



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/ax, ANT+, NFC and WPT

MODEL NUMBER : SM-G973F/DS, SM-G973F, SM-G973X

FCC ID: A3LSMG973F

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TL-637


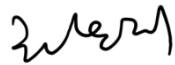
Revision History

Rev.	Date	Revisions	Revised By
V1	12/19/2018	Initial Issue	Eunji Choi
V2	2/13/2019	Revised Sec.8.1, Sec.9.2, Sec.9.3, Sec.9.4, Sec.9.7, and Appendix B	Eunji Choi

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1. Attestation of Test Results

Applicant Name	SAMSUNG ELECTRONICS CO.,LTD.	
FCC ID	A3LSMG973F	
Model Name	SM-G973F/DS, SM-G973F, SM-G973X	
Applicable Standards	FCC 47 CFR § 20.19 ANSI C63.19-2011	
HAC Rating	T4	
Date Tested	11/20/2018 to 12/17/2018 and 2/10/2019 to 2/13/2019	
Test Results	Pass	
<p>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.</p> <p>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.</p>		
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	AM1DV2	1062	01-16-2019
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
Laptop	Lenovo	T450	XU100303-14003A	N/A
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 _i		Std. Unc.	
				ABM1	ABM2	ABM1 (±%)	ABM2 (±%)
Probe Sensitivity							
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
Probe System							
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
Test Signal							
Reference signal spectral response	0.6	R	√3	0	1	0.0	0.4
Positioning							
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
External Contributions							
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
Combined Std. Uncertainty (ABM field)						4.1	6.1
Expanded Std. Uncertainty (%)						8.1	12.3
Notes for table							
1. N - Nomal							
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 ABM1¹ and ABM2². 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.⁴⁶ 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.

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

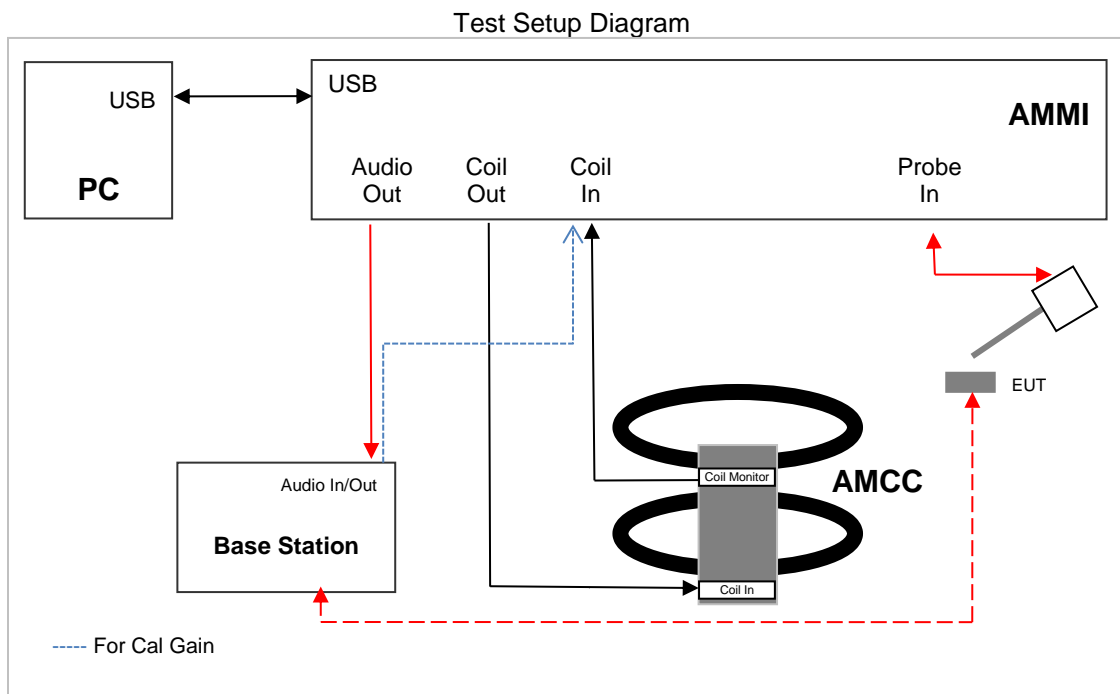
² **Audio Band Magnetic signal - undesired (ABM2):** Measured quantity of the undesired magnetic signal, such as interference from battery current and similar non-signal elements.

- 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.

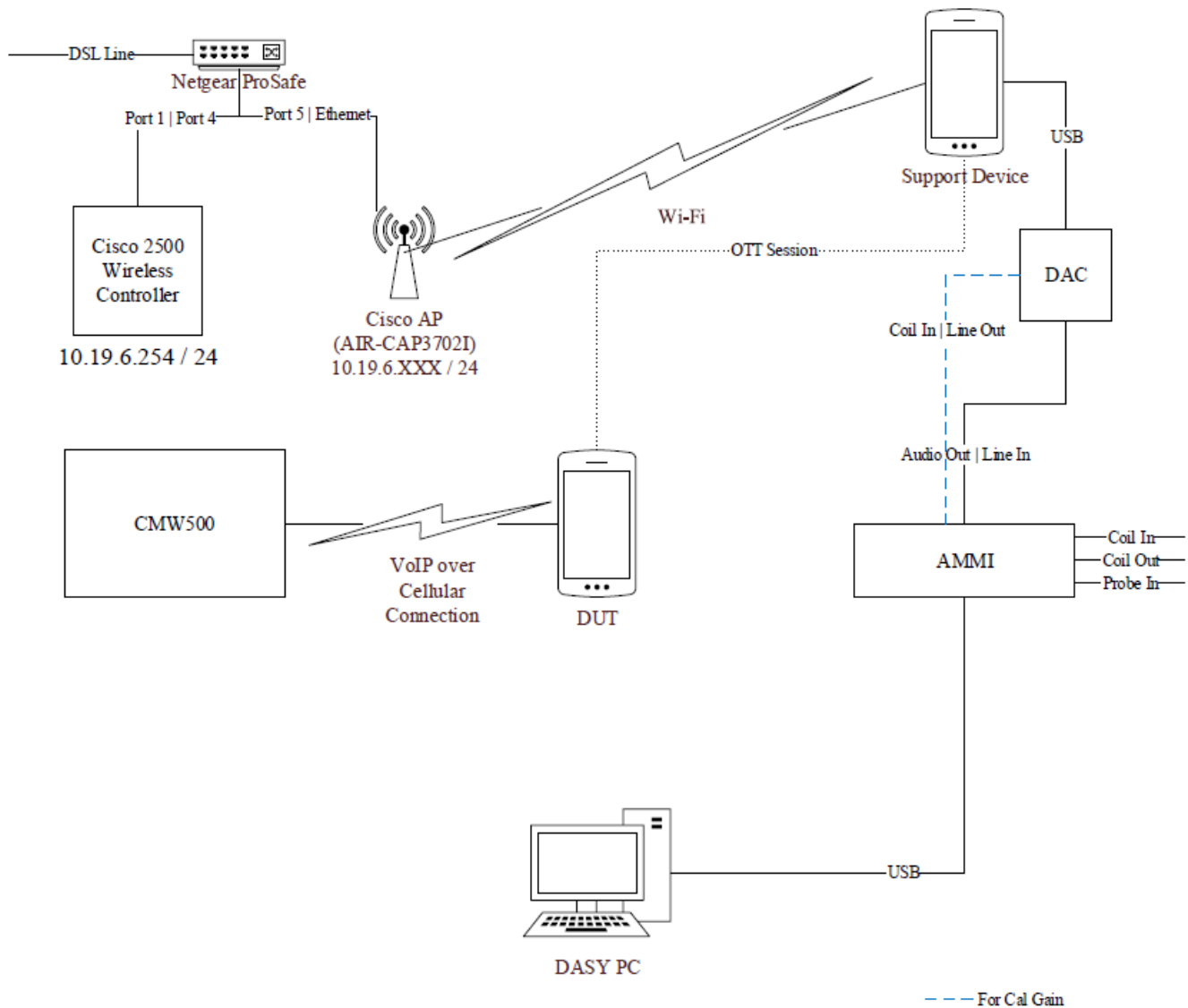


5.1. Over the Top (OTT)

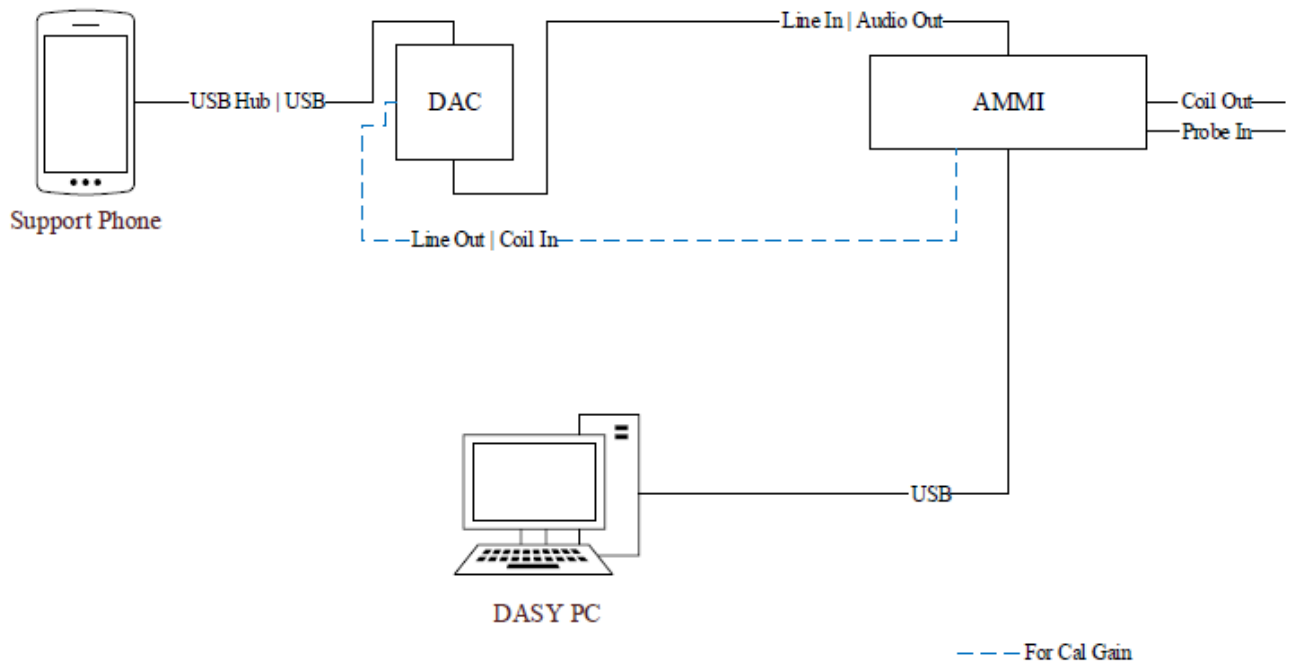
The test procedure for OTT testing is identical to the section above, except for how the signal is sent to the DUT, as outlined in the diagram below.

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	24.32
Voice 300 - 3 kHz	-16.00	33.57	47.70

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	27.71	24.29
Voice 300 - 3 kHz	-16.00	33.56	47.64

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
	KS104	EVS SPEECH CODEC

Signal Type	Audio Level [dBm0]	Gain [dB]	Gain [linear]
Voice 1 kHz	-16.00	27.71	24.29
Voice 300 - 3 kHz	-16.00	33.56	47.64

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
	KS657	WLAN IEEE 802.11ax
V3.7.20 for Audio	KA100	IP APPL ENABLING IPv4
	KA150	IP APPL ENABLING IPv6
	KAA20	IP APPL IMS BASIC
	KM050	DATA APPL MEAS
	KS104	EVS SPEECH CODEC

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

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.

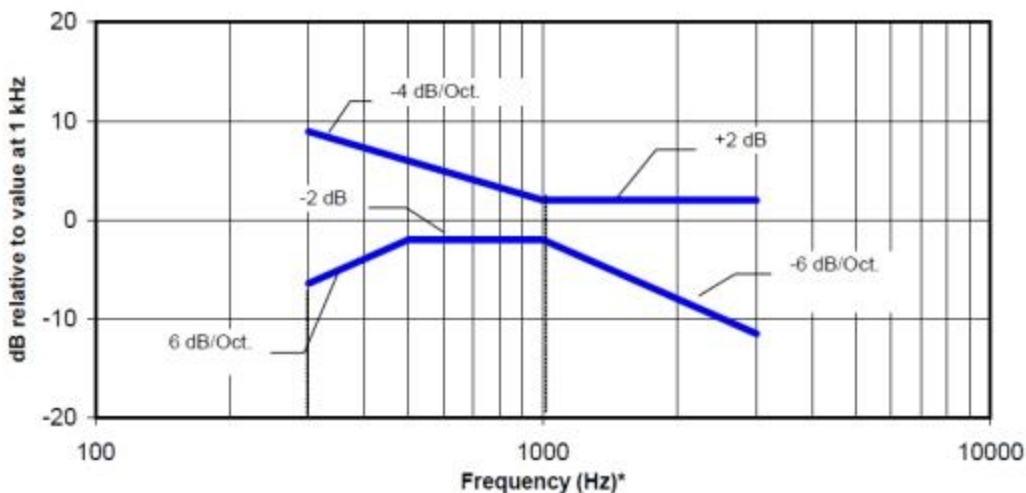
Signal Type	Audio Level [dBm0]	Gain [dB]	Gain [linear]
Voice 1 kHz	-20.00	24.61	17.00
Voice 300 - 3 kHz	-20.00	30.46	33.34

7. T-coil Measurement Criteria

7.1. Frequency Response

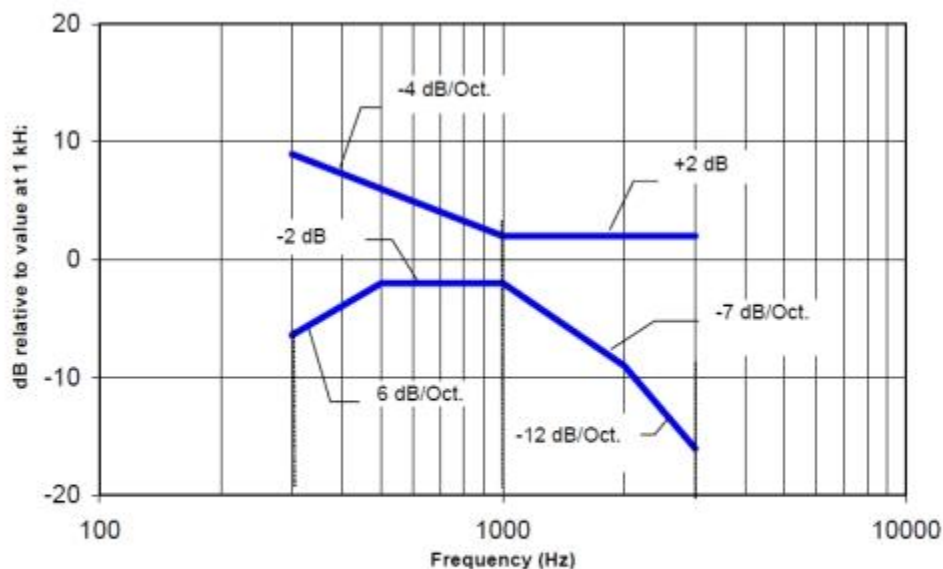
The frequency response of the axial component of the magnetic field, measured in 1/3 octave bands, shall follow the response curve, over the frequency range 300 Hz to 3000 Hz.

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 ≤ -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

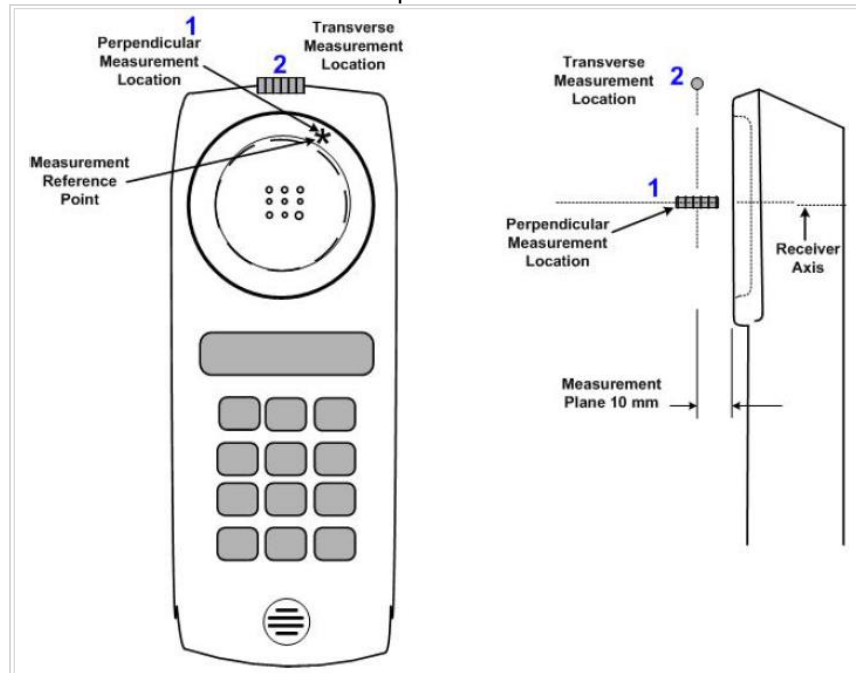
This specifies the signal-to-noise quality requirement for the intended T-Coil signal from a WD. The worst signal to noise of the two T-Coil signal measurements, as determined in Clause 7, shall be used to determine the T-Coil mode category per Table 8.5.

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	The Back Cover is not removable	
Test sample information	S/N	Notes
	R38KA0BE1PY	T-coil Test
	R38KA0BEF0L	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 ²	OPUS
W-CDMA (UMTS)	850 (V)	VO	Yes	Wi-Fi and BT	NA	AMR-NB & AMR-WB
	1700 (IV)					
	1900 (II)					
	HSPA	VD	Yes	Wi-Fi and BT	Yes Google Duo ²	OPUS
LTE - FDD	700 (B12/13/17)	VD	Yes	Wi-Fi and BT	Yes ¹ Google Duo ²	AMR-NB, AMR-WB, nb-EVS, swb-EVS, and OPUS
	850 (B5/26)					
	1700 (B4/66)					
	1900 (B2/25)					
	2600 (B7)					
LTE - TDD	2500 (B38/41)	VD	Yes	Wi-Fi and BT	Yes ¹ Google Duo ²	AMR-NB, AMR-WB, nb-EVS, swb-EVS, and OPUS
Wi-Fi	2450	VD	Yes	WWAN and Wi-Fi 5GHz	Yes Wi-Fi calling Google Duo ²	AMR-NB, AMR-WB, nb-EVS, swb-EVS, 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	Note:
VO: Legacy Cellular Voice Service	1. Ref Lev in accordance with the July 2012 VoLTE interpretatio
DT: Digital Transport only (no voice)	2. Ref Lev -20 dBm0
VD: IP Voice Service over Digital Transport	
BT: Bluetooth	

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)
802.11n HT20 Voice EVS Primary Codec: 5.9 kbit/s	52 5260 MHz	MCS3 26 Mbps	WiFi Ant1	z (Axial)	7.65	-26.43		1.80	56.79	T4	-1.38
				y (Transverse)	-3.45	-17.93		43.98	T4		
			WiFi Ant2	z (Axial)	3.64	-29.53		1.53	53.31	T4	
				y (Transverse)	-3.80	-30.28			45.36	T4	

9.2. Codec Investigation

An investigation between the various codec configurations (Low/Mid/High bit rates for Narrowband, Wideband, and EVS) 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 full codec investigation was performed on one LTE FDD and one LTE TDD band; another full codec investigation was performed on one W-CDMA band.

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

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)	8.40	-2.50	-51.30	2.00	41.54	T4
		y (Transversal)	-3.66	-5.60	-51.35		42.08	T4
GSM 850 Voice Coder Speech Codec: HR V1	CH.190 836.6 MHz	z (Axial)	9.41	-7.10	-50.94	1.89	42.20	T4
		y (Transversal)	-0.10	-9.51	-51.00		45.26	T4

Codec Investigation															
Codec State	AMR-NB (kbit/s)			AMR-WB (kbit/s)			EVS nb (kbit/s)			EVS swb (kbit/s)			Orientation	Band/ BandWidth/ Channel	
	4.75	7.4	12.2	6.6	15.85	23.85	5.9	13.2	24.4	9.6	16.4	24.4			
ABM1 (dB/m)	8.37	8.82	9.11	2.12	3.08	2.90								z (Axial)	WCDMA Band IV CH.1413
ABM2 (dBA/m)	-34.91	-34.83	-35.50	-33.76	-33.50	-34.29									
S+N/N (dB)	65.43	65.90	66.43	58.69	59.74	59.33									
Freq. Resposne (dB)	1.51	2.00	2.00	1.15	2.00	2.00								y (Transversal)	
ABM1 (dB/m)	1.52	1.68	1.87	-5.79	-4.16	-4.15									
ABM2 (dBA/m)	-37.49	-37.32	-38.10	-35.67	-35.62	-36.24									
S+N/N (dB)	60.33	60.66	60.26	52.99	54.25	54.44									
ABM1 (dB/m)	9.39	9.59	9.75	4.43	5.39	5.38	10.32	9.99	9.79	11.02	10.00	10.31		z (Axial)	LTE Band 2 CH.18900 20 MHz BW
ABM2 (dBA/m)	-27.97	-28.39	-27.52	-27.54	-27.02	-26.64	-25.96	-28.04	-27.33	-27.18	-27.07	-26.00			
S+N/N (dB)	64.77	65.35	65.32	60.05	61.16	60.90	61.18	64.84	65.21	66.29	65.69	65.53			
Freq. Resposne (dB)	1.84	2.00	2.00	1.45	1.38	1.79	1.59	1.94	1.78	2.00	1.82	1.80		y (Transversal)	
ABM1 (dB/m)	2.01	2.27	2.60	-2.85	-3.91	-1.95	1.51	1.48	1.71	2.90	1.66	2.21			
ABM2 (dBA/m)	-29.24	-30.05	-28.49	-28.92	-28.64	-27.65	-27.85	-28.29	-28.14	-28.89	-27.13	-28.52			
S+N/N (dB)	60.12	60.37	60.49	54.88	54.67	55.88	58.45	59.62	59.03	60.28	59.22	59.66			
ABM1 (dB/m)	7.72	9.27	7.54	2.91	3.38	4.16	4.56	8.37	8.20	8.57	7.65	6.75		z (Axial)	LTE Band 41 CH.40620 20 MHz BW
ABM2 (dBA/m)	-17.44	-17.40	-17.31	-17.90	-17.74	-16.33	-17.88	-17.73	-17.11	-17.19	-17.28	-17.44			
S+N/N (dB)	58.19	57.72	58.14	52.91	54.57	54.18	56.11	58.57	58.42	59.08	59.58	58.73			
Freq. Resposne (dB)	1.68	2.00	2.00	1.38	1.16	1.04	1.39	1.69	2.00	2.00	1.99	1.97		y (Transversal)	
ABM1 (dB/m)	-1.07	-0.76	-0.62	-6.56	-5.08	-4.54	-6.28	-0.68	-0.82	-0.65	-2.65	-0.92			
ABM2 (dBA/m)	-19.56	-19.50	-19.43	-19.89	-19.74	-19.72	-19.96	-19.85	-19.39	-19.17	-19.37	-19.47			
S+N/N (dB)	55.55	55.37	55.60	50.44	51.37	51.32	52.03	55.57	55.47	55.01	54.34	55.09			

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)	8.40	-2.50	-51.30	2.00	41.54	T4
		y (Transversal)	-3.66	-5.60	-51.35		42.08	T4
GSM 1900 Voice Coder Speech Codec: FR V1	CH.661 1880 MHz	z (Axial)	8.29	-6.42	-51.30	2.00	45.40	T4
		y (Transversal)	-2.74	-9.57	-51.35		44.81	T4
W-CDMA Band IV Voice Wideband AMR Codec: 6.6 kbit/s	CH.1312 1712.4 MHz	z (Axial)	0.06	-34.14	-51.31	1.06	57.36	T4
		y (Transversal)	-5.53	-35.75	-51.39		52.79	T4
	CH.1413 1732.6 MHz	z (Axial)	2.12	-33.76	-51.31	1.15	58.69	T4
		y (Transversal)	-5.79	-35.67	-51.39		52.99	T4
	CH.1513 1752.6 MHz	z (Axial)	1.87	-33.72	-51.31	1.28	57.94	T4
		y (Transversal)	-5.81	-35.68	-51.39		53.26	T4
W-CDMA Band II Voice Wideband AMR Codec: 6.6 kbit/s	CH.9262 1852.4 MHz	z (Axial)	1.25	-34.37	-51.32	1.06	57.66	T4
		y (Transversal)	-5.06	-36.31	-51.35		53.53	T4
W-CDMA Band V Voice Wideband AMR Codec: 6.6 kbit/s	CH.4132 826.4 MHz	z (Axial)	1.97	-34.29	-51.32	1.42	58.24	T4
		y (Transversal)	-5.30	-35.62	-51.35		53.38	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: 15.85 kbit/s	CH.18900 1880 MHz	20MHz	QPSK	1/0	z (Axial)	5.25	-31.59	-51.39	1.31	61.42	T4
					y (Transversal)	-1.80	-33.05	-51.40		57.21	T4
				50/0	z (Axial)	5.24	-32.01	-51.39	1.25	61.89	T4
					y (Transversal)	-1.86	-34.10	-51.40		57.43	T4
				100/0	z (Axial)	5.81	-32.01	-51.39	1.51	61.66	T4
					y (Transversal)	-1.77	-33.98	-51.40		57.26	T4
			16QAM	1/0	z (Axial)	5.39	-27.02	-51.39	1.38	61.16	T4
					y (Transversal)	-3.91	-28.64	-51.40		54.67	T4
				1/49	z (Axial)	9.24	-29.20	-50.91	2.00	62.55	T4
					y (Transversal)	-0.81	-29.93	-50.98		55.90	T4
				1/99	z (Axial)	9.36	-29.51	-50.91	2.00	63.09	T4
					y (Transversal)	-1.84	-26.98	-50.98		55.52	T4
				50/0	z (Axial)	5.26	-31.24	-51.39	1.31	61.63	T4
					y (Transversal)	-1.77	-29.89	-51.40		57.07	T4
				50/24	z (Axial)	8.16	-31.38	-50.91	2.00	63.94	T4
					y (Transversal)	-0.43	-33.72	-50.98		56.20	T4
				50/50	z (Axial)	8.56	-32.96	-50.91	2.00	63.83	T4
					y (Transversal)	-0.78	-33.66	-50.98		55.62	T4
			100/0	z (Axial)	5.53	-31.85	-51.39	1.45	61.24	T4	
				y (Transversal)	-1.78	-32.66	-51.40		57.20	T4	
			64QAM	1/0	z (Axial)	5.46	-27.45	-51.39	1.25	60.94	T4
					y (Transversal)	-1.75	-29.27	-51.40		55.95	T4
				50/0	z (Axial)	5.28	-31.85	-51.39	1.34	61.36	T4
					y (Transversal)	-2.35	-33.56	-51.40		56.91	T4
		100/0		z (Axial)	5.00	-31.06	-51.39	1.28	61.54	T4	
				y (Transversal)	-1.78	-33.11	-51.40		57.00	T4	
		15 MHz	QPSK	1/0	z (Axial)	3.83	-26.89	-51.39	1.13	60.63	T4
					y (Transversal)	-2.62	-28.35	-51.40		56.05	T4
				1/0	z (Axial)	4.55	-26.06	-51.39	1.10	60.27	T4
					y (Transversal)	-2.66	-27.86	-51.40		56.05	T4
				1/0	z (Axial)	5.06	-32.69	-51.39	1.09	61.25	T4
					y (Transversal)	-2.35	-34.51	-51.40		56.76	T4
			1/0	z (Axial)	4.45	-32.20	-51.39	1.12	61.33	T4	
				y (Transversal)	-2.22	-34.14	-51.40		56.69	T4	
			1.4 MHz	1/0	z (Axial)	6.20	-26.66	-51.39	1.22	60.89	T4
					y (Transversal)	-2.12	-34.28	-51.40		56.95	T4
CH.18700 1860 MHz	20 MHz		QPSK	1/0	z (Axial)	6.03	-30.05	-51.39	1.47	61.93	T4
					y (Transversal)	-1.66	-35.88	-51.40		57.06	T4
CH.19100 1900 MHz	20 MHz	QPSK	1/0	z (Axial)	5.35	-32.44	-51.39	1.17	61.26	T4	
				y (Transversal)	-1.73	-35.70	-51.40		57.26	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 12 Voice Wideband AMR Codec: 15.85 kbit/s	CH.23095 707.5 MHz	10 MHz	16QAM	1/0	z (Axial)	4.45	-27.69	-51.37	1.07	60.34	T4
					y (Transversal)	-2.08	-29.12	-51.35		55.74	T4
LTE Band 5 Voice Wideband AMR Codec: 15.85 kbit/s	CH.20525 836.6 MHz	10 MHz			z (Axial)	4.64	-27.64	-51.37	1.13	60.18	T4
					y (Transversal)	-2.23	-29.32	-51.35		55.82	T4
LTE Band 66 Voice Wideband AMR Codec: 15.85 kbit/s	CH.132322 1745 MHz	20 MHz			z (Axial)	4.94	-26.07	-51.37	1.03	59.99	T4
					y (Transversal)	-2.37	-27.38	-51.35		54.92	T4
LTE Band 7 Voice Wideband AMR Codec: 15.85 kbit/s	CH.21100 2535 MHz	20 MHz			z (Axial)	5.07	-20.11	-51.37	1.14	59.86	T4
					y (Transversal)	-2.62	-27.12	-51.35		54.64	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 41 Voice Wideband AMR Codec: 6.6 kbit/s	CH.40620 2593 MHz	20MHz	QPSK	1/0	z (Axial)	0.18	-15.97	-51.38	1.12	50.13	T4	
					y (Transversal)	-5.82	-18.23	-51.36		49.58	T4	
				1/49	z (Axial)	6.20	-29.20	-50.98	1.62	52.24	T4	
					y (Transversal)	-2.42	-29.93	-50.99		51.04	T4	
				1/99	z (Axial)	5.75	-18.91	-50.98	2.00	51.97	T4	
					y (Transversal)	-2.51	-20.29	-50.99		50.57	T4	
				50/0	z (Axial)	2.35	-18.48	-51.38	1.58	53.56	T4	
					y (Transversal)	-3.78	-20.51	-51.36		52.60	T4	
				50/24	z (Axial)	5.76	-20.39	-50.98	2.00	53.23	T4	
					y (Transversal)	-3.13	-21.84	-50.99		51.58	T4	
				50/50	z (Axial)	5.90	-20.32	-50.98	2.00	53.19	T4	
					y (Transversal)	-1.91	-21.87	-50.99		51.33	T4	
				100/0	z (Axial)	5.39	-18.23	-51.38	1.45	54.18	T4	
					y (Transversal)	-6.77	-20.33	-51.36		50.34	T4	
				16QAM	1/0	z (Axial)	2.91	-17.90	-51.38	1.38	52.91	T4
						y (Transversal)	-6.56	-19.89	-51.36		50.44	T4
					50/0	z (Axial)	2.33	-19.15	-51.38	1.12	54.14	T4
						y (Transversal)	-5.56	-21.30	-51.36		51.31	T4
					100/0	z (Axial)	3.54	-19.05	-51.38	1.17	53.63	T4
						y (Transversal)	-5.65	-21.21	-51.36		51.03	T4
				64QAM	1/0	z (Axial)	1.77	-18.53	-51.38	1.47	53.94	T4
						y (Transversal)	-7.48	-20.61	-51.36		50.20	T4
					50/0	z (Axial)	1.00	-19.68	-51.38	1.03	54.11	T4
						y (Transversal)	-3.42	-21.48	-51.36		53.33	T4
		100/0	z (Axial)		1.74	-19.56	-51.38	1.17	54.12	T4		
			y (Transversal)		-3.68	-21.60	-51.36		50.84	T4		
		15 MHz	QPSK	1/0	z (Axial)	2.96	-16.01	-51.38	1.32	51.34	T4	
					y (Transversal)	-5.90	-18.27	-51.36		49.39	T4	
				1/0	z (Axial)	2.27	-17.96	-51.38	1.48	52.80	T4	
		10 MHz	QPSK	1/0	y (Transversal)	-5.64	-20.10	-51.36		50.46	T4	
					z (Axial)	3.45	-16.70	-51.38	1.86	53.98	T4	
		5 MHz	QPSK	1/0	y (Transversal)	-5.17	-18.82	-51.36		51.10	T4	
					z (Axial)	3.78	-14.27	-51.38	1.93	51.39	T4	
		CH.39750 2506 MHz	15 MHz	QPSK	1/0	y (Transversal)	-5.84	-16.45	-51.36		49.73	T4
		CH.40185 2549.5 MHz	15 MHz			z (Axial)	2.84	-16.09	-51.38	1.34	52.21	T4
		CH.41055 2636.5 MHz	15 MHz	QPSK	1/0	y (Transversal)	-6.14	-18.36	-51.36		49.89	T4
z (Axial)	6.56					-17.50	-51.38	2.00	57.74	T4		
CH.41490 2680 MHz	15 MHz	QPSK	1/0	y (Transversal)	-1.82	-19.61	-51.36		54.48	T4		
				z (Axial)	6.63	-16.57	-51.38	2.00	57.01	T4		
					y (Transversal)	-2.48	-18.70	-51.36		54.01	T4	

9.4. VoWi-Fi Codec Investigation

An investigation between the various codec configurations (Low/Mid/High bit rates for Narrowband, Wideband, and EVS) 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 for VoWi-Fi.

Codec Investigation														
Codec State	AMR-NB (kbit/s)			AMR-WB (kbit/s)			EVS nb (kbit/s)			EVS swb (kbit/s)			Orientation	Band/ BandWidth/ Channel
	4.75	7.4	12.2	6.6	15.85	23.85	5.9	13.2	24.4	9.6	16.4	24.4		
ABM1 (dB/m)	6.59	8.97	6.33	8.83	4.87	6.03	4.32	6.56	6.99	7.96	7.57	7.73	z (Axial)	802.11b CH.1 2412 MHz DSSS 1 Mbps
ABM2 (dBA/m)	-18.58	-18.55	-18.67	-18.56	-17.88	-17.86	-27.05	-17.94	-17.90	-17.89	-18.12	-18.08		
S+N/N (dB)	55.91	57.61	55.11	57.66	54.23	55.04	54.11	56.42	56.40	57.71	56.46	56.85		
Freq. Resposne (dB)	1.28	2.00	1.60	1.92	2.00	1.00	1.93	1.90	2.00	2.00	2.00	1.47	y (Transversal)	802.11a CH.36 5180 MHz BPSK 6 Mbps
ABM1 (dB/m)	-0.48	0.30	-1.54	0.28	-2.16	-2.48	-1.76	-0.23	-0.29	0.86	1.49	1.11		
ABM2 (dBA/m)	-21.89	-22.31	-21.92	-22.26	-19.21	-21.90	-29.31	-21.83	-19.61	-26.60	-22.01	-21.87		
S+N/N (dB)	47.67	49.67	47.85	49.09	46.03	47.02	44.98	49.68	49.80	50.81	49.78	50.39	z (Axial)	802.11a CH.36 5180 MHz BPSK 6 Mbps
ABM1 (dB/m)	8.00	8.43	9.46	9.26	11.08	11.52	3.13	9.52	9.19	7.88	9.42	10.93		
ABM2 (dBA/m)	-26.00	-23.98	-26.52	-26.54	-26.34	-25.40	-23.73	-26.41	-30.97	-31.18	-26.17	-28.31		
S+N/N (dB)	55.40	55.67	56.67	56.98	58.88	58.58	53.37	55.92	56.31	54.00	56.38	58.84	y (Transversal)	802.11a CH.36 5180 MHz BPSK 6 Mbps
Freq. Resposne (dB)	1.57	2.00	2.00	1.53	1.88	1.88	1.54	2.00	1.58	1.76	1.85	2.00		
ABM1 (dB/m)	-0.81	1.33	0.78	1.28	1.74	-0.15	-5.08	1.09	-0.21	-1.30	-0.01	1.69		
ABM2 (dBA/m)	-28.12	-20.56	-28.67	-28.81	-28.30	-29.02	-27.31	-30.45	-31.20	-31.02	-31.27	-29.49	y (Transversal)	802.11a CH.36 5180 MHz BPSK 6 Mbps
S+N/N (dB)	46.28	47.10	46.40	46.58	47.76	46.74	45.58	47.20	46.58	45.67	46.19	47.66		

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.

For the 802.11ac mode, we limited our investigation to the MCS8 and MCS9, due to data rate MCS0-8 were all covered by 802.11n mode.

Mode:	Channel and Frequency	Bandwidth	Modulation	Data Rate	Orientation	ABM1 dB(A/m)	ABM2 dB(A/m)	Ambient Noise dB(A/m)	Freq. Response (dB)	ABM SNR (dB)	T-Rating
802.11b Voice EVS Primary Codec: 5.9 kbit/s	CH.1 2412 MHz	20 MHz	DSSS	1 Mbps	z (Axial)	3.16	-27.05	-51.31	1.54	53.37	T4
					y (Transversal)	-5.08	-29.31	-51.41		45.58	T4
			CCK	5.5 Mbps	z (Axial)	2.49	-16.19	-51.31	1.41	52.35	T4
					y (Transversal)	-4.20	-28.22	-51.41		45.79	T4
CCK			11 Mbps	z (Axial)	1.71	-27.72	-51.31	1.47	51.94	T4	
				y (Transversal)	-4.05	-28.72	-51.41		44.90	T4	
802.11g Voice EVS Primary Codec: 5.9 kbit/s			BPSK	6 Mbps	z (Axial)	2.57	-28.70	-51.31	1.62	52.46	T4
					y (Transversal)	-5.31	-30.17	-51.41		44.50	T4
802.11n Voice EVS Primary Codec: 5.9 kbit/s	MCS3	26 Mbps	z (Axial)	3.56	-25.91	-51.31	1.84	54.38	T4		
			y (Transversal)	-2.40	-29.01	-51.41		46.53	T4		
802.11ax Voice EVS Primary Codec: 5.9 kbit/s	MCS9	115 Mbps	z (Axial)	4.85	-30.12	-51.28	1.71	54.18	T4		
			y (Transversal)	-3.50	-23.68	-51.33		46.07	T4		

VoWi-Fi Air Interface Investigation (Continued)

Mode:	Channel and Frequency	Bandwidth	Modulation	Data Rate	Orientation	ABM1 dB(A/m)	ABM2 dB(A/m)	Ambient Noise dB(A/m)	Freq. Response (dB)	ABM SNR (dB)	T-Rating
802.11a Voice EVS Primary Codec: 5.9 kbit/s	CH.36 5180 MHz	20 MHz	BPSK	6 Mbps	z (Axial)	4.32	-23.73	-51.37	1.93	54.11	T4
					y (Transversal)	-1.76	-27.31	-51.34		44.98	T4
			QPSK	18 Mbps	z (Axial)	1.95	-26.36	-51.37	2.00	51.14	T4
					y (Transversal)	-2.75	-29.00	-51.34		47.07	T4
			64QAM	54 Mbps	z (Axial)	5.15	-26.68	-51.37	1.54	54.23	T4
					y (Transversal)	-2.12	-25.98	-51.34		46.65	T4
802.11n HT20 Voice EVS Primary Codec: 5.9 kbit/s	CH.36 5180 MHz	20 MHz	MCS0	6.5 Mbps	z (Axial)	7.50	-29.89	-51.37	1.54	57.28	T4
					y (Transversal)	-5.30	-27.50	-51.34		44.30	T4
			MCS3	26 Mbps	z (Axial)	7.65	-26.43	-51.37	1.80	56.79	T4
					y (Transversal)	-3.45	-17.93	-51.34		43.98	T4
			MCS7	65 Mbps	z (Axial)	4.46	-29.70	-51.37	1.55	54.76	T4
					y (Transversal)	-3.11	-28.52	-51.34		45.60	T4
802.11n HT40 Voice EVS Primary Codec: 5.9 kbit/s	CH.38 5190 MHz	40 MHz	MCS0	13.5 Mbps	z (Axial)	6.54	-30.85	-51.37	2.00	56.21	T4
					y (Transversal)	-6.69	-30.38	-51.34		44.24	T4
			MCS3	54 Mbps	z (Axial)	3.21	-27.97	-51.37	1.47	52.89	T4
					y (Transversal)	-4.84	-30.21	-51.34		46.16	T4
			MCS7	135 Mbps	z (Axial)	4.46	-26.67	-51.37	2.00	54.27	T4
					y (Transversal)	-2.26	-29.42	-51.34		46.32	T4
802.11ac VHT20 Voice EVS Primary Codec: 5.9 kbit/s	CH.36 5180 MHz	20 MHz	MCS0	6.5 Mbps	z (Axial)	4.33	-24.21	-51.32	1.33	53.59	T4
					y (Transversal)	-1.38	-26.72	-51.35		47.98	T4
			MCS4	39 Mbps	z (Axial)	4.18	-26.13	-51.32	1.00	53.76	T4
					y (Transversal)	-4.00	-28.57	-51.35		46.03	T4
			MCS8	78 Mbps	z (Axial)	4.28	-26.94	-51.32	1.84	53.61	T4
					y (Transversal)	-4.17	-28.86	-51.35		45.27	T4
802.11ac VHT40 Voice EVS Primary Codec: 5.9 kbit/s	CH.38 5190 MHz	40 MHz	MCS0	13.5 Mbps	z (Axial)	4.31	-24.08	-51.32	1.82	53.47	T4
					y (Transversal)	-3.11	-24.24	-51.35		46.66	T4
			MCS5	108 Mbps	z (Axial)	3.74	-26.69	-51.32	1.92	53.12	T4
					y (Transversal)	-5.23	-28.84	-51.35		44.17	T4
			MCS9	180 Mbps	z (Axial)	2.71	-13.90	-51.32	1.92	51.38	T4
					y (Transversal)	-4.29	-24.98	-51.35		45.35	T4
802.11ac VHT80 Voice EVS Primary Codec: 5.9 kbit/s	CH.42 52100 MHz	80 MHz	MCS0	13.5 Mbps	z (Axial)	3.25	-23.97	-51.32	1.20	51.39	T4
					y (Transversal)	-4.65	-27.05	-51.35		44.75	T4
			MCS5	108 Mbps	z (Axial)	2.25	-26.37	-51.32	1.21	51.37	T4
					y (Transversal)	-4.38	-24.07	-51.35		44.07	T4
			MCS9	180 Mbps	z (Axial)	2.14	-25.79	-51.32	2.00	51.47	T4
					y (Transversal)	-3.11	-28.22	-51.35		46.05	T4

VoWi-Fi Air Interface Investigation (Continued)

Mode:	Channel and Frequency	Bandwidth	Modulation	Data Rate	Orientation	ABM1 dB(A/m)	ABM2 dB(A/m)	Ambient Noise dB(A/m)	Freq. Response (dB)	ABM SNR (dB)	T-Rating
802.11ax HE20 Voice EVS Primary Codec: 5.9 kbit/s	CH.36 5180 MHz	20 MHz	MCS0	8.6 Mbps	z (Axial)	5.78	-25.37	-51.32	1.28	55.08	T4
					y (Transversal)	-2.66	-29.03	-51.35		47.18	T4
			MCS6	77 Mbps	z (Axial)	4.15	-27.88	-51.32	1.67	53.90	T4
					y (Transversal)	-5.22	-26.92	-51.35		45.26	T4
			MCS11	143 Mbps	z (Axial)	3.29	-20.64	-51.32	1.94	53.39	T4
					y (Transversal)	-6.31	-30.71	-51.35		44.31	T4
802.11ax HE40 Voice EVS Primary Codec: 5.9 kbit/s	CH.38 5190 MHz	40 MHz	MCS0	17.2 Mbps	z (Axial)	3.16	-29.27	-51.33	1.82	53.04	T4
					y (Transversal)	-4.56	-30.84	-51.35		45.04	T4
			MCS6	155 Mbps	z (Axial)	3.49	-29.99	-51.33	1.61	53.81	T4
					y (Transversal)	-5.31	-30.29	-51.35		44.68	T4
			MCS11	287 Mbps	z (Axial)	3.32	-27.24	-51.33	1.16	53.05	T4
					y (Transversal)	-6.55	-29.86	-51.35		44.35	T4
802.11ax HE80 Voice EVS Primary Codec: 5.9 kbit/s	CH.42 5210 MHz	80 MHz	MCS0	36 Mbps	z (Axial)	3.60	-25.35	-51.33	1.29	52.84	T4
					y (Transversal)	-4.51	-30.31	-51.35		45.75	T4
			MCS6	324 Mbps	z (Axial)	2.46	-27.33	-51.33	1.27	52.18	T4
					y (Transversal)	-4.83	-28.66	-51.35		45.41	T4
			MCS11	600 Mbps	z (Axial)	4.53	-26.01	-51.33	1.21	54.50	T4
					y (Transversal)	-7.09	-30.52	-51.35		44.01	T4
802.11n HT20 Voice EVS Primary Codec: 5.9 kbit/s	CH.48 5240 MHz	20 MHz	MCS3	26 Mbps	z (Axial)	2.72	-24.34	-51.37	1.78	51.81	T4
	y (Transversal)				-2.54	-18.04	-51.38		45.63	T4	
	z (Axial)				3.10	-25.32	-51.37	1.75	52.32	T4	
	y (Transversal)				-4.30	-27.42	-51.38		43.48	T4	
	z (Axial)				3.98	-30.00	-51.37	1.80	54.00	T4	
	y (Transversal)				-4.07	-29.60	-51.38		45.96	T4	
	z (Axial)				5.38	-29.17	-51.37	1.96	54.72	T4	
	y (Transversal)				-4.90	-29.89	-51.38		43.96	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 (6/35/64 as Low/Mid/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.

Mode:	Channel and Frequency	Bandwidth / Data Rate	Codec bit rate	Orientation	ABM1 dB(A/m)	ABM2 dB(A/m)	Ambient Noise dB(A/m)	Freq. Response (dB)	ABMSNR (dB)	T-Rating
GSM 850 EDGE 2 Slots Google Duo	CH.190 836.6 MHz	N/A	6 kbit/s	z (Axial)	1.48	-8.82	-51.33	2.00	44.04	T4
				y (Transversal)	-5.78	-11.72	-51.37		41.87	T4
			35 kbit/s	z (Axial)	3.16	-8.85	-51.33	2.00	43.53	T4
				y (Transversal)	-6.61	-11.95	-51.37		41.68	T4
			64 kbit/s	z (Axial)	4.83	-9.12	-51.33	1.75	46.52	T4
				y (Transversal)	-5.60	-11.33	-51.37		42.96	T4
W-CDMA Band IV HSUPA subtest1 Google Duo	CH.1312 1712.4 MHz	N/A	6 kbit/s	z (Axial)	9.50	-32.82	-51.33	2.00	59.34	T4
				y (Transversal)	1.09	-24.66	-51.37		51.84	T4
			35 kbit/s	z (Axial)	9.55	-34.08	-51.33	1.35	59.41	T4
				y (Transversal)	0.73	-33.24	-51.37		51.60	T4
			64 kbit/s	z (Axial)	9.54	-29.50	-51.33	2.00	59.15	T4
				y (Transversal)	0.95	-30.93	-51.37		51.98	T4
LTE Band 7 16QAM RB1/0 Google Duo	CH.21100 2535 MHz	20 MHz	6 kbit/s	z (Axial)	-3.51	-27.14	-51.37	1.16	50.15	T4
				y (Transversal)	-12.50	-28.85	-51.35		45.30	T4
			35 kbit/s	z (Axial)	-0.17	-25.36	-51.37	2.00	54.49	T4
				y (Transversal)	-8.11	-26.42	-51.35		48.88	T4
			64 kbit/s	z (Axial)	-4.50	-25.84	-51.37	1.44	50.38	T4
				y (Transversal)	-11.37	-27.60	-51.35		45.96	T4
LTE Band 41 QPSK RB1/0 Google Duo	CH.40620 2593 MHz	15 MHz	6 kbit/s	z (Axial)	-2.09	-17.48	-51.37	2.00	49.12	T4
				y (Transversal)	-10.30	-19.40	-51.35		45.76	T4
			35 kbit/s	z (Axial)	-1.55	-17.00	-51.37	2.00	48.95	T4
				y (Transversal)	-10.75	-18.98	-51.35		45.67	T4
			64 kbit/s	z (Axial)	-1.82	-16.89	-51.37	2.00	48.54	T4
				y (Transversal)	-10.99	-18.97	-51.35		44.92	T4

OTT Codec Investigation (Continued)

Mode:	Channel and Frequency	Bandwidth / Data Rate	Codec bit rate	Orientation	ABM1 dB(A/m)	ABM2 dB(A/m)	Ambient Noise dB(A/m)	Freq. Response (dB)	ABM SNR (dB)	T-Rating
802.11g Google Duo	CH.1 2412 MHz	20 MHz / BPSK 6Mbps	6 kbit/s	z (Axial)	3.13	-21.78	-51.32	1.21	52.31	T4
				y (Transversal)	-5.93	-25.40	-51.35		41.79	T4
			35 kbit/s	z (Axial)	3.08	-21.22	-51.32	1.51	52.42	T4
				y (Transversal)	-6.15	-25.16	-51.35		41.32	T4
			64 kbit/s	z (Axial)	2.90	-21.02	-51.32	1.45	51.93	T4
				y (Transversal)	-6.22	-24.80	-51.35		40.68	T4
802.11n HT20 Google Duo	CH.36 5180 MHz	20 MHz / MCS3 26 Mbps	6 kbit/s	z (Axial)	2.75	-25.15	-51.32	1.27	52.10	T4
				y (Transversal)	-5.75	-29.00	-51.35		43.46	T4
			35 kbit/s	z (Axial)	2.94	-24.96	-51.32	1.34	52.10	T4
				y (Transversal)	-5.55	-28.64	-51.35		43.24	T4
			64 kbit/s	z (Axial)	2.93	-24.54	-51.32	1.65	52.15	T4
				y (Transversal)	-6.08	-28.14	-51.35		43.12	T4

9.7. HAC (T-coil) Test Results

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 #
GSM 850 Voice Coder Speech Codec: Low	CH.190 836.6 MHz	N/A	z (Axial)	8.40	-2.50	-51.30	2.00	41.54	T4	1-2
			y (Transversal)	-3.66	-5.60	-51.35		42.08	T4	3
z (Axial)	8.29		-6.42	-51.30	2.00	45.40	T4	4-5		
y (Transversal)	-2.74		-9.57	-51.35		44.81	T4	6		
GSM 1900 Voice Coder Speech Codec: Low	CH.661 1880 MHz	N/A	z (Axial)	1.25	-34.37	-51.32	1.06	57.66	T4	7-8
W-CDMA Band II Voice Wideband AMR Codec: 6.6 kbit/s	CH.9262 1852.4 MHz		y (Transversal)	-5.06	-36.31	-51.35		53.53	T4	9
			z (Axial)	0.06	-34.14	-51.31	1.06	57.36	T4	10-11
W-CDMA Band IV Voice Wideband AMR Codec: 6.6 kbit/s	CH.1312 1712.4 MHz		y (Transversal)	-5.53	-35.75	-51.39		52.79	T4	12
			z (Axial)	1.97	-34.29	-51.32	1.42	58.24	T4	13-14
W-CDMA Band V Voice Wideband AMR Codec: 6.6 kbit/s	CH.4132 826.4 MHz		y (Transversal)	-5.30	-35.62	-51.35		53.38	T4	15
		z (Axial)	5.39	-27.02	-51.39	1.38	61.16	T4	16-17	
LTE Band 2 Voice Wideband AMR Codec: 15.85 kbit/s	CH.18900 1880 MHz	20 MHz 16QAM RB 1/0	y (Transversal)	-3.91	-28.64	-51.40		54.67	T4	18
LTE Band 12 Voice Wideband AMR Codec: 15.85 kbit/s	CH.23095 707.5 MHz	10 MHz 16QAM RB 1/0	z (Axial)	4.45	-27.69	-51.37	1.07	60.34	T4	19-20
			y (Transversal)	-2.08	-29.12	-51.35		55.74	T4	21
LTE Band 5 Voice Wideband AMR Codec: 15.85 kbit/s	CH.20525 836.6 MHz	10 MHz 16QAM RB 1/0	z (Axial)	4.64	-27.64	-51.37	1.13	60.18	T4	22-23
			y (Transversal)	-2.23	-29.32	-51.35		55.82	T4	24
LTE Band 66 Voice Wideband AMR Codec: 15.85 kbit/s	CH.132322 1745 MHz	20 MHz 16QAM RB 1/0	z (Axial)	4.94	-26.07	-51.37	1.03	59.99	T4	25-26
			y (Transversal)	-2.37	-27.38	-51.35		54.92	T4	27
LTE Band 7 Voice Wideband AMR Codec: 15.85 kbit/s	CH.21100 2535 MHz	20 MHz 16QAM RB 1/0	z (Axial)	5.07	-20.11	-51.37	1.14	59.86	T4	28-29
			y (Transversal)	-2.62	-27.12	-51.35		54.64	T4	30
LTE Band 41 Voice Wideband AMR Codec: 6.6 kbit/s	CH.40620 2593 MHz	15 MHz QPSK RB 1/0	z (Axial)	2.96	-16.01	-51.38	1.32	51.34	T4	31-32
			y (Transversal)	-5.90	-18.27	-51.36		49.39	T4	33
802.11g Voice EVS Primary Codec: 5.9 kbit/s	CH.1 2412 MHz	20 MHz / BPSK 6Mbps	z (Axial)	2.57	-28.70	-51.31	1.62	52.46	T4	34-35
			y (Transversal)	-5.31	-30.17	-51.41		44.50	T4	36
802.11n HT20 Voice EVS Primary Codec: 5.9 kbit/s	CH.36 5180 MHz	20 MHz / MCS3 26Mbps	z (Axial)	7.65	-26.43	-51.37	1.80	56.79	T4	37-38
			y (Transversal)	-3.45	-17.93	-51.34		43.98	T4	39
802.11n HT20 Voice EVS Primary Codec: 5.9 kbit/s	CH.52 5260 MHz	20 MHz / MCS3 26Mbps	z (Axial)	3.10	-25.32	-51.37	1.75	52.32	T4	40-41
			y (Transversal)	-4.30	-27.42	-51.38		43.48	T4	42
802.11n HT20 Voice EVS Primary Codec: 5.9 kbit/s	CH.100 5500 MHz	20 MHz / MCS3 26Mbps	z (Axial)	3.98	-30.00	-51.37	1.80	54.00	T4	43-44
			y (Transversal)	-4.07	-29.60	-51.38		45.96	T4	45
802.11n HT20 Voice EVS Primary Codec: 5.9 kbit/s	CH.149 5745 MHz	20 MHz / MCS3 26Mbps	z (Axial)	5.38	-29.17	-51.37	1.96	54.72	T4	46-47
			y (Transversal)	-4.90	-29.89	-51.38		43.96	T4	48

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	Codec bit 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 #
GSM 850 EDGE 2 Slots Google Duo	CH.190 836.6 MHz	N/A	35 kbit/s	z (Axial)	3.16	-8.85	-51.33	2.00	43.53	T4	49-50
				y (Transversal)	-6.61	-11.95	-51.37		41.68	T4	51
GSM 1900 EDGE 2 Slots Google Duo	CH.661 1880 MHz		35 kbit/s	z (Axial)	4.43	-10.36	-51.35	1.75	43.56	T4	52-53
				y (Transversal)	-5.60	-13.23	-51.42		42.94	T4	54
W-CDMA Band II HSUPA subtest1 Google Duo	CH.9262 1852.4 MHz	N/A	35 kbit/s	z (Axial)	9.55	-33.18	-51.35	2.00	59.95	T4	55-56
				y (Transversal)	0.61	-23.58	-51.42		51.32	T4	57
W-CDMA Band IV HSUPA subtest1 Google Duo	CH.1312 1712.4 MHz		35 kbit/s	z (Axial)	9.55	-34.08	-51.33	1.35	59.41	T4	58-59
				y (Transversal)	0.73	-33.24	-51.37		51.60	T4	60
W-CDMA Band V HSUPA subtest1 Google Duo	CH.4132 826.4 MHz		35 kbit/s	z (Axial)	9.39	-32.48	-51.35	2.00	59.18	T4	61-62
				y (Transversal)	1.05	-34.76	-51.42		51.80	T4	63
LTE Band 2 16QAM RB1/0 Google Duo	18900 1880 MHz	20 MHz	6 kbit/s	z (Axial)	0.63	-30.09	-50.97	2.00	48.78	T4	64-65
				y (Transversal)	-8.04	-31.21	-50.95		42.37	T4	66
LTE Band 5 16QAM RB1/0 Google Duo	20525 836.6 MHz	10 MHz	6 kbit/s	z (Axial)	1.13	-29.51	-50.97	2.00	49.79	T4	67-68
				y (Transversal)	-8.94	-29.53	-50.95		41.72	T4	69
LTE Band 7 16QAM RB1/0 Google Duo	CH.21100 2535 MHz	20 MHz	6 kbit/s	z (Axial)	-3.51	-27.14	-51.37	1.16	50.15	T4	70-71
				y (Transversal)	-12.50	-28.85	-51.35		45.30	T4	72
LTE Band 12 16QAM RB1/0 Google Duo	23095 707.5 MHz	10 MHz	6 kbit/s	z (Axial)	0.33	-28.18	-50.97	2.00	48.44	T4	73-74
				y (Transversal)	-7.85	-28.05	-50.95		42.34	T4	75
LTE Band 66 16QAM RB1/0 Google Duo	132322 1745 MHz	20 MHz	6 kbit/s	z (Axial)	-0.43	-27.91	-50.97	2.00	47.92	T4	76-77
				y (Transversal)	-8.39	-20.52	-50.95		41.90	T4	78
LTE Band 41 QPSK RB1/0 Google Duo	CH.40620 2593 MHz	15 MHz	64 kbit/s	z (Axial)	-1.82	-16.89	-51.37	2.00	48.54	T4	79-80
				y (Transversal)	-10.99	-18.97	-51.35		44.92	T4	81
802.11g Google Duo	CH.1 2412 MHz	20 MHz / BPSK 6Mbps	64 kbit/s	z (Axial)	2.90	-21.02	-51.32	1.45	51.93	T4	82-83
				y (Transversal)	-6.22	-24.80	-51.35		40.68	T4	84
802.11n HT20 Google Duo	CH.36 5180 MHz	20 MHz / MCS3 26Mbps	64 kbit/s	z (Axial)	2.93	-24.54	-51.32	1.65	52.15	T4	85-86
				y (Transversal)	-6.08	-28.14	-51.35		43.12	T4	87
802.11n HT20 Google Duo	CH.52 5260 MHz	20 MHz / MCS3 26Mbps	64 kbit/s	z (Axial)	2.86	-24.46	-51.30	1.35	52.07	T4	88-89
				y (Transversal)	-5.66	-28.00	-51.35		43.04	T4	90
802.11n HT20 Google Duo	CH.100 5500 MHz	20 MHz / MCS3 26Mbps	64 kbit/s	z (Axial)	2.51	-24.11	-51.30	1.38	51.92	T4	91-92
				y (Transversal)	-6.02	-25.42	-51.35		43.05	T4	93
802.11n HT20 Google Duo	CH.149 5745 MHz	20 MHz / MCS3 26Mbps	64 kbit/s	z (Axial)	2.50	-24.41	-51.30	1.32	51.88	T4	94-95
				y (Transversal)	-5.88	-28.19	-51.35		43.23	T4	96

Note:

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

9.8. Worst Case T-Coil Test Plot

Test Laboratory: UL Korea Ltd. Suwon Laboratory

Date: 2018-12-09

OTT_802.11g

Communication System: UID 0, IEEE 802.11b/g/n 2.4 GHz Band (0); Frequency: 2412 MHz; Duty Cycle: 1:1
Phantom section: TCoil Section

DASY5 Configuration:

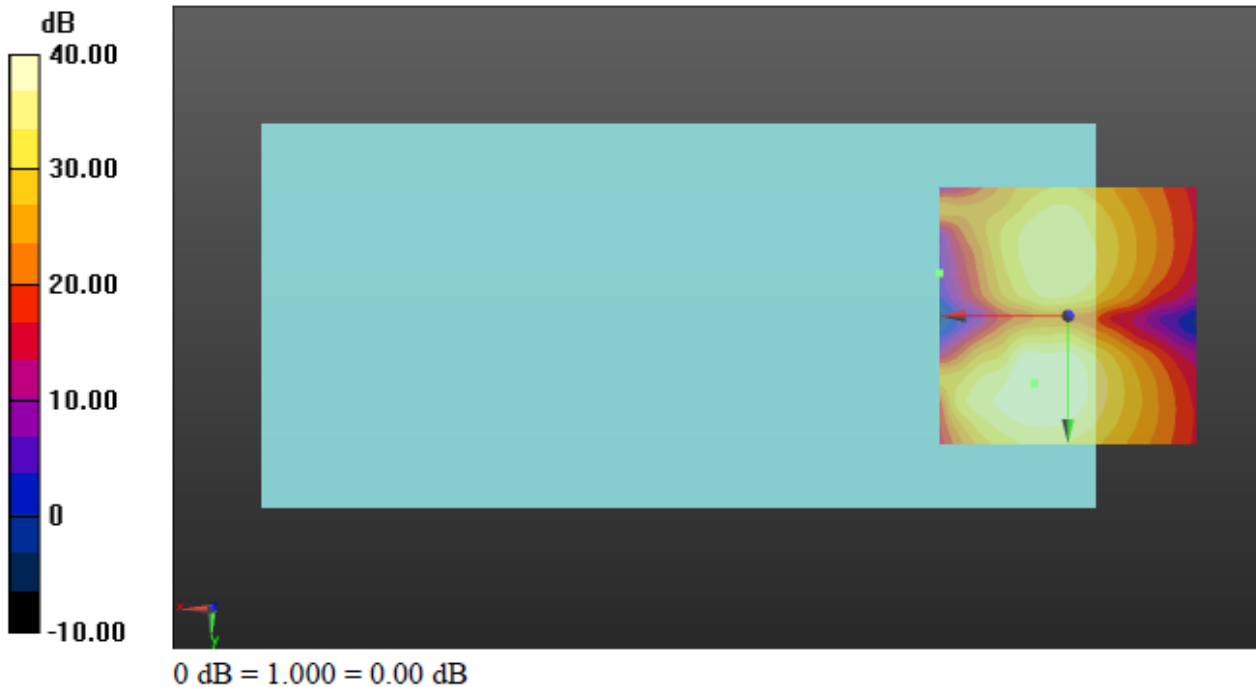
- Probe: AM1DV3 - 3137; ; Calibrated: 2018-11-20
- Sensor-Surface: 0mm (Fix Surface)
- Electronics: DAE4 Sn1447; Calibrated: 2018-03-15
- Phantom: HAC Test Arch with AMCC; Type: SD HAC P01 BB
- Measurement SW: DASY52, Version 52.8 (8);SEMCAD X Version 14.6.10 (7331)

T-Coil scan (scan for ANSI C63.19 2011 compliance)/802.11g 6Mbps ch1 duo 64kbps/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: 17
Measure Window Start: 300ms
Measure Window Length: 3000ms
BWC applied: 0.16 dB
Device Reference Point: 0, 0, -6.3 mm

Cursor:

ABM1/ABM2 = 40.68 dB
ABM1 comp = -6.22 dBA/m
BWC Factor = 0.16 dB
Location: 6.7, 13.3, 3.7 mm
ABM2 = -24.80 dBA/m
Location: 25, -8.3, 3.7 mm



Appendix

Refer to separated files for the following appendixes

4788725460-S3V2-Appendix A: T-Coil Setup Photo

4788725460-S3V2-Appendix B: T-Coil Test Plots

4788725460-S3V2-Appendix C: T-Coil Probe Certificates

END OF REPORT