HAC T-COIL SIGNAL TEST REPORT

FCC 47 CFR § 20.19
ANSI C63.19-2011

For
GSM/WCDMA/LTE Phablet with BT, DTS/UNII a/b/g/n/ac, NFC, ANT+ and WPT

FCC ID: A3LSMN770F
Model Name: SM-N770F & SM-N770F/DS

Report Number: 13094578-S2V3
Issue Date: 12/11/2019

Prepared for
SAMSUNG ELECTRONICS CO., LTD.
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NVLAP LAB CODE 200065-0

Revision History

Rev.	Date	Revisions	Revised By
V1	11/25/2019	Initial Issue	--
V2	12/2/2019	Updated Model Names and EUT Description Section 8.1: Updated Table	Coltyce Sanders
V3	12/11/2019	Updated: §5.2.: Removed mention of VoLTE and VoWi-Fi; §6.1. & §6.2.: Removed mention of VoLTE and VoWi-Fi; §8.1: Changed VoLTE and VoWi-Fi support from VD to DT; §9.1.1., §9.2., §9.3., §9.4., §9.5., & §10.1.: Removed VoLTE and VoWi-Fi data; Appendix B: Removed VoLTE and VoWi-Fi plots	Nathan Sousa

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1. Attestation of Test Results

Applicant Name	SAMSUNG ELECTRONICS CO., LTD.
FCC ID	A3LSMN770F
Model Name	SM-N770F & SM-N770F/DS (Model SM-N770F was used for testing)
Applicable Standards	FCC 47 CFR § 20.19 ANSI C63.19-2011
HAC Rating	T3
Date Tested	11/4/2019to 11/24/2019
Test Results	Pass

UL Verification Services Inc. tested the above equipment in accordance with the requirements set forth in the above standards. The test results show that the equipment tested is capable of demonstrating compliance with the requirements as documented in this report.
The results documented in this report apply only to the tested sample, under the conditions and modes of operation as described herein. It is the manufacturer's responsibility to assure that additional production units of this model are manufactured with identical electrical and mechanical components. All samples tested were in good operating condition throughout the entire test program. Measurement Uncertainties are published for informational purposes only and were not taken into account unless noted otherwise.
This document may not be altered or revised in any way unless done so by UL Verification Services Inc. and all revisions are duly noted in the revisions section. Any alteration of this document not carried out by UL Verification Services Inc. will constitute fraud and shall nullify the document. This report must not be used by the client to claim product certification, approval, or endorsement by NVLAP, NIST, any agency of the Federal Government, or any agency of the U.S. government.

Approved & Released By:	Prepared By:
	
Dave Weaver Operations Leader UL Verification Services Inc.	Nathan Sousa Senior Test Engineer UL Verification Services Inc.

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2. Test Methodology

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

47266 Benicia Street
SAR Lab 3
SAR Lab 7

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

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	3083	1/15/2020
Data Acquisition Electronics	SPEAG	DAE4	1540	2/18/2020
DAC	Sound Devices	USBPre 2	HB11173410003	N/A
Support Device	Lenovo	T450	PC-0A2UWH	N/A
Radio Communication Tester	R & S	CMW 500	125236	04/10/2020

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4.2. Measurement Uncertainty

Measurement Uncertainty for Audio Band Magnetic Measurement

Error Description	Uncertainty values (±%)	Probe Dist.	Div.	c_i ABM1	c_i ABM2	Std. Unc. ABM1 (±%)	Std. Unc. 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 disturbation	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

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5. Test Procedures for all Technologies

5.1. General Procedures C63.19-2011, §7

ANSI C63.19-2011, §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[1] and ABM2[2]. 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.*

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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.

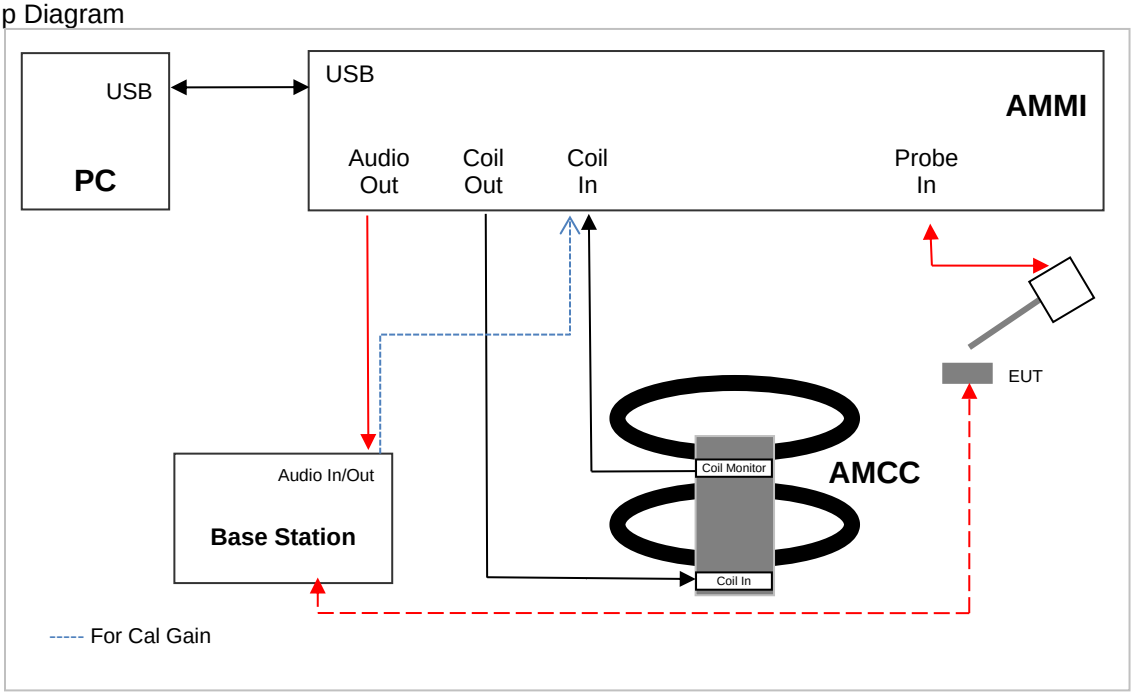
Equivalent methods of determining the frequency response may also be employed, such as fast Fourier transform (FFT) analysis using noise excitation or input–output comparison using simulated speech. The full-band integrated or half-band integrated probe output, as specified in D.9, may be used, as long 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.

Test Setup Diagram



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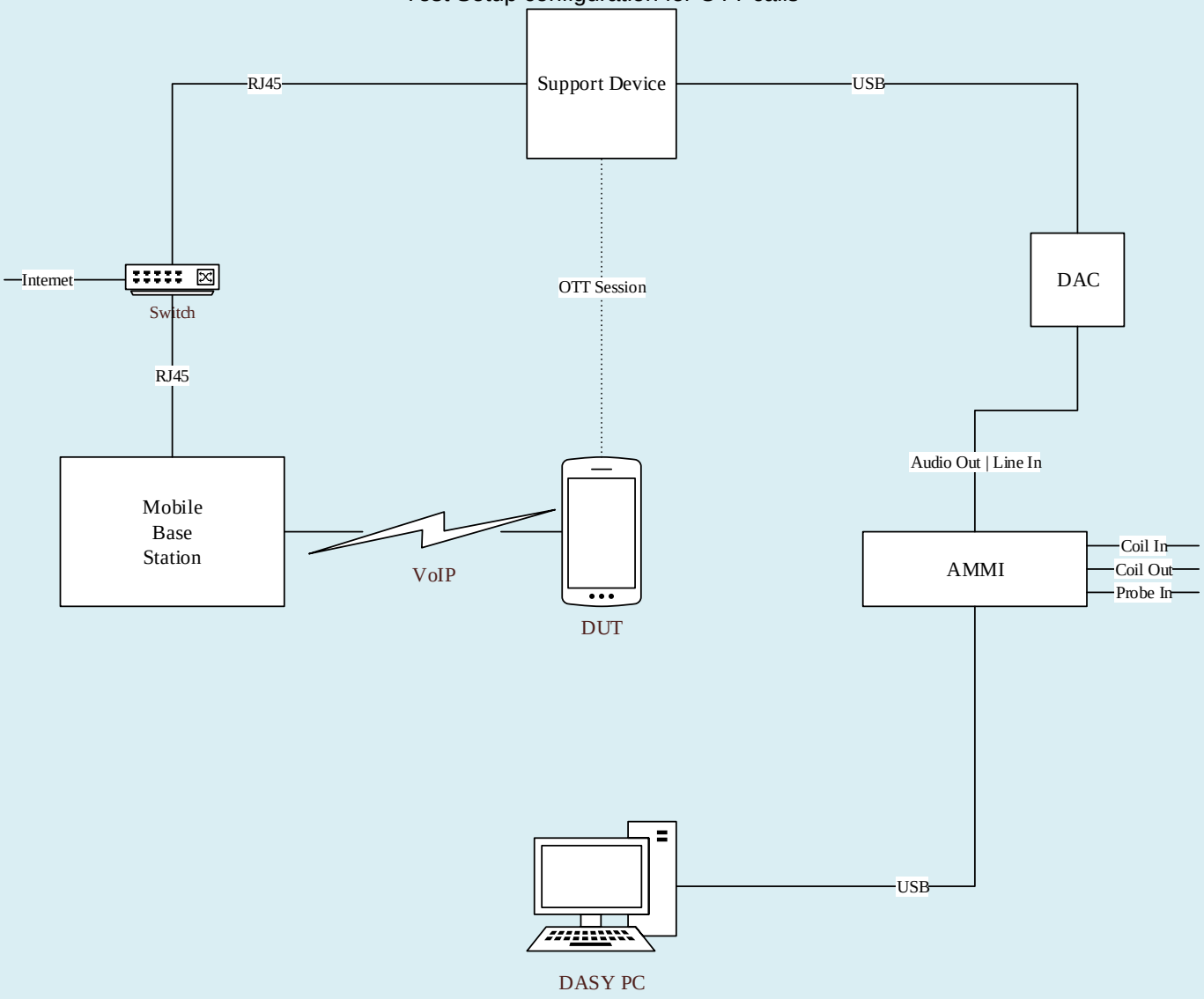
5.2. Over the Top (OTT) – For PAG REUSE

This device supports VoIP via a preinstalled application that uses the Google Duo service, using **OPUS** as its only codec (refer to §8.1 for air interface details and §9.6 for codec bit rates). VoIP capabilities require HAC assessment when voice calls are supported over the cellular data connection via pre-installed VoIP applications and the assessment is subject to Pre-Approval Guidance procedures.

The equipment is set up as shown below with a support device used to originate the call using the IP transport. The support device[3] connects to the cloud-based Google Duo service via a Wi-Fi access point and router, or a RJ45 Ethernet connection. The DUT connects to the VoIP service via a cellular/unlicensed air interface to the call box and an Ethernet connection from call box to Internet. The various codec bit rate and air interface configurations are evaluated to determine the worst-case configuration (refer to §9.6).

Test Setup configuration for OTT calls



For the OTT call, the calibrated audio card within the CMW500 cannot be used so the AMMI is connected to an external Digital-Analog Converter (DAC) and the DAC is connected to the Support Device via USB. The test signal is sent from the DASY PC to the AMMI, from the AMMI to the DAC, from the DAC to the Support Device, and, via the VoIP call, to the DUT.

[3] The support device is a Lenovo ThinkPad

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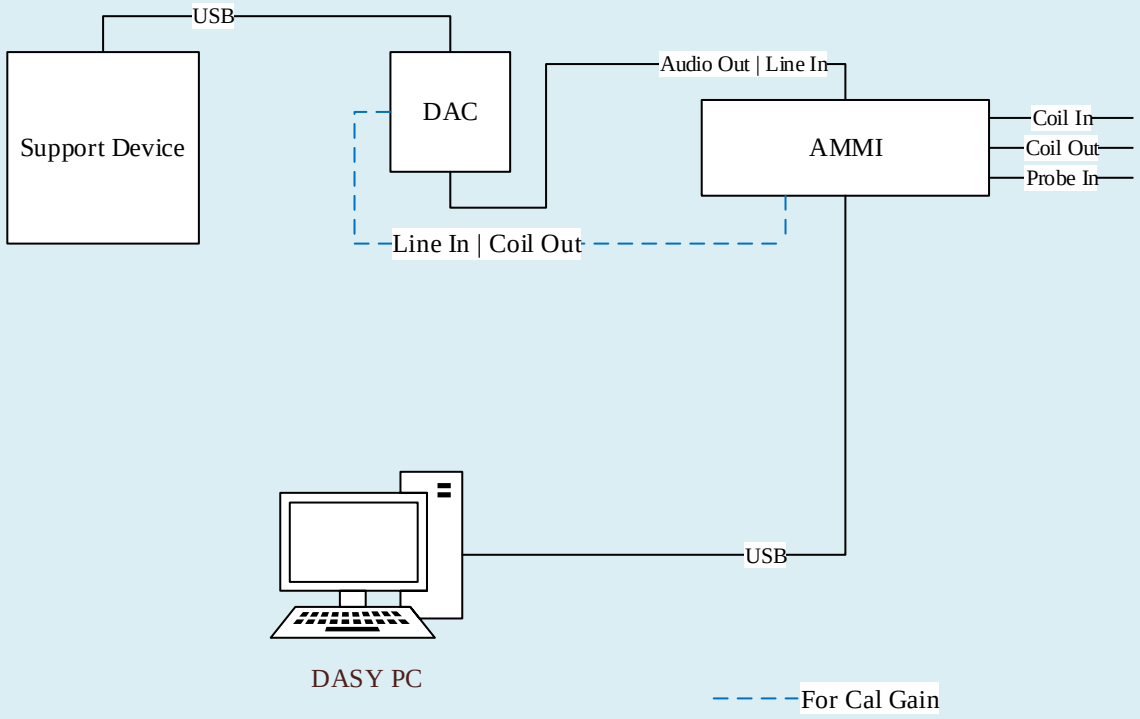
As this test set up uses an external DAC between the AMMI's audio output and support device, the appropriate gain factor for the OTT call needs be determined. This is done by connecting the DAC between the AMMI Audio output and Coil input as shown below.



Using the metering function on the DAC, the DAC gain is adjusted until the volume reaches 0 dBFS (3.14 dBm0 based on TIA/EIA 810-A). SPEAG's "TN-LK-05042018-C-T-Coil_Levels" document (Appendix E) steps E through H are then followed to determine the adjusted gain values as detailed in §6 so that the reference level is set to 23.14dB below full scale, i.e. at -20dBm0. A verification of the DAC's output is performed prior to testing.

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6. Audio Level and Gain Measurements

The adjusted gain was calculated using Speag's *TN-LK-05042018-D-T-Coil_Levels* document (please refer to Appendix E). First, the output of AMMI is determined in a closed loop, then, using the CMW500's input sensitivity, the adjusted gain required for testing can then be calculated. The adjusted linear gain used within this report is as follows:

6.1. GSM/W-CDMA

Signal type	Audio level [dBm0]	Gain [dB]	Gain (linear)
1 kHz sine	-16.00	14.90	5.56
Voice 1 kHz	-16.00	27.63	24.07
Voice 300-3kHz	-16.00	33.48	47.20

6.2. Over the Top (OTT) – For PAG REUSE

For EDGE, HSPA, LTE, and Wi-Fi, the linear gain levels are listed below. 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.

To calibrate the DAC (refer §5.3), 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 DAC. The Helmholtz resonator measures the field strength, which represents the AMMI to DAC 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)
1 kHz sine	-20.00	18.69	8.60
Voice 1 kHz	-20.00	31.42	37.22
Voice 300-3kHz	-20.00	37.27	72.99

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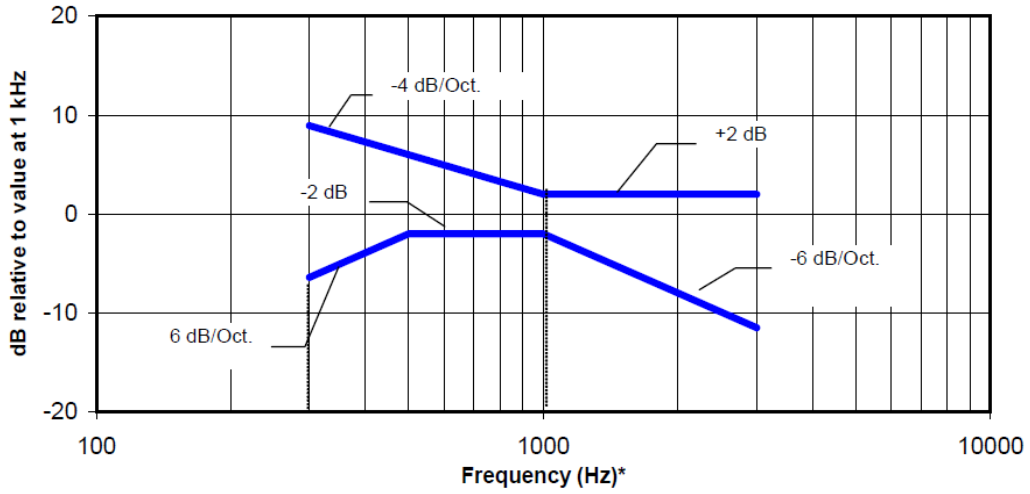
7. T-coil Measurement Criteria

7.1. Frequency Response

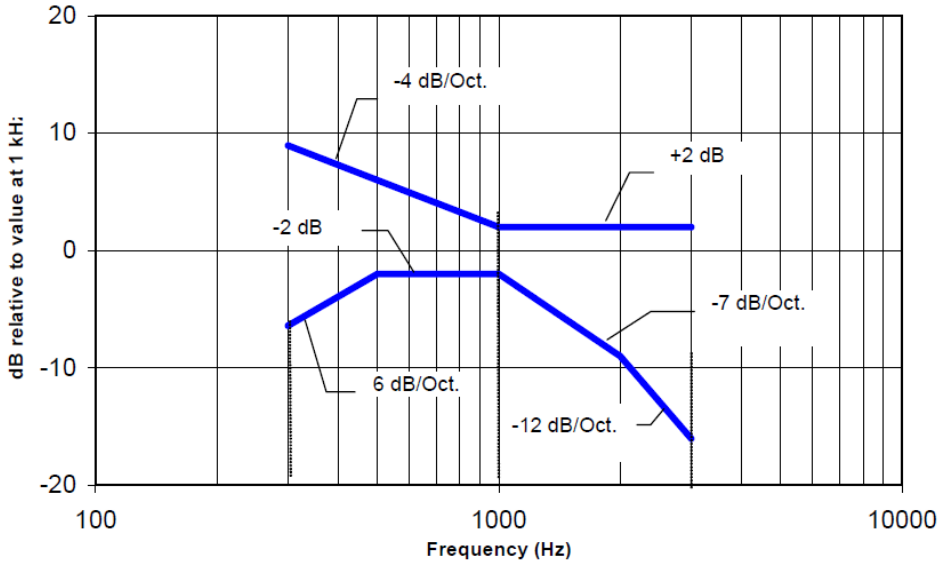
The frequency response of the axial component of the magnetic field, measured in 1/3 octave bands, shall follow the response curve, over the frequency range 300 Hz to 3000 Hz.

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

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7.2. Signal to Noise

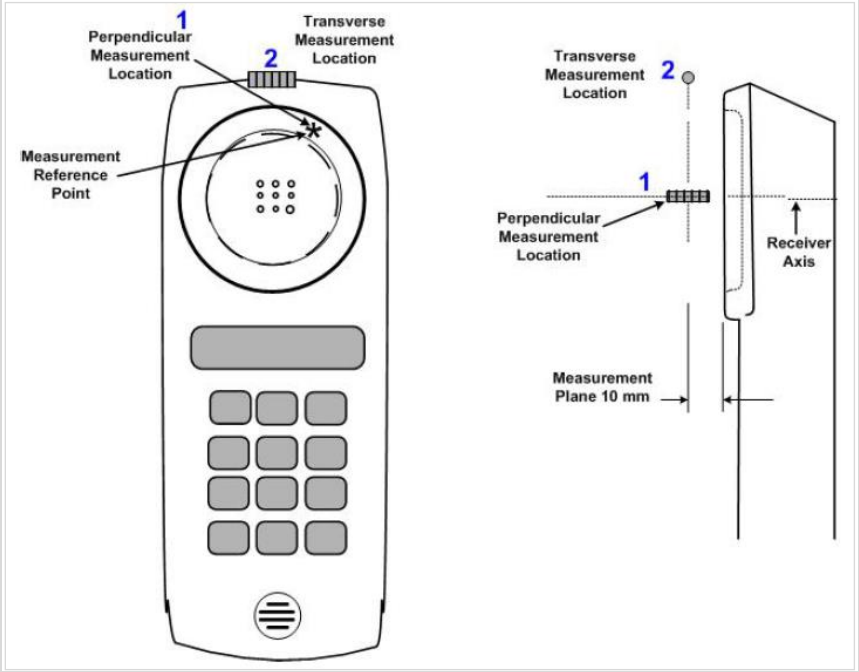
This specifies the signal-to-noise quality requirement for the intended T-Coil signal from a WD. The worst signal to noise of the two T-Coil signal measurements, as determined in Clause 7, shall be used to determine the T-Coil mode category per Table 8.5.

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



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8. Device Under Test

Normal operation	Held to head		
Back Cover	The Back Cover is not removable		
Test sample information	**S/N**	**IMEI**	**Notes**
	R38MA039RMJ	352339110058415	HAC Radiated
	R38MA039SPF	352339110058761	HAC Radiated

8.1. Air Interfaces and Operating Mode

Air Interface	Bands (MHz)	Type	C63.19 Tested	Simultaneous Transmitter	OTT Testing Required? Name of Voice Service[2]	Power Reduction	Audio Codecs Evaluated
GSM	850	VO	Yes	Wi-Fi, BT	CMRS	NA	EFR
	1900					No	
	GPRS/EDGE	VD	Yes	Wi-Fi, BT	Yes Google Duo	NA	OPUS
W-CDMA (UMTS)	850	VO	Yes	Wi-Fi, BT	CMRS	NA	AMR-NB & AMR-WB
	1700						
	1900						
	HSPA	VD	Yes	Wi-Fi, BT	Yes Google Duo	NA	OPUS
LTE – FDD[1]	700 (B12/13/17)	DT	Yes	Wi-Fi, BT	Yes Google Duo	NA	OPUS
	850 (B5)						
	1700 (B4/66)						
	1900 (B2)						
LTE – TDD[1]	2600 (B41)	DT	Yes	Wi-Fi, BT	Yes Google Duo	NA	OPUS
Wi-Fi[1]	2450	DT	Yes	WWAN and Wi-Fi 5GHz	Yes Google Duo	NA	OPUS
	5200 (U-NII-1)			WWAN, BT and Wi-Fi 2.4GHz			
	5300 (U-NII-2A)						
	5500 (U-NII-2C)						
	5800 (U-NII-3)						
BT	2450	DT	NA	WWAN, Wi-Fi 5GHz	NA	NA	N/A

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

Note:
1. VoLTE and VoWi-Fi calling are not installed by the manufacturer for devices in the US and its territories. No Associated T-Coil measurement has been made in accordance with 285076 D02 T-Coil testing for CMRS IP.
2. **For PAG REUSE**

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9. Investigations (Antenna, Codec, & Air Interface)

9.1. Antenna Investigation

An investigation was performed to determine the worst-case antenna per technology. All subsequent measurements were determined by this investigation.

9.1.1. OTT Application

Mode:	Channel and Frequency	Bandwidth (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	Location
802.11b Codec Bit Rate: 6 kbps	6 2437 MHz	20 MHz (1 Mbps)	ANT1	z (Axial)	2.66	-15.48	-50.57	1.53	46.25	T4	2.9, -4.2, 3.7
				y (Transversal)	-3.57	-20.89	-50.53		39.99	T4	3.8, -16.7, 3.7
			ANT2	z (Axial)	1.79	-15.24	-50.57	1.49	45.79	T4	1.7, -4.2, 3.7
				y (Transversal)	-8.12	-20.35	-50.53		**38.63**	T4	-3.7, -17.1, 3.7
802.11a Codec Bit Rate: 6 kbps	36 5180 MHz	20 MHz (6 Mbps)	ANT1	z (Axial)	1.25	-19.66	-50.57	1.32	47.57	T4	1.3, -3.8, 3.7
				y (Transversal)	-5.55	-23.88	-50.53		41.08	T4	-0.4, -19.6, 3.7
			ANT2	z (Axial)	0.83	-19.73	-50.57	1.24	47.23	T4	3.3, -1.7, 3.7
				y (Transversal)	-5.55	-21.41	-50.53		**40.66**	T4	-0.4, -19.6, 3.7

Note(s):

1. ANT 2 has been determined to be the worst-case antenna for Wi-Fi 2.4 GHz.
2. ANT 2 has been determined to be the worst-case antenna for Wi-Fi 5 GHz.

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9.2. Standard Phone Application Codec Bit-rate 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 codec investigation was performed on one band for W-CDMA.

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

W-CDMA Codec Investigation:

W-CDMA Codec Investigation								
Codec State	AMR-NB (kbps)			AMR-WB (kbps)			Orientation	Band/Channel/ Bandwidth
	4.75	7.4	12.2	6.6	15.85	23.85		
ABM1 (dB/m)	-3.96	-3.75	-3.50	-3.22	-1.91	-1.93	z (Axial)	W-CDMA BV Ch. 4183
ABM2 (dBA/m)	-20.05	-45.77	-46.68	-22.41	-45.69	-45.35		
SNR (dB)	42.08	42.02	43.18	42.51	43.78	43.42		
Freq. Resposne (dB)	1.32	1.04	1.05	1.54	2.00	2.00		
ABM1 (dB/m)	-10.35	-10.11	-9.97	-9.77	-8.37	-8.33	y (Transversal)	W-CDMA BV Ch. 4183
ABM2 (dBA/m)	-22.51	-47.85	-49.01	-23.36	-48.01	-47.81		
SNR (dB)	38.55	**37.74**	39.04	38.25	39.64	39.48		

Note(s):

A bitrate investigation was performed on the pre-installed phone application to determine the worst-case bitrate:

1. For W-CDMA, it is observed that 7.40 kbps is the worst-case.

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9.3. Standard Phone Application Air Interface Investigation

Using the worst-case bitrate found in §9.2, a limited set of bands/channels/bandwidths were then tested to confirm that there is no effect to the T-rating when changing the band/channel/bandwidth.

W-CDMA Air Interface Investigation:

W-CDMA Air Interface Investigation										
Mode:	Channel and Frequency	Bandwidth (if applicable)	Orientation	ABM1 dB(A/m)	ABM2 dB(A/m)	Ambient Noise dB(A/m)	Freq. Response (dB)	ABM SNR (dB)	T-Rating	Location
W-CDMA BV AMR-NB Bit rate: 7.4 kbps	4132 826.4 MHz	N/A	z (Axial)	-7.35	-23.40	-50.49	1.66	39.27	T4	0.8, -7.9, 3.7
			y (Transversal)	-12.86	-26.57	-50.50		36.13	T4	5, -16.7, 3.7
	4183 836.6 MHz	N/A	z (Axial)	-3.75	-45.77	-50.47	1.04	42.02	T4	0.4, -9.4, 3.7
			y (Transversal)	-10.11	-47.85	-50.44		37.74	T4	3.6, -16.8, 3.7
	4233 846.6 MHz	N/A	z (Axial)	-7.14	-46.28	-50.49	1.61	39.13	T4	1, -8, 3.7
			y (Transversal)	-12.51	-48.43	-50.50		**35.92**	T4	4.8, -16.7, 3.7
W-CDMA BIV AMR-NB Bit rate: 7.4 kbps	1312 1712.4 MHz	N/A	z (Axial)	-9.09	-23.91	-50.49	2.00	37.23	T4	2.1, -8.3, 3.7
			y (Transversal)	-14.94	-27.39	-50.50		34.06	T4	4.6, -16.7, 3.7
	1413 1732.6 MHz	N/A	z (Axial)	-8.83	-45.55	-50.49	2.00	36.72	T4	2.2, -8.4, 3.7
			y (Transversal)	-14.82	-47.67	-50.50		**32.85**	T4	4.7, -16.5, 3.7
	1513 1752.6 MHz	N/A	z (Axial)	-6.36	-24.55	-50.49	1.71	36.98	T4	2.5, -7.9, 3.7
			y (Transversal)	-12.65	-25.77	-50.50		36.02	T4	5, -16.7, 3.7
W-CDMA BII AMR-NB Bit rate: 7.4 kbps	9262 1852.4 MHz	N/A	z (Axial)	-7.40	-25.33	-50.49	1.87	39.74	T4	0.4, -8.3, 3.7
			y (Transversal)	-13.69	-29.19	-50.50		36.07	T4	0.8, -17.1, 3.7
	9400 1880 MHz	N/A	z (Axial)	-7.15	-47.00	-50.49	1.26	39.85	T4	0.5, -8.2, 3.7
			y (Transversal)	-13.76	-49.38	-50.50		**35.62**	T4	0.9, -17.2, 3.7
	9538 1907.6 MHz	N/A	z (Axial)	-7.26	-46.99	-50.49	1.29	39.73	T4	0.5, -8.2, 3.7
			y (Transversal)	-13.71	-49.61	-50.50		35.90	T4	0.9, -17.2, 3.7

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9.4. OTT Codec Investigation

An investigation between the various codec configurations (Low/Mid/High bit rates for Google Duo's OPUS codec) and specific parameters are documented (ABM1, ABM2, S+N/N, frequency response) to determine the worst-case bit rates for each VoIP service type. The table below compares the varying codec configurations. A codec investigation was performed on one band for the following technologies: GSM, W-CDMA, LTE FDD, LTE TDD, and Wi-Fi.

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

GSM Codec Investigation:

GSM Codec Investigation					
Codec State	OTT Application Bit Rate (kbps)			Orientation	Band/Channel/ Bandw idth
	6	40	75		
ABM1 (dB/m)	3.10	3.77	2.81	z (Axial)	GSM1900 EGPRS 2 Slots Ch. 661
ABM2 (dBA/m)	-13.59	-22.14	-23.60		
SNR (dB)	27.33	**25.92**	26.41		
Freq. Resposne (dB)	1.86	1.43	1.27		
ABM1 (dB/m)	-5.99	-5.39	-6.44	y (Transversal)	GSM1900 EGPRS 2 Slots Ch. 661
ABM2 (dBA/m)	-13.95	-41.19	-42.43		
SNR (dB)	36.24	35.80	35.89		

W-CDMA Codec Investigation:

W-CDMA Codec Investigation					
Codec State	OTT Application Bit Rate (kbps)			Orientation	Band/Channel/ Bandw idth
	6	40	75		
ABM1 (dB/m)	2.47	2.62	2.62	z (Axial)	W-CDMA BII HSPA Ch. 9400
ABM2 (dBA/m)	-19.64	-44.27	-44.40		
SNR (dB)	46.66	46.89	47.02		
Freq. Resposne (dB)	1.07	1.00	1.59		
ABM1 (dB/m)	-3.96	-3.80	-3.81	y (Transversal)	W-CDMA BII HSPA Ch. 9400
ABM2 (dBA/m)	-23.37	-48.17	-48.12		
SNR (dB)	**44.13**	44.37	44.31		

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LTE Codec Investigation:

LTE Codec Investigation					
Codec State	OTT Application Bit Rate (kbps)			Orientation	Band/Channel/ Bandw idth
	6	40	75		
ABM1 (dB/m)	2.55	2.65	2.63	z (Axial)	LTE Band 2 CH. 18900 1/49 RB QPSK 20 MHz BW
ABM2 (dBA/m)	-19.99	-43.83	-43.90		
SNR (dB)	46.61	46.48	46.53		
Freq. Resposne (dB)	1.20	1.79	1.46		
ABM1 (dB/m)	-4.30	-4.18	-4.20	y (Transversal)	
ABM2 (dBA/m)	-24.55	-46.96	-47.42		
SNR (dB)	43.66	**42.78**	43.22		
ABM1 (dB/m)	4.00	4.00	3.99	z (Axial)	LTE Band 41 CH. 40620 1/49 RB QPSK 20 MHz BW
ABM2 (dBA/m)	-3.40	-26.14	-26.16		
SNR (dB)	30.15	**30.13**	30.15		
Freq. Resposne (dB)	1.45	1.31	1.22		
ABM1 (dB/m)	-4.99	-5.07	-5.10	y (Transversal)	
ABM2 (dBA/m)	-9.44	-38.89	-39.07		
SNR (dB)	33.73	33.82	33.97		

Wi-Fi Codec Investigation:

Wi-Fi Codec Investigation					
Codec State	OTT Application Bit Rate (kbit/s)			Orientation	Band/Channel/ Bandw idth
	6	40	75		
ABM1 (dB/m)	1.79	1.85	1.84	z (Axial)	802.11b Ch. 6 DSSS 1 Mbps
ABM2 (dBA/m)	-15.24	-44.72	-44.76		
SNR (dB)	45.79	46.57	46.60		
Freq. Resposne (dB)	1.49	1.43	1.94		
ABM1 (dB/m)	-8.12	-7.65	-7.65	y (Transversal)	802.11b Ch. 6 DSSS 1 Mbps
ABM2 (dBA/m)	-20.35	-46.95	-47.22		
SNR (dB)	**38.63**	39.30	39.58		
ABM1 (dB/m)	0.83	0.82	0.83	z (Axial)	802.11a Ch. 36 BPSK 6 Mbps
ABM2 (dBA/m)	-19.73	-46.39	-46.48		
SNR (dB)	47.23	47.21	47.31		
Freq. Resposne (dB)	1.24	1.40	1.31		
ABM1 (dB/m)	-5.55	-5.50	-5.50	y (Transversal)	802.11a Ch. 36 BPSK 6 Mbps
ABM2 (dBA/m)	-21.41	-48.20	-48.05		
SNR (dB)	**40.66**	42.70	42.55		

Note(s):

A bitrate investigation was performed on the pre-installed phone application to determine the worst-case bitrate:

1. For GSM, it is observed that 40 kbps is the worst-case.
2. For W-CDMA, it is observed that 6 kbps is the worst-case.
3. For LTE-FDD and LTE-TDD, it is observed that 40 kbps is the worst-case.
4. For Wi-Fi 2.4 GHz and 5 GHz, it is observed that 6 kbps is the worst-case.

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9.5. OTT Air Interface Investigation

Using the worst-case bitrate found in §9.6, a limited set of bands/channels/bandwidths were then tested to confirm that there is no effect to the T-rating when changing the band/channel/bandwidth.

GSM Air Interface Investigation:

GSM Air Interface Investigation										
Mode:	Channel and Frequency	Bandwidth (if applicable)	Orientation	ABM1 dB(A/m)	ABM2 dB(A/m)	Ambient Noise dB(A/m)	Freq. Response (dB)	ABM SNR (dB)	T-Rating	Location
GSM850 EDGE/EGPRS 2 Slots 40 kbps	128 824.2 MHz	N/A	z (Axial)	2.53	-22.01	-50.49	2.00	**24.53**	T3	0.6, -8.5, 3.7
			y (Transversal)	-5.82	-39.65	-50.49		33.82	T4	2.4, -13.3, 3.7
	190 836.6 MHz	N/A	z (Axial)	2.63	-22.07	-50.49	2.00	24.70	T3	0.6, -8.5, 3.7
			y (Transversal)	-5.38	-39.56	-50.49		34.18	T4	2.4, -13.3, 3.7
	251 848.8 MHz	N/A	z (Axial)	2.84	-9.87	-50.49	2.00	25.06	T3	0.4, -8.3, 3.7
			y (Transversal)	-5.08	-10.88	-50.49		34.67	T4	2.5, -13.3, 3.7
GSM1900 EDGE/EGPRS 2 Slots 40 kbps	512 1850.2 MHz	N/A	z (Axial)	3.09	-11.51	-50.49	1.81	26.54	T3	0.8, -7.9, 3.7
			y (Transversal)	-5.88	-11.74	-50.49		35.29	T4	0.4, -13.8, 3.7
	661 1880.0 MHz	N/A	z (Axial)	3.77	-22.14	-50.49	1.43	25.92	T3	2.7, -7.9, 3.7
			y (Transversal)	-5.39	-41.19	-50.49		35.80	T4	0.3, -13.9, 3.7
	810 1909.8 MHz	N/A	z (Axial)	2.64	-23.28	-50.49	1.08	**25.92**	T3	0.7, -7.9, 3.7
			y (Transversal)	-6.25	-40.81	-50.49		34.56	T4	0.6, -13.7, 3.7

W-CDMA Air Interface Investigation:

W-CDMA Air Interface Investigation										
Mode:	Channel and Frequency	Bandwidth (if applicable)	Orientation	ABM1 dB(A/m)	ABM2 dB(A/m)	Ambient Noise dB(A/m)	Freq. Response (dB)	ABM SNR (dB)	T-Rating	Location
W-CDMA BII HSPA 6 kbps	9262 1852.4 MHz	N/A	z (Axial)	2.63	-44.48	-50.49	1.33	47.11	T4	1.2, -7.9, 3.7
			y (Transversal)	-3.80	-48.25	-50.49		44.44	T4	3.2, -17.8, 3.7
	9400 1880.0 MHz	N/A	z (Axial)	2.47	-19.64	-50.49	1.07	46.66	T4	1.3, -7.9, 3.7
			y (Transversal)	-3.96	-23.37	-50.49		**44.13**	T4	3.3, -17.9, 3.7
	9538 1907.6 MHz	N/A	z (Axial)	2.61	-44.54	-50.49	1.31	47.16	T4	1.2, -7.9, 3.7
			y (Transversal)	-3.53	-48.23	-50.49		44.70	T4	3.2, -17.8, 3.7
W-CDMA BIV HSPA 6 kbps	1312 1712.4 MHz	N/A	z (Axial)	3.58	-41.86	-50.49	1.34	45.44	T4	2.5, -8.6, 3.7
			y (Transversal)	-3.94	-46.56	-50.49		**42.62**	T4	2.8, -17.1, 3.7
	1413 1732.6 MHz	N/A	z (Axial)	3.22	-16.95	-50.49	1.19	44.41	T4	2.5, -8.8, 3.7
			y (Transversal)	-4.05	-22.25	-50.49		43.38	T4	2.9, -17.1, 3.7
	1513 1752.6 MHz	N/A	z (Axial)	3.58	-41.35	-50.49	1.08	44.93	T4	2.5, -8.6, 3.7
			y (Transversal)	-3.94	-47.26	-50.49		43.31	T4	2.8, -17.1, 3.7
W-CDMA BV HSPA 6 kbps	4132 826.4 MHz	N/A	z (Axial)	2.95	-41.78	-50.49	1.03	44.73	T4	1.7, -7.8, 3.7
			y (Transversal)	-3.76	-47.12	-50.49		43.36	T4	2.7, -17.7, 3.7
	4183 836.6 MHz	N/A	z (Axial)	2.80	-19.27	-50.49	1.12	44.37	T4	1.7, -7.9, 3.7
			y (Transversal)	-4.19	-23.54	-50.49		43.33	T4	2.5, -17.9, 3.7
	4233 846.6 MHz	N/A	z (Axial)	2.98	-41.58	-50.49	1.21	44.56	T4	1.7, -7.8, 3.7
			y (Transversal)	-3.97	-46.32	-50.49		**42.35**	T4	2.7, -17.7, 3.7

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LTE Air Interface Investigation:

VoLTE Air Interface Investigation												
Mode:	Bandwidth (if applicable)	Channel and Frequency	RB Allocation		Orientation	ABM1 dB(A/m)	ABM2 dB(A/m)	Ambient Noise dB(A/m)	Freq. Response (dB)	ABM SNR (dB)	T-Rating	Location
LTE Band 2 QPSK 40 kbps	20 MHz	18700 1860 MHz	1	49	z (Axial)	2.68	-43.52	-50.45	1.58	46.19	T4	1.2, -8.4, 3.7
					y (Transversal)	-4.13	-47.90	-50.48		43.76	T4	2.6, -17.3, 3.7
		18900 1880 MHz	1	0	z (Axial)	2.63	-43.83	-50.45	1.35	46.46	T4	1.2, -8.4, 3.7
					y (Transversal)	-4.21	-47.82	-50.48		43.61	T4	2.6, -17.3, 3.7
			1	49	z (Axial)	2.65	-43.83	-50.45	1.79	46.48	T4	1.2, -8.4, 3.7
					y (Transversal)	-4.18	-46.96	-50.48		42.78	T4	2.6, -17.3, 3.7
			1	99	z (Axial)	2.65	-45.01	-50.45	1.39	47.65	T4	1.2, -8.4, 3.7
					y (Transversal)	-4.17	-48.27	-50.48		44.10	T4	2.6, -17.3, 3.7
			50	0	z (Axial)	2.62	-45.69	-50.45	1.61	48.31	T4	1.2, -8.4, 3.7
					y (Transversal)	-4.20	-48.31	-50.48		44.11	T4	2.6, -17.3, 3.7
			50	24	z (Axial)	2.63	-44.84	-50.45	1.31	47.46	T4	1.2, -8.4, 3.7
					y (Transversal)	-4.18	-48.48	-50.48		44.29	T4	2.6, -17.3, 3.7
			50	49	z (Axial)	2.64	-44.39	-50.45	1.15	47.03	T4	1.2, -8.4, 3.7
					y (Transversal)	-4.18	-48.47	-50.48		44.28	T4	2.6, -17.3, 3.7
			100	0	z (Axial)	2.67	-44.45	-50.45	1.28	47.13	T4	1.2, -8.4, 3.7
					y (Transversal)	-4.13	-48.63	-50.48		44.50	T4	2.6, -17.3, 3.7
		19100 1900 MHz	1	49	z (Axial)	2.69	-43.29	-50.45	1.13	45.98	T4	1.2, -8.4, 3.7
					y (Transversal)	-4.13	-47.39	-50.48		43.26	T4	2.6, -17.3, 3.7
LTE Band 2 16QAM 40 kbps	20 MHz	18900 1880 MHz	1	49	z (Axial)	3.10	-15.42	-50.45	1.55	40.98	T4	2.5, -9.2, 3.7
					y (Transversal)	-4.88	-21.78	-50.48		**39.48**	T4	0.8, -17.1, 3.7
LTE Band 2 64QAM 40 kbps	20 MHz	18900 1880 MHz	1	49	z (Axial)	3.20	-15.65	-50.45	1.10	41.60	T4	2.5, -8.8, 3.7
					y (Transversal)	-4.84	-22.06	-50.48		39.98	T4	0.8, -17.1, 3.7
LTE Band 2 16QAM 40 kbps	15 MHz	18900 1880 MHz	1	37	z (Axial)	2.82	-20.03	-50.45	1.34	45.55	T4	1.7, -8.3, 3.7
					y (Transversal)	-4.18	-25.01	-50.48		43.16	T4	2.9, -17.1, 3.7
LTE Band 12 16QAM 40 kbps	10 MHz	23095 707.5 MHz	1	25	z (Axial)	2.81	-20.38	-50.45	1.51	46.05	T4	1.7, -8.3, 3.7
					y (Transversal)	-4.43	-24.88	-50.48		43.25	T4	2.1, -17.5, 3.7

Note(s):

For all subsequent tests for LTE-FDD, middle channel, 16QAM, 1% RB size and Mid RB allocation were used in conjunction with the worst-case bitrate found in §9.6.

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LTE Air Interface Investigation (continued):

VoLTE Air Interface Investigation												
Mode:	Bandwidth (if applicable)	Channel and Frequency	RB Allocation		Orientation	ABM1 dB(A/m)	ABM2 dB(A/m)	Ambient Noise dB(A/m)	Freq. Response (dB)	ABM SNR (dB)	T-Rating	Location
LTE Band 41 QPSK 40 kbps	20 MHz	39750 2506 MHz	1	99	z (Axial)	3.75	-25.69	-50.57	1.19	29.44	T3	11.4, -8.5, 3.7
					y (Transversal)	-6.06	-39.37	-50.53		33.31	T4	-0.8, -15.9, 3.7
		40185 2549.5 MHz	1	99	z (Axial)	3.82	-24.73	-50.57	1.11	28.55	T3	11.4, -8.5, 3.7
					y (Transversal)	-6.00	-37.80	-50.53		31.80	T4	-0.8, -15.9, 3.7
		40620 2593 MHz	1	0	z (Axial)	3.92	-4.43	-50.57	1.28	30.15	T4	11.3, -8.3, 3.7
					y (Transversal)	-6.13	-9.24	-50.53		31.95	T4	-0.8, -15.8, 3.7
			1	49	z (Axial)	4.00	-26.14	-50.45	1.31	30.13	T4	8.1, -11.8, 3.7
					y (Transversal)	-5.07	-38.89	-50.48		33.82	T4	0.2, -17, 3.7
			1	99	z (Axial)	3.75	-25.65	-50.57	1.15	29.40	T3	11.4, -8.5, 3.7
					y (Transversal)	-6.03	-39.36	-50.53		33.33	T4	-0.8, -15.9, 3.7
			50	0	z (Axial)	3.74	-25.79	-50.57	1.07	29.53	T3	11.4, -8.5, 3.7
					y (Transversal)	-6.03	-38.50	-50.53		32.47	T4	-0.8, -15.9, 3.7
			50	24	z (Axial)	3.81	-24.71	-50.57	1.09	29.52	T3	11.4, -8.5, 3.7
					y (Transversal)	-6.04	-39.60	-50.53		33.56	T4	-0.8, -15.9, 3.7
			50	49	z (Axial)	3.78	-25.95	-50.57	1.38	29.73	T3	11.4, -8.5, 3.7
					y (Transversal)	-6.04	-39.82	-50.53		33.78	T4	-0.8, -15.9, 3.7
			100	0	z (Axial)	3.75	-25.92	-50.57	1.11	29.67	T3	11.4, -8.5, 3.7
					y (Transversal)	-6.05	-39.60	-50.53		33.55	T4	-0.8, -15.9, 3.7
		41055 2636.5 MHz	1	99	z (Axial)	3.78	-24.26	-50.57	1.15	28.04	T3	11.4, -8.5, 3.7
					y (Transversal)	-6.00	-37.20	-50.53		31.20	T4	-0.8, -15.9, 3.7
		41490 2680 MHz	1	99	z (Axial)	3.80	-25.47	-50.57	1.75	29.28	T3	11.4, -8.5, 3.7
					y (Transversal)	-5.97	-38.92	-50.53		32.94	T4	-0.8, -15.9, 3.7
LTE Band 41 QPSK 40 kbps	15 MHz	41055 2636.5 MHz	1	74	z (Axial)	4.14	-1.96	-50.57	1.32	27.96	T3	8.3, -10.8, 3.7
					y (Transversal)	-6.08	-8.21	-50.53		30.85	T4	-0.8, -15.8, 3.7
	10 MHz	41055 2636.5 MHz	1	49	z (Axial)	4.15	-1.99	-50.57	1.56	**27.92**	T3	8.3, -10.8, 3.7
					y (Transversal)	-6.08	-8.25	-50.53		30.89	T4	-0.8, -15.8, 3.7
LTE Band 41 16QAM 40 kbps	10 MHz	41055 2636.5 MHz	1	49	z (Axial)	3.97	-2.58	-50.57	1.17	28.61	T3	8.3, -11.3, 3.7
					y (Transversal)	-6.07	-8.85	-50.53		31.61	T4	-0.8, -15.8, 3.7
LTE Band 41 64QAM 40 kbps	10 MHz	41055 2636.5 MHz	1	49	z (Axial)	4.23	-3.58	-50.57	1.18	29.36	T3	10.4, -8.8, 3.7
					y (Transversal)	-6.07	-9.84	-50.53		32.76	T4	-0.8, -15.8, 3.7

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Wi-Fi Air Interface Investigation:

Wi-Fi Air Interface Investigation												
Mode:	Channel and Frequency	Antenna	Modulation/Index	Data Rate	Orientation	ABM1 dB(A/m)	ABM2 dB(A/m)	Ambient Noise dB(A/m)	Freq. Response (dB)	ABM SNR (dB)	T-Rating	Location
802.11b 6 kbps	6 2437 MHz	ANT2	CCK	5.5 Mbps	z (Axial)	1.86	-44.76	-50.57	1.37	46.62	T4	1.7, -4.1, 3.7
					y (Transversal)	-7.63	-47.06	-50.53		39.43	T4	-3.7, -17.3, 3.7
				11 Mbps	z (Axial)	1.86	-45.01	-50.57	1.32	46.88	T4	1.7, -4.1, 3.7
					y (Transversal)	-7.64	-47.20	-50.53		39.55	T4	-3.7, -17.3, 3.7
802.11g 6 kbps	6 2437 MHz	ANT2	DSSS	1 Mbps	z (Axial)	1.82	-15.50	-50.57	1.35	46.14	T4	1.7, -4.2, 3.7
					y (Transversal)	-3.64	-21.23	-50.53		**38.50**	T4	3.3, -17.1, 3.7
			QPSK	12 Mbps	z (Axial)	1.96	-46.06	-50.57	1.00	48.02	T4	1.8, -4.1, 3.7
					y (Transversal)	-3.48	-46.66	-50.53		43.18	T4	3.3, -16.9, 3.7
			64QAM	54 Mbps	z (Axial)	1.97	-46.04	-50.57	1.41	48.01	T4	1.8, -4.1, 3.7
					y (Transversal)	-3.48	-47.11	-50.53		43.63	T4	3.3, -16.9, 3.7
802.11n 6 kbps	6 2437 MHz	ANT2	MCS0	6.5 Mbps	z (Axial)	2.08	-18.45	-50.55	1.31	46.91	T4	4.2, -2.9, 3.7
					y (Transversal)	-5.32	-23.36	-50.50		40.68	T4	-0.4, -19.2, 3.7
			MCS3	26 Mbps	z (Axial)	2.12	-44.84	-50.55	1.32	46.96	T4	4.3, -3, 3.7
					y (Transversal)	-5.20	-48.62	-50.50		43.42	T4	-0.3, -19.3, 3.7
			MCS7	65 Mbps	z (Axial)	2.11	-45.16	-50.55	1.07	47.27	T4	4.3, -3, 3.7
					y (Transversal)	-5.20	-48.71	-50.50		43.51	T4	-0.3, -19.3, 3.7
802.11ac 6 kbps	6 2437 MHz	ANT2	MCS0	6.5 Mbps	z (Axial)	3.07	-19.26	-50.55	1.24	44.65	T4	4.2, -4.2, 3.7
					y (Transversal)	-3.89	-23.85	-50.50		40.95	T4	2.1, -17.5, 3.7
			MCS4	39 Mbps	z (Axial)	3.06	-41.95	-50.55	1.30	45.01	T4	4, -4.3, 3.7
					y (Transversal)	-3.73	-46.17	-50.50		42.44	T4	2.2, -17.3, 3.7
			MCS7	65 Mbps	z (Axial)	3.04	-41.90	-50.55	1.58	44.95	T4	4, -4.3, 3.7
					y (Transversal)	-3.74	-46.13	-50.50		42.39	T4	2.2, -17.3, 3.7
802.11a 6 kbps	36 5180 MHz	ANT2	QPSK	18 Mbps	z (Axial)	0.84	-46.78	-50.57	1.32	47.62	T4	3.5, -1.8, 3.7
					y (Transversal)	-5.50	-48.33	-50.53		42.83	T4	-0.4, -19.5, 3.7
			64QAM	54 Mbps	z (Axial)	0.85	-46.56	-50.57	1.04	47.41	T4	3.5, -1.8, 3.7
					y (Transversal)	-5.50	-48.10	-50.53		42.60	T4	-0.4, -19.5, 3.7
802.11n 20 MHz 6 kbps	36 5180 MHz	ANT2	MCS0	6.5 Mbps	z (Axial)	3.44	-18.13	-50.55	1.61	43.81	T4	7.1, -4.2, 3.7
					y (Transversal)	-5.58	-22.83	-50.50		39.89	T4	-0.4, -20.4, 3.7
			MCS3	26 Mbps	z (Axial)	3.48	-40.79	-50.55	1.17	44.28	T4	7, -4.2, 3.7
					y (Transversal)	-5.48	-46.55	-50.50		41.06	T4	-0.3, -20.3, 3.7
			MCS7	65 Mbps	z (Axial)	3.52	-40.70	-50.55	1.23	44.22	T4	7, -4.2, 3.7
					y (Transversal)	-5.49	-46.11	-50.50		40.62	T4	-0.3, -20.3, 3.7
802.11n 40 MHz 6 kbps	38 5190 MHz	ANT2	MCS0	13.5 Mbps	z (Axial)	0.23	-15.83	-50.52	1.48	42.50	T4	4.2, -0.8, 3.7
					y (Transversal)	-11.87	-20.17	-50.47		**36.66**	T4	-7.9, -20.4, 3.7
			MCS3	54 Mbps	z (Axial)	-0.33	-43.96	-50.52	1.20	43.63	T4	4.3, -0.6, 3.7
					y (Transversal)	-11.64	-49.25	-50.47		37.61	T4	-7.8, -20.4, 3.7
			MCS7	135 Mbps	z (Axial)	0.40	-45.41	-50.52	2.00	45.82	T4	4.3, -0.6, 3.7
					y (Transversal)	-10.66	-50.04	-50.47		39.38	T4	-7.8, -20.4, 3.7
802.11ac 20 MHz 6 kbps	36 5180 MHz	ANT2	MCS0	6.5 Mbps	z (Axial)	2.85	-18.32	-50.52	1.21	46.41	T4	2.5, -3.8, 3.7
					y (Transversal)	-4.61	-23.15	-50.47		40.17	T4	-0.4, -18.3, 3.7
			MCS4	39 Mbps	z (Axial)	2.87	-41.74	-50.52	1.43	44.61	T4	2.7, -3.7, 3.7
					y (Transversal)	-4.69	-47.31	-50.47		42.62	T4	-0.5, -18.4, 3.7
			MCS8	78 Mbps	z (Axial)	2.85	-41.80	-50.52	1.21	44.65	T4	2.7, -3.7, 3.7
					y (Transversal)	-4.69	-47.36	-50.47		42.67	T4	-0.5, -18.4, 3.7

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Wi-Fi Air Interface Investigation (continued):

Wi-Fi Air Interface Investigation												
Mode:	Channel and Frequency	Antenna	Modulation/Index	Data Rate	Orientation	ABM1 dB(A/m)	ABM2 dB(A/m)	Ambient Noise dB(A/m)	Freq. Response (dB)	ABM SNR (dB)	T-Rating	Location
802.11ac 40 MHz 6 kbps	38 5190 MHz	ANT2	MCS0	13.5 Mbps	z (Axial)	3.64	-18.44	-50.52	1.55	44.31	T4	3.8, -4.2, 3.7
					y (Transversal)	-5.52	-22.93	-50.47		40.33	T4	-1.7, -17.9, 3.7
			MCS5	108 Mbps	z (Axial)	3.65	-41.12	-50.52	1.02	44.76	T4	4, -4.2, 3.7
					y (Transversal)	-5.72	-47.79	-50.47		42.07	T4	-2, -17.7, 3.7
			MCS9	180 Mbps	z (Axial)	3.63	-41.32	-50.52	1.47	44.95	T4	4, -4.2, 3.7
					y (Transversal)	-5.72	-47.95	-50.47		42.23	T4	-2, -17.7, 3.7
802.11ac 80 MHz 6 kbps	42 5210 MHz	ANT2	MCS0	13.5 Mbps	z (Axial)	3.62	-18.80	-50.52	1.41	44.69	T4	3.8, -4.2, 3.7
					y (Transversal)	-4.85	-23.33	-50.47		40.69	T4	-0.8, -17.9, 3.7
			MCS5	108 Mbps	z (Axial)	3.54	-41.18	-50.52	1.14	44.72	T4	3.5, -4.3, 3.7
					y (Transversal)	-4.94	-47.38	-50.47		42.44	T4	-0.9, -17.9, 3.7
			MCS9	180 Mbps	z (Axial)	3.55	-41.29	-50.52	1.25	44.84	T4	3.5, -4.3, 3.7
					y (Transversal)	-4.95	-47.57	-50.47		42.62	T4	-0.9, -17.9, 3.7

Note(s):

1. For all subsequent tests for 2.4 GHz, 802.11g with DSSS 1 Mbps was used in conjunction with the worst-case bitrate found in §9.6.
2. For all subsequent tests for 5 GHz, 802.11n HT40 MHz with MCS0 was used in conjunction with the worst-case bitrate found in §9.6.

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10. HAC (T-coil) Test Results

As the margin for the worst-case T-rating is greater than T3/T4, no further investigation is required into the technology's supported channels to affirm the T-rating.

10.1. Standard Phone Application

GSM/W-CDMA:

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	Location	Plot Page #
GSM 850 Voice Coder Speechcodec Low	190 836.6 MHz	N/A	z (Axial)	-3.43	-16.60	-50.47	1.11	**23.88**	T3	2.1, -7.9, 3.7	1 - 3
			y (Transversal)	-11.03	-16.69	-50.44		32.90	T4	3.8, -13.3, 3.7	
GSM 1900 Voice Coder Speechcodec Low	661 1880 MHz	N/A	z (Axial)	-3.52	-19.02	-50.47	1.06	26.54	T3	1.3, -8.3, 3.7	4 - 6
			y (Transversal)	-10.49	-18.46	-50.44		33.84	T4	3.8, -14.2, 3.7	
W-CDMA BII AMR-NB Bit rate: 7.4 kbps	9400 1880 MHz	N/A	z (Axial)	-7.15	-47.00	-50.49	1.26	39.85	T4	0.5, -8.2, 3.7	7 - 9
			y (Transversal)	-13.76	-49.38	-50.50		35.62	T4	0.9, -17.2, 3.7	
W-CDMA BIV AMR-NB Bit rate: 7.4 kbps	1413 1732.6 MHz	N/A	z (Axial)	-8.83	-45.55	-50.49	2.00	36.72	T4	2.2, -8.4, 3.7	10 - 12
			y (Transversal)	-14.82	-47.67	-50.50		32.85	T4	4.7, -16.5, 3.7	
W-CDMA BV AMR-NB Bit rate: 7.4 kbps	4233 846.6 MHz	N/A	z (Axial)	-7.14	-46.28	-50.49	1.61	39.13	T4	1, -8, 3.7	13 - 15
			y (Transversal)	-12.51	-48.43	-50.50		35.92	T4	4.8, -16.7, 3.7	

Note:

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

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10.2. OTT Application

GSM/W-CDMA:

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	Location	Plot Page #
GSM850 EDGE/EGPRS 2 Slots 40 kbps	128 824.2 MHz	N/A	z (Axial)	2.53	-22.01	-50.49	2.00	24.53	T3	0.6, -8.5, 3.7	1 - 3
			y (Transversal)	-5.82	-39.65	-50.49		33.82	T4	2.4, -13.3, 3.7	
GSM1900 EDGE/EGPRS 2 Slots 40 kbps	810 1909.8 MHz	N/A	z (Axial)	2.64	-23.28	-50.49	1.08	25.92	T3	0.7, -7.9, 3.7	4 - 6
			y (Transversal)	-6.25	-40.81	-50.49		34.56	T4	0.6, -13.7, 3.7	
W-CDMA BII HSPA 6 kbps	9400 1880 MHz	N/A	z (Axial)	2.47	-19.64	-50.49	1.07	46.66	T4	1.3, -7.9, 3.7	7 - 9
			y (Transversal)	-3.96	-23.37	-50.49		44.13	T4	3.3, -17.9, 3.7	
W-CDMA BIV HSPA 6 kbps	1312 1712.4 MHz	N/A	z (Axial)	3.58	-41.86	-50.49	1.34	45.44	T4	2.5, -8.6, 3.7	10 - 12
			y (Transversal)	-3.94	-46.56	-50.49		42.62	T4	2.8, -17.1, 3.7	
W-CDMA BV HSPA 6 kbps	4233 846.6 MHz	N/A	z (Axial)	2.98	-41.58	-50.49	1.21	44.56	T4	1.7, -7.8, 3.7	13 - 15
			y (Transversal)	-3.97	-46.32	-50.49		42.35	T4	2.7, -17.7, 3.7	

LTE:

Mode:	Channel and Frequency	Bandwidth (Data Rate)	RB Allocation		Orientation	ABM1 dB(A/m)	ABM2 dB(A/m)	Ambient Noise dB(A/m)	Freq. Response (dB)	ABM SNR (dB)	T-Rating	Location	Plot Page #
LTE Band 2 16QAM 40 kbps	18900 1880 MHz	20 MHz	1	49	z (Axial)	3.10	-15.42	-50.45	1.55	40.98	T4	2.5, -9.2, 3.7	16 - 18
					y (Transversal)	-4.88	-21.78	-50.48		39.48	T4	0.8, -17.1, 3.7	
LTE Band 5 16QAM 40 kbps	20525 836.5 MHz	10 MHz	1	25	z (Axial)	2.99	-19.53	-50.45	1.09	46.74	T4	2.1, -8.3, 3.7	19 - 21
					y (Transversal)	-3.89	-24.78	-50.48		43.66	T4	3.3, -17.1, 3.7	
LTE Band 12 16QAM 40 kbps	23095 707.5 MHz	10 MHz	1	25	z (Axial)	2.81	-20.38	-50.45	1.51	46.05	T4	1.7, -8.3, 3.7	22 - 24
					y (Transversal)	-4.43	-24.88	-50.48		43.25	T4	2.1, -17.5, 3.7	
LTE Band 13 16QAM 40 kbps	23230 782 MHz	10 MHz	1	25	z (Axial)	3.36	-17.02	-50.45	1.24	43.86	T4	2.9, -9.2, 3.7	25 - 27
					y (Transversal)	-4.26	-22.78	-50.48		42.15	T4	2.1, -17.1, 3.7	
LTE Band 41 QPSK 40 kbps	41055 2636.5 MHz	10 MHz	1	49	z (Axial)	4.15	-1.99	-50.57	1.56	27.92	T3	8.3, -10.8, 3.7	28 - 30
					y (Transversal)	-6.08	-8.25	-50.53		30.89	T4	-0.8, -15.8, 3.7	
LTE Band 66 16QAM 40 kbps	132322 1745 MHz	20 MHz	1	49	z (Axial)	3.23	-17.48	-50.45	1.35	44.54	T4	2.5, -8.8, 3.7	31 - 33
					y (Transversal)	-4.10	-22.84	-50.48		42.63	T4	2.5, -17.1, 3.7	

Note:

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

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Wi-Fi:

Mode:	Channel and Frequency	Bandwidth (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	Location	Plot Page #
802.11g 6 kbps	6 2437 MHz	20 MHz (DSSS 1 Mbps)	ANT 2	z (Axial)	1.82	-15.50	-50.57	1.35	46.14	T4	1.7, -4.2, 3.7	34 - 36
				y (Transversal)	-3.64	-21.23	-50.53		38.50	T4	3.3, -17.1, 3.7	
802.11n 40 MHz 6 kbps	38 5190 MHz	40 MHz (MCS0 13.5 Mbps)	ANT 2	z (Axial)	0.23	-15.83	-50.52	1.48	42.50	T4	4.2, -0.8, 3.7	37 - 39
				y (Transversal)	-11.87	-20.17	-50.47		36.66	T4	-7.9, -20.4, 3.7	
	54 5270 MHz	40 MHz (MCS0 13.5 Mbps)	ANT 2	z (Axial)	3.68	-18.68	-50.52	1.49	44.07	T4	4.2, -4.2, 3.7	40 - 42
				y (Transversal)	-5.92	-23.06	-50.47		40.29	T4	-2.1, -17.5, 3.7	
	102 5510 MHz	40 MHz (MCS0 13.5 Mbps)	ANT 2	z (Axial)	3.97	-18.41	-50.52	1.21	44.22	T4	6.3, -4.2, 3.7	43 - 45
				y (Transversal)	-5.98	-23.02	-50.47		40.23	T4	-2.1, -17.5, 3.7	
	151 5755 MHz	40 MHz (MCS0 13.5 Mbps)	ANT 2	z (Axial)	3.69	-18.40	-50.52	1.19	44.00	T4	4.2, -4.2, 3.7	46 - 48
				y (Transversal)	-7.22	-23.03	-50.47		40.10	T4	-3.3, -17.5, 3.7	

Note:

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

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10.3. Worst Case T-Coil Test Plot

Test Laboratory: UL Verification Services Inc. SAR Lab 7 Date: 11/8/2019

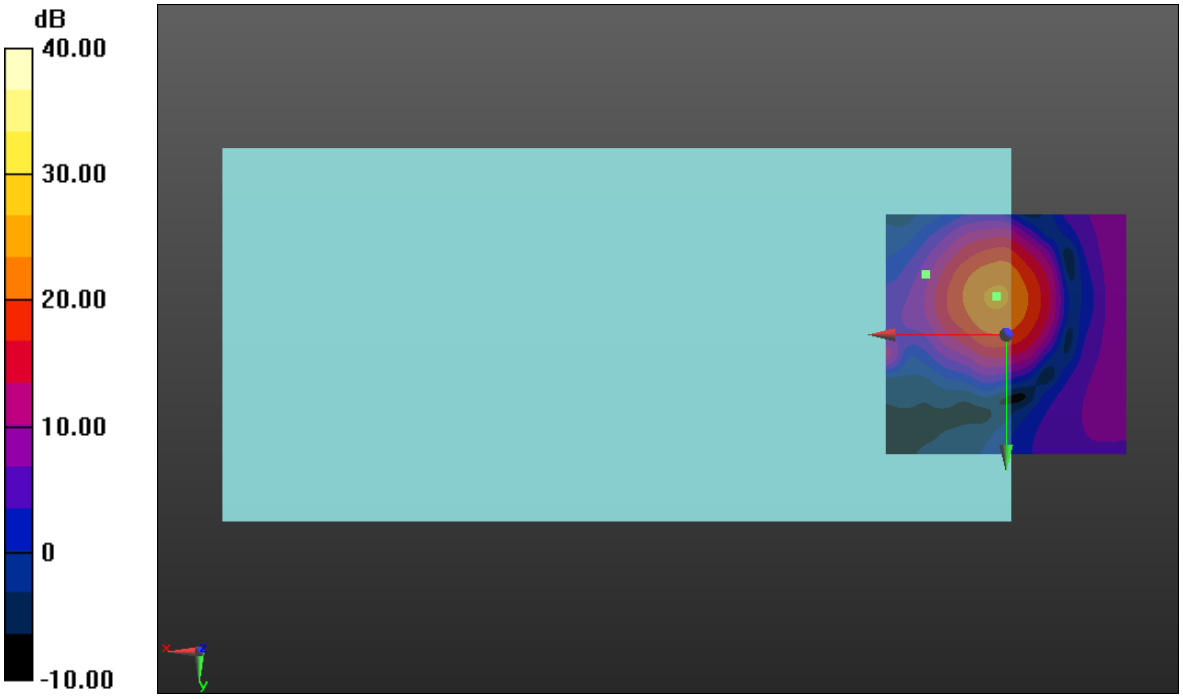
GSM 850

Communication System: UID 0, GPRS-FDD (TDMA, GMSK, 1 slot) (0); Frequency: 836.6 MHz; Duty Cycle: 1:8.00018
Phantom section: TCoil Section
DASY5 Configuration:
- Probe: AM1DV3 - 3083; ; Calibrated: 1/15/2018
- Sensor-Surface: 0mm (Fix Surface)
- Electronics: DAE4 Sn1540; Calibrated: 2/18/2019
- Phantom: HAC Test Arch with AMCC; Type: SD HAC P01 BB
- Measurement SW: DASY52, Version 52.10 (2);SEMCAD X Version 14.6.12 (7470)

T-Coil scan (scan for ANSI C63.19 2011 compliance)/GSM 850 ch 190/z (axial) 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: 24.07
Measure Window Start: 300ms
Measure Window Length: 1000ms
BWC applied: 0.16 dB
Device Reference Point: 0, 0, -6.3 mm

Cursor:
ABM1/ABM2 = 23.88 dB
ABM1 comp = -3.43 dBA/m
BWC Factor = 0.16 dB
Location: 2.1, -7.9, 3.7 mm
ABM2 = -16.60 dBA/m
Location: 16.7, -12.5, 3.7 mm



0 dB = 1.000 = 0.00 dB

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Appendix

Refer to separated files for the following appendixes

Appendix A: T-Coil Setup Photo

Appendix B: T-Coil Test Plots

Appendix C: T-Coil Test Plots (OTT)

Appendix D: T-Coil Probe Certificates

Appendix E: Adjusted Gain Procedure

END OF REPORT

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