MHz	20MHz 64QAM 54 Mbps	z (Axial)	-2.68	-14.33	-50.90	1.93	39.96	T4	103,104
			y (Transversal)	-11.84	-23.12	-50.93		37.59	T4	105
	CH.157 5785 MHz	20MHz 64QAM 54 Mbps	z (Axial)	-3.75	-16.84	-50.90	1.91	39.01	T4	106,107
			y (Transversal)	-12.85	-23.06	-50.93		36.71	T4	108

**Note:**

The radial longitudinal (x axis) measurements are no longer required per ANSI C63.19

### 9.9. Worst Case T-Coil Test Plot

Test Laboratory: UL Korea Ltd. Suwon Laboratory

Date: 2019-03-28

#### OTT\_LTE TDD

Communication System: UID 0, LTE (TDD) (0); Frequency: 2593 MHz; Duty Cycle: 1:1.59956

Phantom section: TCoil Section

DASY5 Configuration:

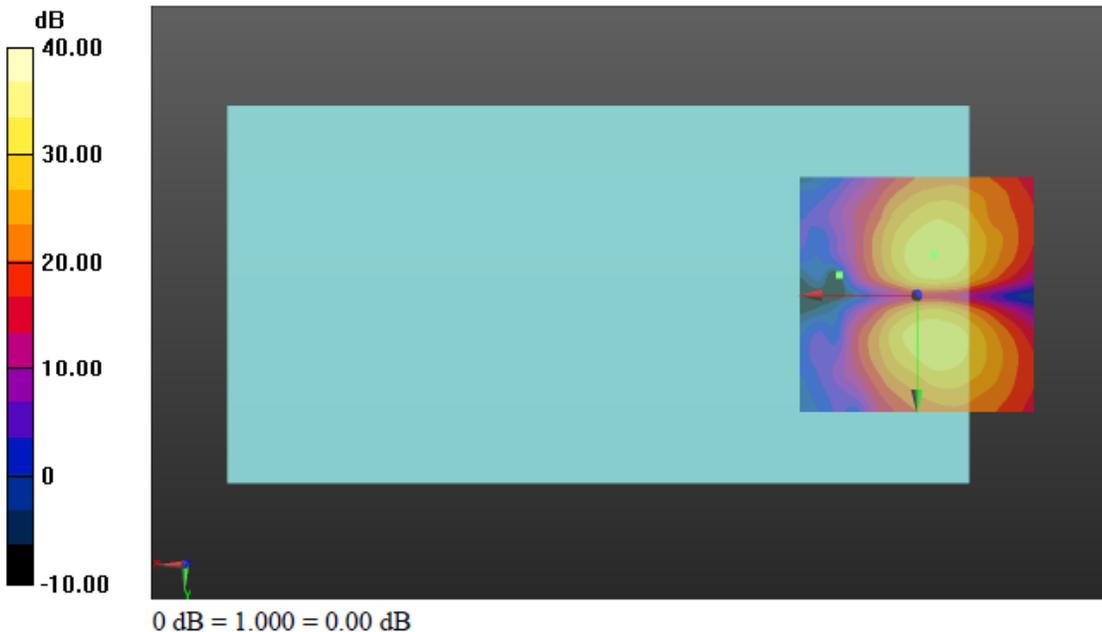
- Probe: AM1DV3 - 3137; ; Calibrated: 2018-11-20
- Sensor-Surface: 0mm (Fix Surface)
- Electronics: DAE4 Sn1494; Calibrated: 2018-07-23
- Phantom: HAC Test Arch with AMCC; Type: SD HAC P01 BB
- Measurement SW: DASY52, Version 52.8 (8);SEMCAD X Version 14.6.10 (7331)

#### T-Coil scan (scan for ANSI C63.19 2011 compliance)/LTE Band 41 ch40620 QPSK RB1/0 codec6/y (transversal) 4.2mm 50 x 50/ABM Interpolated SNR(x,y,z) (121x121x1):

Interpolated grid: dx=1.000 mm, dy=1.000 mm  
 Signal Type: Audio File (.wav) 48k\_voice\_1kHz\_1s.wav  
 Output Gain: 20.46  
 Measure Window Start: 300ms  
 Measure Window Length: 1000ms  
 BWC applied: 0.16 dB  
 Device Reference Point: 0, 0, -6.3 mm

#### Cursor:

ABM1/ABM2 = 33.14 dB  
 ABM1 comp = -13.55 dBA/m  
 BWC Factor = 0.16 dB  
 Location: -3.7, -8.8, 3.7 mm  
 ABM2 = -18.20 dBA/m  
 Location: 16.7, -4.2, 3.7 mm



## **Appendix**

**Refer to separated files for the following appendixes**

**4788768228-S3V1-Appendix A: T-Coil Setup Photo**

**4788768228-S3V1-Appendix B: T-Coil Test Plots**

**4788768228-S3V1-Appendix C: T-Coil Probe Certificates**

**END OF REPORT**