HEARING AID COMPATIBILITY

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

Date of Testing:
05/31/2018 - 06/05/2018
Test Site/Location:
PCTEST Lab, Columbia, MD, USA
Test Report Serial No.:
1M1804300090-13.A3L

FCC ID:	**A3LSMN9600**
APPLICANT:	**SAMSUNG ELECTRONICS CO., LTD.**

Scope of Test:	Audio Band Magnetic Testing (T-Coil)
Application Type:	Certification
FCC Rule Part(s):	CFR §20.19(b)
HAC Standard:	ANSI C63.19-2011 285076 D01 HAC Guidance v05 285076 D02 T-Coil testing for CMRS IP v03
DUT Type:	Portable Handset
Model:	SM-N9600
Additional Model(s):	SM-N9600/SS
Test Device Serial No.:	*Pre-Production Sample* [S/N: 32928]

C63.19-2011 HAC Category:	**T3 (SIGNAL TO NOISE CATEGORY)**

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

I attest to the accuracy of data. All measurements reported herein were performed by me or were made under my supervision and are correct to the best of my knowledge and belief. I assume full responsibility for the completeness of these measurements and vouch for the qualifications of all persons taking them.

Randy Ortanez
President

ACCREDITED
TESTING CERT#2041.01

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1. INTRODUCTION

On July 10, 2003, the Federal Communications Commission (FCC) adopted new rules requiring wireless manufacturers and service providers to provide digital wireless phones that are compatible with hearing aids. The FCC has modified the exemption for wireless phones under the Hearing Aid Compatibility Act of 1998 (HAC Act) in WT Docket 01-309 RM-8658[1] to extend the benefits of wireless telecommunications to individuals with hearing disabilities. These benefits encompass business, social and emergency communications, which increase the value of the wireless network for everyone. An estimated more than 10% of the population in the United States show signs of hearing impairment and of that fraction, almost 80% use hearing aids. Approximately 500 million people worldwide and 30 million people in the United States suffer from hearing loss.

Compatibility Tests Involved:

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

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

The hearing aid must be measured for:

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

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

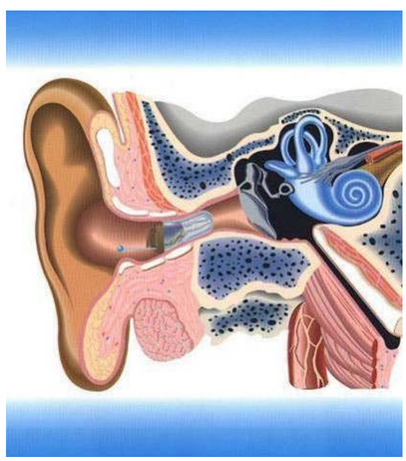


Figure 1-1 Hearing Aid *in-vitu*

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

2. DUT DESCRIPTION

FCC ID:	A3LSMN9600
Applicant:	Samsung Electronics Co., Ltd. 129, Samsung-ro, Maetan dong, Yeongtong-gu, Suwon-si Gyeonggi-do 16677, Korea
Model:	SM-N9600
Additional Model(s):	SM-N9600/SS
Serial Number:	32928
HW Version:	REV0.1
SW Version:	N9600.001
Antenna:	Internal Antenna
DUT Type:	Portable Handset

I. LTE Band Selection

This device supports the following pairs of LTE bands with similar frequencies: LTE B12 & B17 as well as B4 & B66. Each pair of LTE bands has the same target power and shares the same transmission path. Since the supported frequency spans for the smaller LTE bands are completely covered by the larger LTE bands, only the larger LTE bands (LTE B66 and B12) were evaluated for hearing-aid compliance.

Table 2-1
A3LSMN9600 HAC Air Interfaces

Air-Interface	Band (MHz)	Type Transport	HAC Tested	Simultaneous But Not Tested	Name of Voice Service
CDMA	835	VO	Yes	Yes: WIFI or BT	CMRS Voice*
	EvDO	VD	Yes	Yes: WIFI or BT	Google Duo**
GSM	850	VO	Yes	Yes: WIFI or BT	CMRS Voice*
	1900				
	GPRS/EDGE	VD	Yes	Yes: WIFI or BT	Google Duo**
UMTS	850	VD	Yes	Yes: WIFI or BT	CMRS Voice*
	1700				
	1900				
	HSPA	VD	Yes	Yes: WIFI or BT	Google Duo**
LTE (FDD)	700 (B12)	VD	Yes	Yes: WIFI or BT	Google Duo**
	700 (B17)				
	780 (B13)				
	850 (B5)				
	850 (B26)				
	1700 (B4)				
	1700 (B66)				
	1900 (B2)				
	1900 (B25)				
LTE (TDD)	2600 (B41)	VD	Yes	Yes: WIFI or BT	Google Duo**
WIFI	2450	VD	Yes	Yes: CDMA, GSM, UMTS, or LTE	Google Duo**
	5200 (U-NII 1)				
	5300 (U-NII 2A)				
	5500 (U-NII 2C)				
	5800 (U-NII 3)				
BT	2450	DT	No	Yes: CDMA, GSM, UMTS, or LTE	N/A

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

Notes:
* Reference level in accordance with 7.4.2.1 of ANSI C63.19-2011 and July 2012 C63 VoLTE Interpretation.
** Reference level is -20dBm0 in accordance with FCC KDB 285076 D02

3. ANSI C63.19-2011 PERFORMANCE CATEGORIES

I. MAGNETIC COUPLING

Axial and Radial Field Intensity

All orientations of the magnetic field, in the axial and radial position along the measurement plane shall be ≥ -18 dB(A/m) at 1 kHz in a 1/3 octave band filter per §8.3.1.

Frequency Response

The frequency response of the axial component of the magnetic field shall follow the response curve specified in EIA RS-504-1983, over the frequency range 300 Hz – 3000 Hz per §8.3.2.

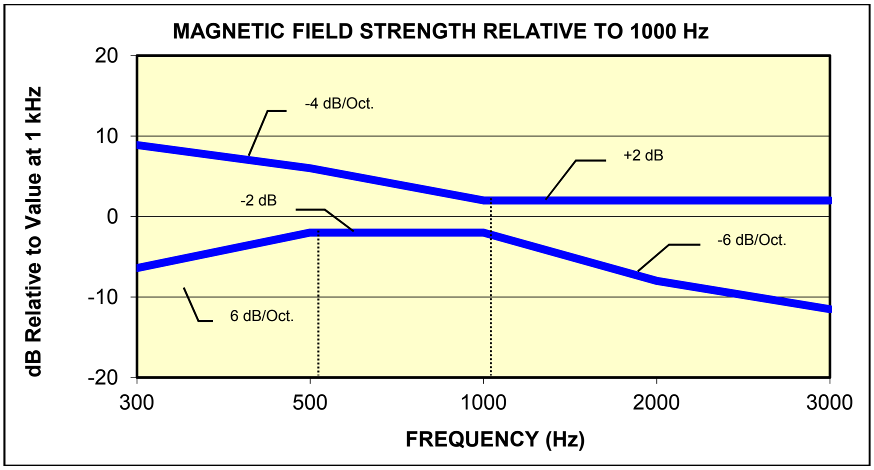


Figure 3-1
Magnetic field frequency response for Wireless Devices with an axial field ≤-15 dB(A/m) at 1 kHz

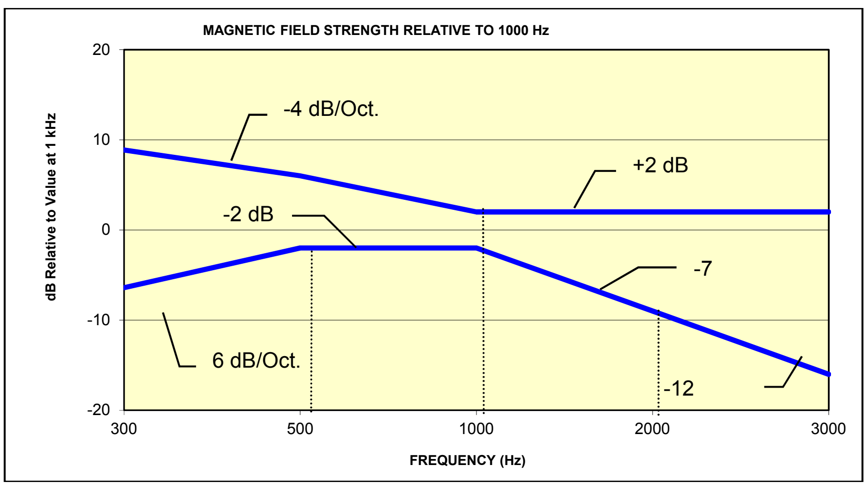


Figure 3-2
Magnetic Field frequency response for wireless devices with an axial field that exceeds -15 dB(A/m) at 1 kHz

Signal Quality

The table below provides the signal quality requirement for the intended audio magnetic signal from a wireless device. 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. The only criterion that can be measured is the RF immunity in T-coil mode. This is measured using the same procedure as the audio coupling mode at the same levels.

The signal quality of the axial and radial components of the magnetic field was used to determine the T-coil mode category.

Category	Telephone RF Parameters
	Wireless Device Signal Quality [(Signal + Noise)-to-noise ratio in dB]
T1	0 to 10 dB
T2	10 to 20 dB
T3	20 to 30 dB
T4	> 30 dB

Table 3-1
Magnetic Coupling Parameters

Note: The FCC limit for SNNR is 20dB and the test data margins will indicate a margin from the FCC limit for compliance.

4. METHOD OF MEASUREMENT

I. Test Setup

The equipment was connected as shown in an acoustic/RF hemi-anechoic chamber:

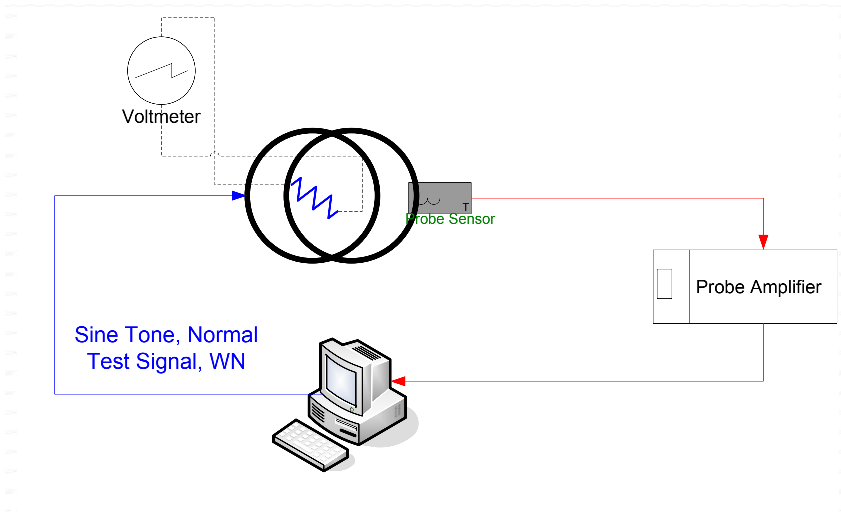


Figure 4-1
Validation Setup with Helmholtz Coil

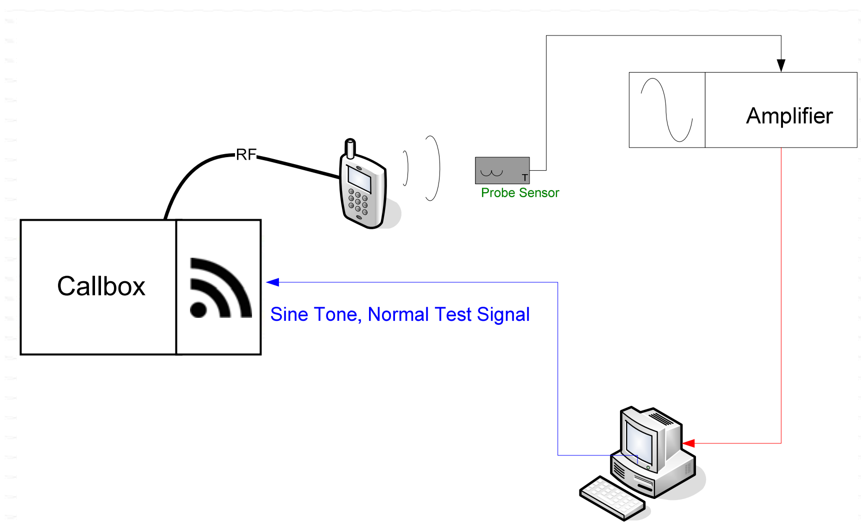


Figure 4-2
T-Coil Test Setup

II. Scanning Mechanism

Manufacturer:	TEM
Accuracy:	± 0.83 cm/meter
Minimum Step Size:	0.1 mm
Maximum speed	6.1 cm/sec
Line Voltage:	115 VAC
Line Frequency:	60 Hz
Material Composite:	Delrin (Acetal)
Data Control:	Parallel Port
Dynamic Range (X-Y-Z):	45 x 31.75 x 47 cm
Dimensions:	36” x 25” x 38”
Operating Area:	36” x 49” x 55”
Reflections:	< -20 dB (in anechoic chamber)

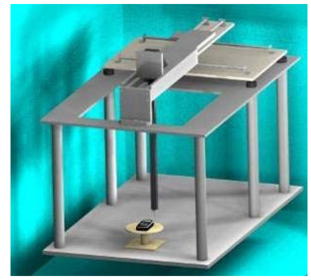


Figure 4-3
RF Near-Field Scanner

III. 3GPP2 Normal Test Signal (Speech)

Manufacturer:	3GPP2 (TIA 1042 §3.3.1)
Stimulus Type:	Modified-IRS weighted, multi-talker speech signal, 4 Male and 4 Female speakers (alternating)
Single Sample Duration:	51.62 seconds
Activity Level:	77.4%

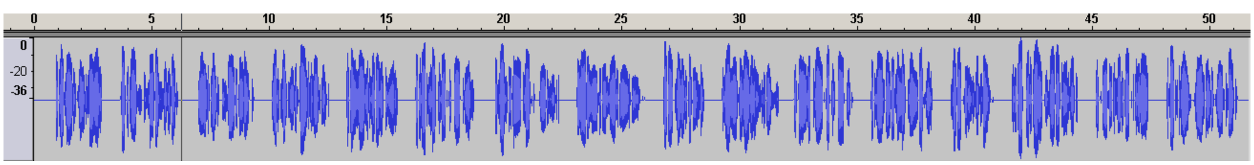
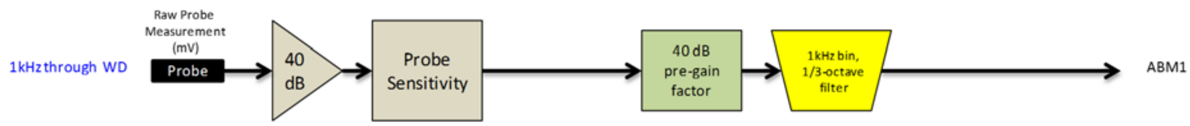


Figure 4-4
Temporal Characteristic of Normal Test Signal

ABM1 Measurement Block Diagram:



ABM2 Measurement Block Diagram:

Figure 4-5 Magnetic Measurement Processing Steps

IV. Test Procedure

1. Ambient Noise Check per C63.19 §7.3.1
    a. Ambient interference was monitored using a Real-Time Analyzer between 100-10,000 Hz with 1/3 octave filtering.
    b. "A-weighting" and Half-Band Integration was applied to the measurements.
    c. Since this measurement was measured in the same method as ABM2 measurements, this level was verified to be more than 10 dB below the lowest measurement signal (which is the highest ABM2 measurement for a T4 WD). Therefore the maximum noise level for a T4 WD with an ABM1 = -18 dBA/m is:

    -18 - 30 - 10= -58 dBA/m

2. Measurement System Validation(See Figure 4-1)
    a. The measurement system including the probe, pre-amplifier and acquisition system were validated as an entire system to ensure the reliability of test measurements.
    b. ABM1 Validation

    The magnetic field at the center of the Helmholtz coil is given by the equation (per C63.19 Annex D.10.1):

$$H_c = \frac{NI}{r\sqrt{1.25^3}} = \frac{N(\frac{V}{R})}{r\sqrt{1.25^3}}$$

Where H_c = magnetic field strength in amperes per meter
N = number of turns per coil

For the Helmholtz Coil, N=20; r=0.08m; R=10.2Ω and using V=18mV:

$$H_c = \frac{20 \cdot (\frac{0.018}{10.2})}{0.08 \cdot \sqrt{1.25^3}} = 0.316 A/m \approx -10 dB(A/m)$$

Therefore a pure tone of 1kHz was applied into the coils such that 18mV was observed across the resistor. The voltmeter used for measurement was verified to be capable of measurements in the audio band range. This theoretically generates an expected field of -10 dB(A/m) in the center of the Helmholtz coil which was used to validate the probe measurement at -10dB(A/m). This was verified to be within ± 0.5 dB of the -10dB(A/m) value (see Page 32).

c. Frequency Response Validation
The frequency response through the Helmholtz Coil was verified to be within 0.5 dB relative to 1kHz, between 300 – 3000 Hz using the Normal signal as shown below:

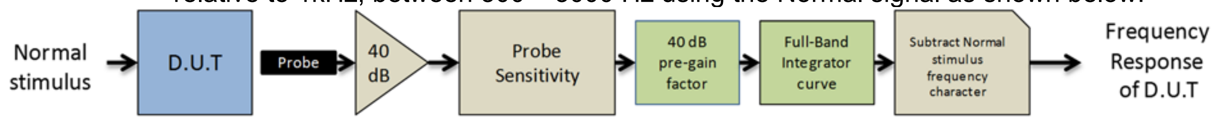


Figure 4-6 Frequency Response Validation

d. ABM2 Measurement Validation
WD noise measurements are filtered with A-weighting and Half-Band Integration over a frequency range of 100Hz – 10kHz to process ABM2 measurements. Below is the verification of the system processing A-weighting and Half-Band integration between system input to output within 0.5 dB of the theoretical result:

Table 4-1
ABM2 Frequency Response Validation

f (Hz)	HBI, A - Measured (dB re 1kHz)	HBI, A - Theoretical (dB re 1kHz)	dB Var.
100	-16.180	-16.170	-0.010
125	-13.257	-13.250	-0.007
160	-10.347	-10.340	-0.007
200	-8.017	-8.010	-0.007
250	-5.925	-5.920	-0.005
315	-4.045	-4.040	-0.005
400	-2.405	-2.400	-0.005
500	-1.212	-1.210	-0.002
630	-0.349	-0.350	0.001
800	0.071	0.070	0.001
1000	0.000	0.000	0.000
1250	-0.503	-0.500	-0.003
1600	-1.513	-1.510	-0.003
2000	-2.778	-2.780	0.002
2500	-4.316	-4.320	0.004
3150	-6.166	-6.170	0.004
4000	-8.322	-8.330	0.008
5000	-10.573	-10.590	0.017
6300	-13.178	-13.200	0.022
8000	-16.241	-16.270	0.029
10000	-19.495	-19.520	0.025

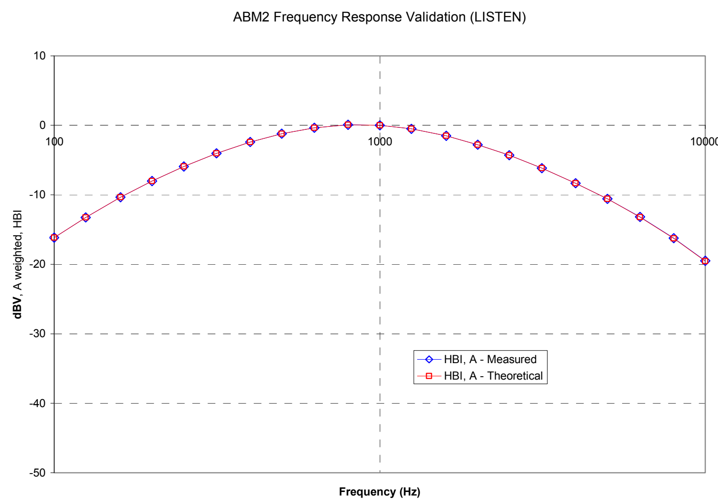


Figure 4-7
ABM2 Frequency Response Validation

The ABM2 result is a power sum from 100Hz to 10kHz with half-band integration and A-weighting. To verify the power sum measurement, a power sum over the full band was measured and verified to track with the source level (See Figure 4-8). Therefore the setup in this step was used to verify the power sum post-processing for ABM2 measurements. See below block diagram:

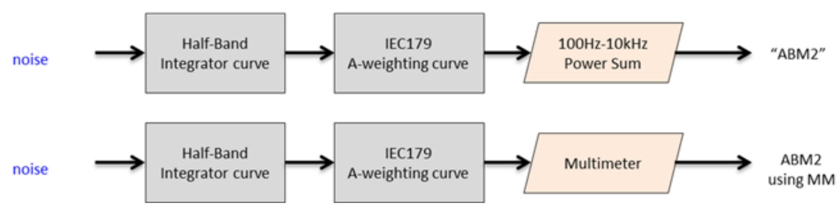


Figure 4-8
ABM2 Validation Block Diagram

The power summed output results for a known input were compared to the multi-meter results to verify any deviation in the post-processing implemented with the power-sum.

Table 4-2
ABM2 Power Sum Validation

WN Input (dBV)	Power Sum (dBV)	Multimeter-Full (dBV)	Dev (dB)
-60	-60.36	-60.2	0.16
-50	-50.19	-50.13	0.06
-40	-40.14	-40.03	0.11
-30	-30.13	-30.01	0.12
-20	-20.12	-20	0.12
-10	-10.14	-10	0.14

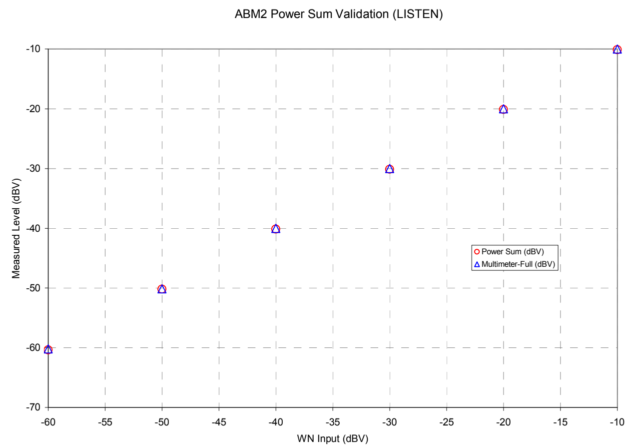


Figure 4-9
ABM2 Power Sum Validation

3. Measurement Test Setup
    a. Fine scan above the WD (TEM)
        i. A multitone signal was applied to the handset such that the phone acoustic output was stable within 1dB over the probe settling time and with the acoustic output level at the C63.19 specified levels (below). The measurement step size was in 2 mm increments at a distance of 10 mm between the surface of the wireless device as shown below (note that in Figure 4-11, the grid is not to scale but merely a graphical representation of the coordinate system in use):

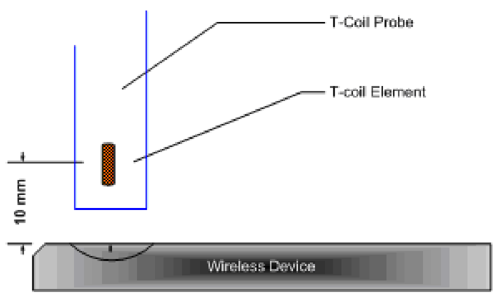


Figure 4-10
Measurement Distance

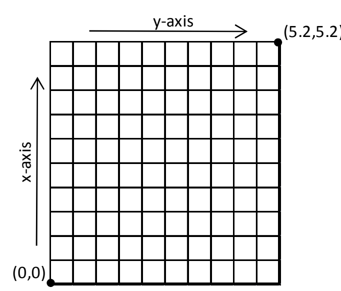


Figure 4-11
Measurement Grid

        ii. After scanning, the planar field maximum point was determined. The position of the probe was moved to this location to setup the test using the SoundCheck system.
        iii. These steps were repeated for all T-coil orientations (axial and radial) per Figure 4-14 after a T-coil orientation was fully measured with the SoundCheck system.

b. Speech Signal Setup to Base Station Simulator
   i. C63.19 Table 7-1 states audio reference input levels for various technologies:

Standard	Technology	Input Level (dBm0)
TIA/EIA/IS-2000	CDMA	-18
J-STD-007	GSM (217)	-16
T1/T1P1/3GPP	UMTS (WCDMA)	-16
iDEN™	TDMA (22 and 11 Hz)	-18

   ii. See Section 5 for more information regarding audio level settings for Over-The-Top (OTT) Voice Over IP (VoIP) Testing.
c. Real-Time Analyzer (RTA)
   i. The Real-Time Analyzer was configured to analyze measurements using 1/3 Octave band weighted filtering.
d. WD Radio Configuration Selection
   i. The device was chosen to be tested in the worst-case ABM2 condition (see below for GSM, see Section 6 for more information regarding worst-case configurations for CDMA and UMTS. LTE and WIFI configuration information can be found in Section 5):

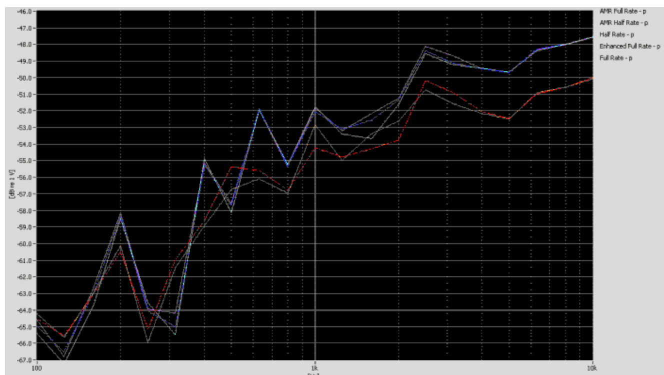


Figure 4-12
Vocoder Analysis for ABM Noise for GSM

4. Signal Quality Data Analysis
   a. Narrow-band Magnetic Intensity
      i. The standard specifies a 1kHz 1/3 octave band minimum field intensity for a sine tone. The ABM1 measurements were evaluated at 1kHz with 1/3 octave band filtering over an averaged period of 10 seconds.
   b. Frequency Response
      i. The appropriate frequency response curve was measured to curves in Figure 3-1 or Figure 3-2 between 300 – 3000 Hz using digital linear averaging (limit lines chosen according to measurement found in step 4a). A linear average over 3x the length of the artificial voice signal (3x sampling) was performed. A 10 second delay was configured in the measurement process of the stimulus to ensure handset vocoder latency effects and echo cancellation devices (if any) were appropriately stabilized during measurements.
      ii. The appropriate post-processing was applied according to the system processing chain illustrated in Figure 4-6. All R10 frequencies were plotted with respect to 0dB at 1kHz value and aligned with respect to the EIA-504 mask.
      iii. The margin is represented by the closest measured data point on the curve to the EIA-504 limit lines, in dB.

c. Signal Quality Index

i. Ensuring the WD was at maximum RF power, maximum volume, backlight off, display on, maximum contrast setting, keypad lights on (when possible) with no audio signal through the vocoder, the WD was measured over at least 100 Hz – 10,000 Hz, maximized over 5 seconds with a 50ms sample time for the ABM2 measurement (5 second time period is used in noise measurements under standards such as IEEE 269, etc.).

ii. After applying half-band integration and A-weighting to the result, a power sum was applied over each 1/3 octave bandwidth frequency for an ABM2 value.

iii. This result was subtracted from the ABM1 result in step a, to obtain the Signal Quality.

V. Test Setup

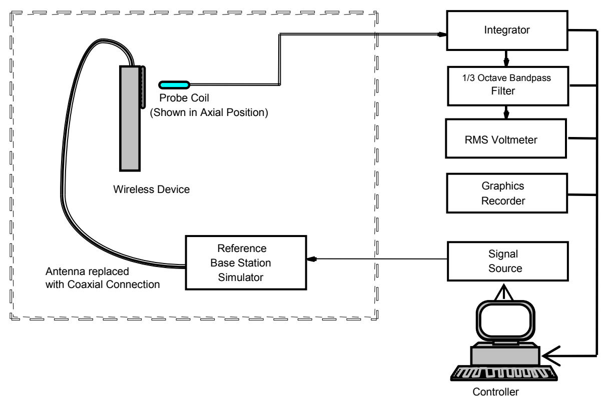


Figure 4-13
Audio Magnetic Field Test Setup

VI. Deviation from C63.19 Test Procedure

Non-conducted RF connection due to inaccessible RF ports.

VII. Air Interface Technologies Tested

All air interfaces which support voice capabilities over a managed CMRS or pre-installed OTT VoIP applications were tested for T-coil unless otherwise noted. See Table 2-1 for more details regarding which modes were tested.

VIII. Wireless Device Channels and Frequencies

1. 2G/3G Modes

The frequencies listed in the table below are those that lie in the center of the bands used for cellular telephony. Low, middle and high channels were tested in each band for FCC compliance evaluation to ensure the maximum emission is captured across the entire band. Only middle channels were evaluated for data modes since circuit-switched voice modes were worst-case.

Table 4-3
Center Channels and Frequencies

Test frequencies & associated channels	
Channel	**Frequency (MHz)**
Cellular 850	
384 (CDMA)	836.52
190 (GSM)	836.60
4183 (UMTS)	836.60
AWS 1750	
1412 (UMTS)	1730.40
PCS 1900	
661 (GSM)	1880
9400 (UMTS)	1880

2. 4G (LTE) Modes

The middle channel and supported bandwidths from the worst-case bands according to Tables 5-7 were evaluated with OTT VoIP for each probe orientation. The bandwidth from each probe orientation resulting in the worst-case SNNR was additionally tested using low and high channels for that bandwidth. Low-mid and mid-high channels are additionally tested for LTE TDD. See Tables 7-8 to 7-9 for LTE bandwidths and channels.

3. WIFI

The middle channel for each 802.11 standard was tested for each probe orientation. The 2.4GHz 802.11 standard from each probe orientation resulting in the worst-case SNNR was additionally tested using low and high channels. The 5GHz 802.11 standard from each probe orientation resulting in the worst-case SNNR was additionally tested on higher U-NII bands as well as applicable low and high channels. See Tables 7-10 to 7-13 for WIFI standards and channels.

IX. Test Flow

The flow diagram below was followed (From C63.19):

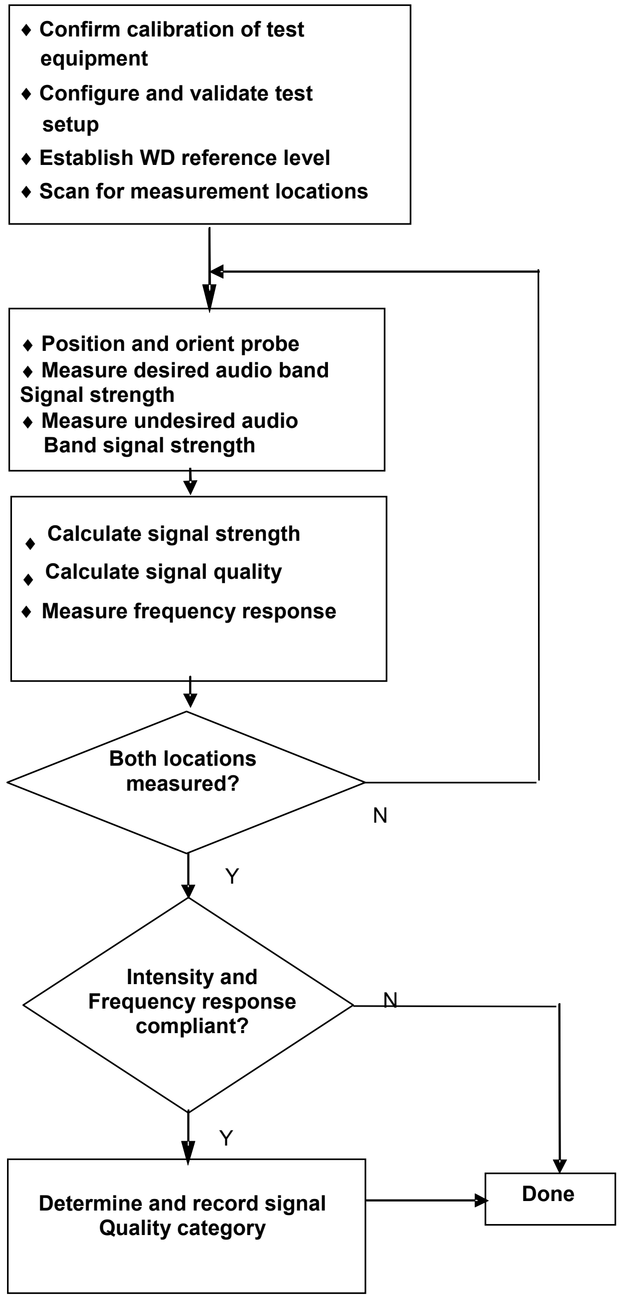


Figure 4-14
C63.19 T-Coil Signal Test Process

5. OTT VOIP TEST SYSTEM AND DUT CONFIGURATION

I. Test System Setup for OTT VoIP T-Coil Testing

1. OTT VoIP Application

Google Duo is a pre-installed application on the DUT which allows for VoIP calls in a held-to-ear scenario. Duo uses the OPUS audio codec and supports a bitrate range of 6kb/s to 64kb/s. All air interfaces capable of a data connection were evaluated with Google Duo.

2. Equipment Setup

A CMW500 callbox was used to perform OTT VoIP T-coil measurements. The Data Application Unit (DAU) of the CMW500 was connected to the internet and allowed for an IP data connection on the DUT. An auxiliary VoIP unit was used to initiate an OTT VoIP call to the DUT. The auxiliary VoIP unit allowed for the configuration and monitoring of the OTT VoIP codec bitrate during a call. Both high and low bitrate settings were evaluated in to determine the worst-case configuration.

3. Audio Level Settings

According to KDB 285076 D02, the average speech level of -20dBm0 shall be used for protocols not specifically listed in Table 7.1 of ANSI C63.19-2011 or the ANSI C63.19-2011 VoLTE interpretation[2]. The auxiliary VoIP unit allowed for monitoring the signal input level to ensure that the settings for speech input and full scale levels resulted in the -20dBm0 speech input level to the DUT for the OTT VoIP call.

II. DUT Configuration for OTT VoIP T-Coil Testing

1. Codec Configuration

An investigation was performed for each applicable data mode to determine the audio codec configuration to be used for testing. The 6kbps codec setting was used for the audio codec on the auxiliary VoIP unit for OTT VoIP T-Coil testing. See below tables for comparisons between codec data rates on all applicable data modes:

Table 5-1
Codec Investigation – OTT VoIP (EvDO)

Codec Setting:	64kbps	6kbps	Orientation	Channel
ABM1 (dBA/m)	8.85	8.11	Axial	384
ABM2 (dBA/m)	-56.19	-55.84		
Frequency Response	Pass	Pass		
S+N/N (dB)	65.04	**63.95**		

[2] FCC Office of Engineering and Technology KDB, "285076 D02 T-Coil Testing for CMRS IP v03," September 13, 2017

Table 5-2
Codec Investigation – OTT VoIP (EDGE)

Codec Setting:	64kbps	6kbps	Orientation	Channel
ABM1 (dBA/m)	7.42	7.37	Axial	661
ABM2 (dBA/m)	-37.69	-37.27		
Frequency Response	Pass	Pass		
S+N/N (dB)	45.11	**44.64**		

Table 5-3
Codec Investigation – OTT VoIP (HSPA)

Codec Setting:	64kbps	6kbps	Orientation	Channel
ABM1 (dBA/m)	7.85	7.34	Axial	9400
ABM2 (dBA/m)	-56.44	-55.74		
Frequency Response	Pass	Pass		
S+N/N (dB)	64.29	**63.08**		

Table 5-4
Codec Investigation – OTT VoIP (LTE)

Codec Setting:	64kbps	6kbps	Orientation	Band / BW	Channel
ABM1 (dBA/m)	6.77	6.33	Axial	Band 2 20MHz	18900
ABM2 (dBA/m)	-54.59	-54.51			
Frequency Response	Pass	Pass			
S+N/N (dB)	61.36	**60.84**			

Table 5-5
Codec Investigation – OTT VoIP (WIFI)

Codec Setting:	64kbps	6kbps	Orientation	Band	Standard	Channel
ABM1 (dBA/m)	8.82	8.33	Axial	2.4GHz	IEEE 802.11b	6
ABM2 (dBA/m)	-45.40	-43.43				
Frequency Response	Pass	Pass				
S+N/N (dB)	54.22	**51.76**				

- Mute on; Backlight off; Max Volume; Max Contrast
- Radio Configurations can be found in Section 7.II.E

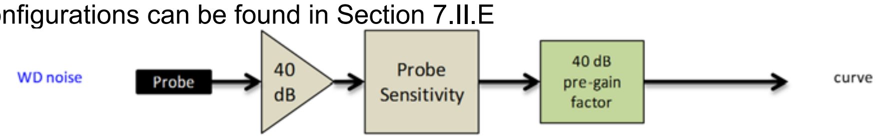


Figure 5-1
Audio Band Magnetic Curve Measurement Block Diagram

2. Radio Configuration for OTT VoIP (LTE)

An investigation was performed to determine the modulation and RB configuration to be used for testing. 16QAM, 1RB, 0RB offset was used for the testing as the worst-case configuration for the handset. See below table for SNNR comparison between different radio configurations:

Table 5-6
OTT VoIP (LTE) SNNR by Radio Configuration

Frequency [MHz]	Channel	Bandwidth [MHz]	Modulation	RB Size	RB Offset	ABM1 [dB(A/m)]	ABM2 [dB(A/m)]	SNNR [dB]
1880.0	18900	20	QPSK	1	0	6.24	-56.27	62.51
1880.0	18900	20	QPSK	1	50	6.39	-55.83	62.22
1880.0	18900	20	QPSK	1	99	6.20	-55.81	62.01
1880.0	18900	20	QPSK	50	0	6.20	-56.49	62.69
1880.0	18900	20	QPSK	50	25	6.23	-56.66	62.89
1880.0	18900	20	QPSK	50	50	6.30	-56.51	62.81
1880.0	18900	20	QPSK	100	0	6.50	-56.31	62.81
1880.0	18900	20	16QAM	1	0	6.79	-54.17	**60.96**
1880.0	18900	20	16QAM	1	50	6.48	-55.04	61.52
1880.0	18900	20	16QAM	1	99	6.55	-54.49	61.04
1880.0	18900	20	16QAM	50	0	6.48	-55.35	61.83
1880.0	18900	20	16QAM	50	25	6.47	-56.05	62.52
1880.0	18900	20	16QAM	50	50	6.13	-55.79	61.92
1880.0	18900	20	16QAM	100	0	6.47	-55.29	61.76
1880.0	18900	20	64QAM	1	0	6.09	-55.03	61.12
1880.0	18900	20	64QAM	1	50	6.21	-55.04	61.25
1880.0	18900	20	64QAM	1	99	6.56	-55.18	61.74
1880.0	18900	20	64QAM	50	0	6.25	-55.04	61.29
1880.0	18900	20	64QAM	50	25	6.36	-56.46	62.82
1880.0	18900	20	64QAM	50	50	6.51	-55.74	62.25
1880.0	18900	20	64QAM	100	0	6.12	-56.22	62.34

An investigation was performed to determine the worst-case LTE FDD band and mode to be used for OTT VoIP testing. LTE FDD Band 13 was used for the testing as the worst-case configuration for the handset. See below tables for SNNR comparison between different LTE bands:

Table 5-7
OTT VoIP (LTE FDD) SNNR by LTE Band

Band	Frequency [MHz]	Channel	Bandwidth [MHz]	Modulation	RB Size	RB Offset	ABM1 [dB(A/m)]	ABM2 [dB(A/m)]	SNNR [dB]
2	1880.0	18900	20	16QAM	1	0	7.29	-54.62	61.91
5	836.5	20525	10	16QAM	1	0	7.62	-53.52	61.14
12	707.5	23095	10	16QAM	1	0	7.57	-54.57	62.14
13	782.0	23230	10	16QAM	1	0	7.48	-52.73	60.21
25	1882.5	26365	20	16QAM	1	0	7.60	-55.36	62.96
26	831.5	26865	15	16QAM	1	0	7.16	-53.72	60.88
66	1745.0	132322	20	16QAM	1	0	7.63	-53.33	60.96

3. LTE TDD Uplink-Downlink Configuration Investigation for OTT VoIP

An investigation was performed to determine the worst-case Uplink-Downlink configuration for OTT VoIP T-Coil testing.

Per 3GPP TS 36.211, the total frame length for each TDD radio frame of length $T_f = 307200 \cdot T_s = 10$ ms, where T_s is a number of time units equal to 1/(15000 x 2048) seconds. Additionally, each radio frame consists of 10 subframes, each of length $30720 \cdot T_s = 1$ ms, and subframes can be designated as uplink (U), downlink (D), or special subframe (S), depending on the Uplink-Downlink configuration as indicated in Table 4.2-2 of 3GPP TS 36.211. In the transmission duty factor calculation, the special subframe configuration with the shortest UpPTS duration within the special subframe is used and will be applied for measurement. From 3GPP TS 36.211 Table 4.2-1, the shortest UpPTS is $2192 \cdot Ts$ which occurs in the normal cyclic prefix and special subframe configuration 4.

See table below outlining the calculated transmission duty cycles for each Uplink-Downlink configuration:

Table 5-8
Uplink-Downlink Configurations for Type 2 Frame Structures

Uplink-downlink configuration	Downlink-to-Uplink Switch-point periodicity	Subframe number										Calculated Transmission Duty Cycle (%)
		0	1	2	3	4	5	6	7	8	9	
0	5 ms	D	S	U	U	U	D	S	U	U	U	61.4%
1	5 ms	D	S	U	U	D	D	S	U	U	D	41.4%
2	5 ms	D	S	U	D	D	D	S	U	D	D	21.4%
3	10 ms	D	S	U	U	U	D	D	D	D	D	30.7%
4	10 ms	D	S	U	U	D	D	D	D	D	D	20.7%
5	10 ms	D	S	U	D	D	D	D	D	D	D	10.7%
6	5 ms	D	S	U	U	U	D	S	U	U	D	51.4%

a. Power Class 3 Uplink-Downlink Configuration Investigation

LTE TDD was evaluated with the following radio configuration: channel 40620, 20MHz BW, 16QAM, 1RB, 0RB Offset. For Power Class 3, all configurations (0-6) are supported. The configuration which resulted in the worst SNNR was used for full testing. Uplink-Downlink configuration 2 was used as the worst-case configuration for Power Class 3 OTT VoIP T-Coil testing. See table below for the SNNR comparison between each Uplink-Downlink configuration:

Table 5-9
Power Class 3 OTT VoIP SNNR by UL-DL Configuration

Frequency [MHz]	Channel	Bandwidth [MHz]	Modulation	RB Size	RB Offset	UL-DL Configuration	ABM1 [dB(A/m)]	ABM2 [dB(A/m)]	SNNR [dB]
2593.0	40620	20	16QAM	1	0	0	7.70	-45.18	52.88
2593.0	40620	20	16QAM	1	0	1	7.67	-45.48	53.15
2593.0	40620	20	16QAM	1	0	2	7.41	-44.84	**52.25**
2593.0	40620	20	16QAM	1	0	3	7.54	-48.19	55.73
2593.0	40620	20	16QAM	1	0	4	7.45	-48.29	55.74
2593.0	40620	20	16QAM	1	0	5	7.57	-47.36	54.93
2593.0	40620	20	16QAM	1	0	6	7.53	-45.58	53.11

b. Conclusion

Per the investigations above, UL-DL Configuration 2 was used to evaluate Power Class 3 OTT VoIP.

4. LTE TDD Uplink Carrier Aggregation for OTT VoIP

LTE TDD ULCA was evaluated with the worst-case bandwidth and channel combination from Table 7-9. The PCC radio configuration was channel 41055, 5MHz BW, 16QAM, 1RB, 0RB Offset. The SCC radio configuration was channel 40938, 20MHz BW, 16QAM, 1RB, 99RB Offset. ULCA operates in LTE TDD Power Class 3 so UL-DL configuration 2 was used for evaluation. This radio configuration satisfied the configuration requirements of the applicable LTE CA combination. See results below:

Table 5-10
LTE SNNR for OTT VoIP Uplink Carrier Aggregation

Combination	PCC							SCC							ABM1 [dB(A/m)]	ABM2 [dB(A/m)]	SNNR [dB]
	PCC Band	PCC Bandwidth [MHz]	PCC (UL/DL) Channel	PCC (UL/DL) Frequency [MHz]	Modulation	PCC UL# RB	PCC UL RB Offset	SCC Band	SCC Bandwidth [MHz]	SCC (UL/DL) Channel	SCC (UL/DL) Frequency [MHz]	Modulation	SCC UL# RB	SCC UL RB Offset			
CA_41C (1)	LTE B41	5	41055	2636.5	16QAM	1	0	LTE B41	20	40938	2624.8	16QAM	1	99	0.74	-42.70	43.44

5. Radio Configuration for OTT VoIP (WIFI)

An investigation was performed on all applicable data rates and modulations to determine the radio configuration to be used for testing. See tables below for SNNR comparison between radio configurations in each 802.11 standard:

Table 5-11
802.11b SNNR by Radio Configuration

Mode	Channel	Modulation	Data Rate [Mbps]	ABM1 [dB(A/m)]	ABM2 [dB(A/m)]	SNNR [dB]
802.11b	6	DSSS	1	8.21	-45.92	54.13
802.11b	6	DSSS	2	8.31	-44.06	**52.37**
802.11b	6	CCK	5.5	8.57	-47.06	55.63
802.11b	6	CCK	11	8.33	-46.43	54.76

Table 5-12
802.11g/a SNNR by Radio Configuration

Mode	Channel	Modulation	Data Rate [Mbps]	ABM1 [dB(A/m)]	ABM2 [dB(A/m)]	SNNR [dB]
802.11g	6	BPSK	6	8.34	-43.77	**52.11**
802.11g	6	BPSK	9	8.70	-45.02	53.72
802.11g	6	QPSK	12	8.95	-44.81	53.76
802.11g	6	QPSK	18	8.44	-45.65	54.09
802.11g	6	16-QAM	24	8.70	-47.54	56.24
802.11g	6	16-QAM	36	8.52	-43.98	52.50
802.11g	6	64-QAM	48	8.61	-49.22	57.83
802.11g	6	64-QAM	54	8.65	-49.34	57.99

Table 5-13
802.11n/ac 20MHz BW SNNR by Radio Configuration

Mode	Bandwidth [MHz]	Channel	Modulation	Data Rate [Mbps]	ABM1 [dB(A/m)]	ABM2 [dB(A/m)]	SNNR [dB]
802.11n	20	40	BPSK	6.5	8.59	-49.88	58.47
802.11n	20	40	QPSK	13	8.70	-51.43	60.13
802.11n	20	40	QPSK	19.5	8.56	-50.90	59.46
802.11n	20	40	16-QAM	26	8.48	-51.85	60.33
802.11n	20	40	16-QAM	39	8.43	-49.00	**57.43**
802.11n	20	40	64-QAM	52	8.34	-51.36	59.70
802.11n	20	40	64-QAM	58.5	8.60	-52.36	60.96
802.11n	20	40	64-QAM	65	8.70	-49.40	58.10
802.11ac	20	40	256-QAM	78	8.70	-49.92	58.62

Table 5-14
802.11n/ac 40MHz BW SNNR by Radio Configuration

Mode	Bandwidth [MHz]	Channel	Modulation	Data Rate [Mbps]	ABM1 [dB(A/m)]	ABM2 [dB(A/m)]	SNNR [dB]
802.11n	40	38	BPSK	13.5	8.75	-49.90	58.65
802.11n	40	38	QPSK	27	8.59	-51.55	60.14
802.11n	40	38	QPSK	40.5	8.78	-50.20	58.98
802.11n	40	38	16-QAM	54	8.67	-52.38	61.05
802.11n	40	38	16-QAM	81	8.67	-51.84	60.51
802.11n	40	38	64-QAM	108	8.82	-48.46	**57.28**
802.11n	40	38	64-QAM	121.5	8.87	-50.69	59.56
802.11n	40	38	64-QAM	135	8.60	-50.52	59.12
802.11ac	40	38	256-QAM	162	7.99	-52.52	60.51
802.11ac	40	38	256-QAM	180	8.24	-52.29	60.53

6. FCC 3G MEASUREMENTS

I. CDMA Test Configurations

Radio Configuration 1, Service Option 3 (thick, green data curve) was used for the testing as the worst-case configuration for the handset due to vocoder gating from the EVRC logic. See below plot for ABM noise comparison between operational field service options and radio configurations for a CDMA2000 handset:

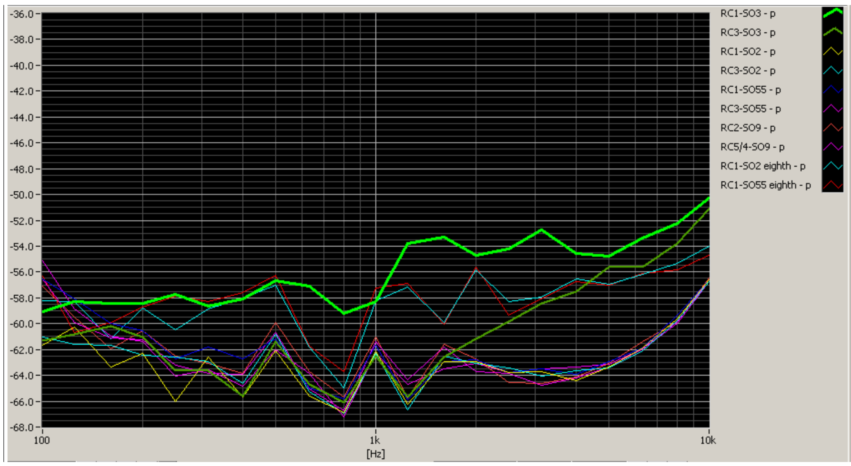


Figure 6-1
CDMA Audio Band Magnetic Noise

Table 6-1
FCC 3G ABM Measurements for A3LSMN9600 (CDMA)

Configuration:	RC1/SO3	RC3/SO3	RC4/SO3	Orientation	Channel
ABM1 (dBA/m)	1.42	0.85	0.30	Axial	384
ABM2 (dBA/m)	-48.60	-52.60	-52.35		
Frequency Response	Pass	Pass	Pass		
S+N/N (dB)	**50.02**	53.45	52.65		

- Mute on; Backlight off; Max Volume; Max Contrast
- Power Control Bits = "All Up"

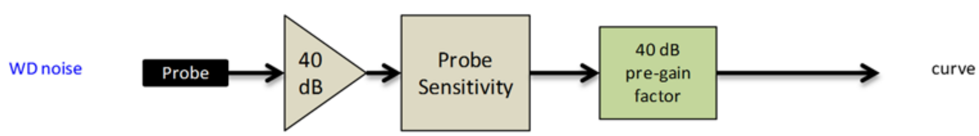


Figure 6-2
Audio Band Magnetic Curve Measurement Block Diagram

II. UMTS Test Configurations

AMR at 12.2kbps, 13.6kbps SRB was used for the testing as the worst-case configuration for the handset. See below plot for ABM noise comparison between vocoder rates:

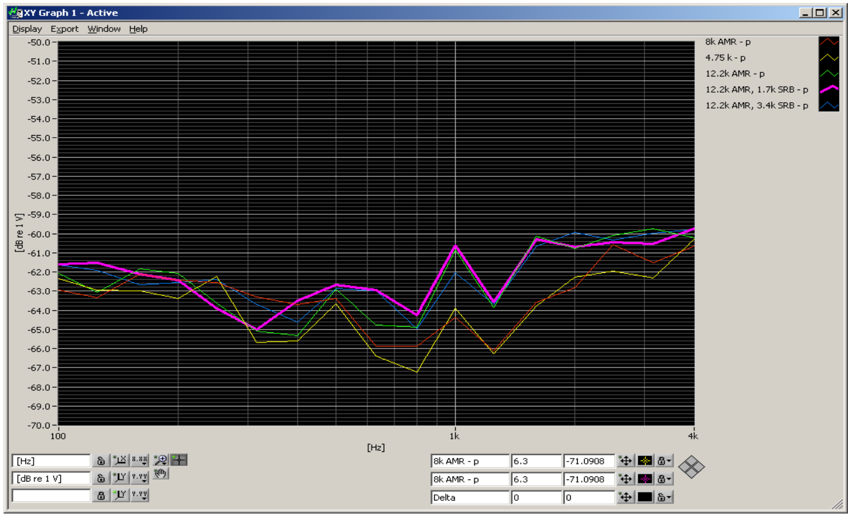


Figure 6-3
UMTS Audio Band Magnetic Noise

Table 6-2
Codec Investigation - UMTS

Codec Setting:	AMR 12.2kbps	AMR 7.95kbps	AMR 4.75kbps	Orientation	Channel
ABM1 (dBA/m)	2.82	2.78	2.63	Axial	9262
ABM2 (dBA/m)	-56.67	-56.96	-57.14		
Frequency Response	Pass	Pass	Pass		
S+N/N (dB)	59.49	59.74	59.77		

- Mute on; Backlight off; Max Volume; Max Contrast
- TPC="All 1s"

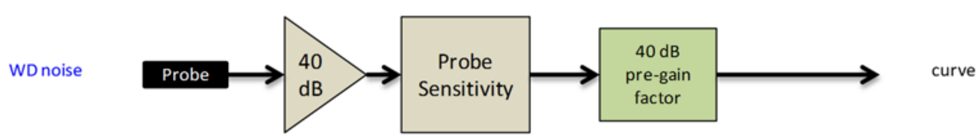


Figure 6-4
Audio Band Magnetic Curve Measurement Block Diagram

7. T-COIL TEST SUMMARY

Table 7-1
Consolidated Tabled Results

		Freq. Response Margin		Magnetic Intensity Verdict		FCC SNNR Verdict		Margin from FCC Limit (dB)	C63.19-2011 Rating
C63.19 Section		8.3.2		8.3.1		8.3.4			
		Axial	Radial	Axial	Radial	Axial	Radial		
CDMA	Cellular	PASS	NA	PASS	PASS	PASS	PASS	-18.06	T4
EvDO (OTT VoIP)	Cellular	PASS	NA	PASS	PASS	PASS	PASS	-35.93	T4
GSM	Cellular	PASS	NA	PASS	PASS	PASS	PASS	-5.77	T3
	PCS	PASS	NA	PASS	PASS	PASS	PASS		
EDGE (OTT VoIP)	Cellular	PASS	NA	PASS	PASS	PASS	PASS	-14.80	T4
	PCS	PASS	NA	PASS	PASS	PASS	PASS		
UMTS	Cellular	PASS	NA	PASS	PASS	PASS	PASS	-28.17	T4
	AWS	PASS	NA	PASS	PASS	PASS	PASS		
	PCS	PASS	NA	PASS	PASS	PASS	PASS		
HSPA (OTT VoIP)	Cellular	PASS	NA	PASS	PASS	PASS	PASS	-35.19	T4
	AWS	PASS	NA	PASS	PASS	PASS	PASS		
	PCS	PASS	NA	PASS	PASS	PASS	PASS		
LTE FDD (OTT VoIP)	B13	PASS	NA	PASS	PASS	PASS	PASS	-28.63	T4
LTE TDD (OTT VoIP)	B41	PASS	NA	PASS	PASS	PASS	PASS	-23.31	T4
WLAN (OTT VoIP)	802.11b	PASS	NA	PASS	PASS	PASS	PASS	-24.94	T4
	802.11g	PASS	NA	PASS	PASS	PASS	PASS		
	802.11n	PASS	NA	PASS	PASS	PASS	PASS		
U-NII (OTT VoIP)	802.11a	PASS	NA	PASS	PASS	PASS	PASS	-20.83	T4
	802.11n	PASS	NA	PASS	PASS	PASS	PASS		
	802.11ac	PASS	NA	PASS	PASS	PASS	PASS		

I. Raw Handset Data

Table 7-2
Raw Data Results for CDMA

Mode	Orientation	Channel	ABM1 [dB(A/m)]	ABM2 [dB(A/m)]	Ambient Noise [dB(A/m)]	Frequency Response Margin (dB)	S+N/N (dB)	FCC Limit (dB)	Margin from FCC Limit (dB)	C63.19-2011 Rating	Test Coordinates
Cellular	Axial	1013	1.34	-49.96	-63.60	2.00	51.30	20.00	-31.30	T4	2.2, 2.6
		384	1.41	-48.57		2.00	49.98	20.00	-29.98	T4	
		777	1.26	-47.72		2.00	48.98	20.00	-28.98	T4	
	Radial	1013	-7.04	-45.10	-64.53	N/A	38.06	20.00	-18.06	T4	2.6, 1.4
		384	-6.29	-44.59			38.30	20.00	-18.30	T4	
		777	-6.34	-44.98			38.64	20.00	-18.64	T4	

Table 7-3
Raw Data Results for GSM

Mode	Orientation	Channel	ABM1 [dB(A/m)]	ABM2 [dB(A/m)]	Ambient Noise [dB(A/m)]	Frequency Response Margin (dB)	S+N/N (dB)	FCC Limit (dB)	Margin from FCC Limit (dB)	C63.19-2011 Rating	Test Coordinates
GSM850	Axial	128	3.15	-31.39	-63.60	2.00	34.54	20.00	-14.54	T4	2.2, 2.6
		190	3.09	-31.70		2.00	34.79	20.00	-14.79	T4	
		251	3.00	-31.93		2.00	34.93	20.00	-14.93	T4	
	Radial	128	-4.29	-30.06	-64.53	N/A	25.77	20.00	-5.77	T3	2.6, 1.4
		190	-4.30	-30.09			25.79	20.00	-5.79	T3	
		251	-4.32	-30.87			26.55	20.00	-6.55	T3	
GSM1900	Axial	512	3.11	-34.55	-63.60	2.00	37.66	20.00	-17.66	T4	2.2, 2.6
		661	3.12	-34.00		2.00	37.12	20.00	-17.12	T4	
		810	3.10	-33.64		2.00	36.74	20.00	-16.74	T4	
	Radial	512	-4.33	-34.51	-64.53	N/A	30.18	20.00	-10.18	T4	2.6, 1.4
		661	-4.12	-33.91			29.79	20.00	-9.79	T3	
		810	-4.30	-33.28			28.98	20.00	-8.98	T3	

Table 7-4
Raw Data Results for UMTS

Mode	Orientation	Channel	ABM1 [dB(A/m)]	ABM2 [dB(A/m)]	Ambient Noise [dB(A/m)]	Frequency Response Margin (dB)	S+N/N (dB)	FCC Limit (dB)	Margin from FCC Limit (dB)	C63.19-2011 Rating	Test Coordinates
UMTS V	Axial	4132	2.81	-56.70	-63.60	2.00	59.51	20.00	-39.51	T4	2.2, 2.6
		4183	2.80	-56.38		2.00	59.18	20.00	-39.18	T4	
		4233	2.80	-56.70		2.00	59.50	20.00	-39.50	T4	
	Radial	4132	-4.43	-53.03	-64.53	N/A	48.60	20.00	-28.60	T4	2.6, 1.4
		4183	-4.44	-54.15			49.71	20.00	-29.71	T4	
		4233	-4.48	-52.65			48.17	20.00	-28.17	T4	
UMTS IV	Axial	1312	2.82	-56.65	-63.60	2.00	59.47	20.00	-39.47	T4	2.2, 2.6
		1412	2.80	-56.95		2.00	59.75	20.00	-39.75	T4	
		1513	2.81	-56.15		2.00	58.96	20.00	-38.96	T4	
	Radial	1312	4.43	-44.22	-64.53	N/A	48.65	20.00	-28.65	T4	2.6, 1.4
		1412	-4.41	-54.48			50.07	20.00	-30.07	T4	
		1513	-4.42	-54.60			50.18	20.00	-30.18	T4	
UMTS II	Axial	9262	2.81	-56.63	-63.60	2.00	59.44	20.00	-39.44	T4	2.2, 2.6
		9400	2.82	-56.63		2.00	59.45	20.00	-39.45	T4	
		9538	2.83	-56.83		2.00	59.66	20.00	-39.66	T4	
	Radial	9262	-4.41	-55.75	-64.53	N/A	51.34	20.00	-31.34	T4	2.6, 1.4
		9400	-4.42	-54.36			49.94	20.00	-29.94	T4	
		9538	-4.42	-54.00			49.58	20.00	-29.58	T4	

Table 7-5
Raw Data Results for EvDO (OTT VoIP)

Mode	Orientation	Channel	ABM1 [dB(A/m)]	ABM2 [dB(A/m)]	Ambient Noise [dB(A/m)]	Frequency Response Margin (dB)	S+N/N (dB)	FCC Limit (dB)	Margin from FCC Limit (dB)	C63.19-2011 Rating	Test Coordinates
Cellular EvDO	Axial	384	8.39	-56.10	-63.60	2.00	64.49	**20.00**	-44.49	**T4**	2.2, 2.6
	Radial	384	1.01	-54.92	-64.53	N/A	55.93	**20.00**	-35.93	**T4**	2.6, 1.4

Table 7-6
Raw Data Results for EDGE (OTT VoIP)

Mode	Orientation	Channel	ABM1 [dB(A/m)]	ABM2 [dB(A/m)]	Ambient Noise [dB(A/m)]	Frequency Response Margin (dB)	S+N/N (dB)	FCC Limit (dB)	Margin from FCC Limit (dB)	C63.19-2011 Rating	Test Coordinates
EDGE850	Axial	190	6.82	-35.29	-63.60	2.00	42.11	**20.00**	-22.11	**T4**	2.2, 2.6
	Radial	190	0.42	-34.38	-64.53	N/A	34.80	**20.00**	-14.80	**T4**	2.6, 1.4
EDGE1900	Axial	661	7.14	-37.54	-63.60	2.00	44.68	**20.00**	-24.68	**T4**	2.2, 2.6
	Radial	661	0.35	-37.21	-64.53	N/A	37.56	**20.00**	-17.56	**T4**	2.6, 1.4

Table 7-7
Raw Data Results for HSPA (OTT VoIP)

Mode	Orientation	Channel	ABM1 [dB(A/m)]	ABM2 [dB(A/m)]	Ambient Noise [dB(A/m)]	Frequency Response Margin (dB)	S+N/N (dB)	FCC Limit (dB)	Margin from FCC Limit (dB)	C63.19-2011 Rating	Test Coordinates
HSPA V	Axial	4183	7.20	-55.31	-63.60	1.73	62.51	**20.00**	-42.51	**T4**	2.2, 2.6
	Radial	4183	0.90	-55.87	-64.53	N/A	56.77	**20.00**	-36.77	**T4**	2.6, 1.4
HSPA IV	Axial	1412	7.34	-55.74	-63.60	2.00	63.08	**20.00**	-43.08	**T4**	2.2, 2.6
	Radial	1412	0.60	-54.59	-64.53	N/A	55.19	**20.00**	-35.19	**T4**	2.6, 1.4
HSPA II	Axial	9400	7.72	-54.45	-63.60	2.00	62.17	**20.00**	-42.17	**T4**	2.2, 2.6
	Radial	9400	0.74	-55.84	-64.53	N/A	56.58	**20.00**	-36.58	**T4**	2.6, 1.4

Table 7-8
Raw Data Results for LTE FDD B13 (OTT VoIP)

Mode	Orientation	Bandwidth	Channel	ABM1 [dB(A/m)]	ABM2 [dB(A/m)]	Ambient Noise [dB(A/m)]	Frequency Response Margin (dB)	S+N/N (dB)	FCC Limit (dB)	Margin from FCC Limit (dB)	C63.19-2011 Rating	Test Coordinates
LTE Band 13	Axial	10MHz	23230	7.35	-52.18	-63.60	1.79	59.53	**20.00**	-39.53	**T4**	2.2, 2.6
		5MHz	23230	7.34	-54.48		2.00	61.82	**20.00**	-41.82	**T4**	
	Radial	10MHz	23230	0.72	-47.91	-64.53	N/A	48.63	**20.00**	-28.63	**T4**	2.6, 1.4
		5MHz	23230	0.72	-51.79			52.51	**20.00**	-32.51	**T4**	

Table 7-9
Raw Data Results for LTE TDD B41 (OTT VoIP)

Mode	Orientation	Bandwidth	Channel	ABM1 [dB(A/m)]	ABM2 [dB(A/m)]	Ambient Noise [dB(A/m)]	Frequency Response Margin (dB)	S+N/N (dB)	FCC Limit (dB)	Margin from FCC Limit (dB)	C63.19-2011 Rating	Test Coordinates
LTE Band 41	Axial	20MHz	41490	7.39	-43.63	-63.60	1.80	51.02	20.00	-31.02	T4	2.2, 2.6
		20MHz	41055	7.42	-43.61		2.00	51.03	20.00	-31.03	T4	
		20MHz	40620	7.61	-44.85		2.00	52.46	20.00	-32.46	T4	
		20MHz	40185	7.42	-48.60		2.00	56.02	20.00	-36.02	T4	
		20MHz	39750	7.67	-47.46		1.78	55.13	20.00	-35.13	T4	
		15MHz	40620	7.63	-44.94		1.99	52.57	20.00	-32.57	T4	
		10MHz	40620	7.52	-45.12		1.91	52.64	20.00	-32.64	T4	
		5MHz	40620	7.70	-45.27		2.00	52.97	20.00	-32.97	T4	
	Radial	20MHz	40620	0.86	-43.33	-64.53	N/A	44.19	20.00	-24.19	T4	2.6, 1.4
		15MHz	40620	0.88	-43.40			44.28	20.00	-24.28	T4	
		10MHz	41490	1.11	-42.48			43.59	20.00	-23.59	T4	
		10MHz	41055	1.08	-42.23			43.31	20.00	-23.31	T4	
		10MHz	40620	0.65	-42.76			43.41	20.00	-23.41	T4	
		10MHz	40185	1.02	-47.14			48.16	20.00	-28.16	T4	
		10MHz	39750	0.74	-46.42			47.16	20.00	-27.16	T4	
		5MHz	40620	1.15	-43.61			44.76	20.00	-24.76	T4	

Table 7-10
Raw Data Results for 2.4GHz WIFI (OTT VoIP)

Mode	Orientation	Channel	ABM1 [dB(A/m)]	ABM2 [dB(A/m)]	Ambient Noise [dB(A/m)]	Frequency Response Margin (dB)	S+N/N (dB)	FCC Limit (dB)	Margin from FCC Limit (dB)	C63.19-2011 Rating	Test Coordinates
WLAN 802.11b	Axial	6	8.58	-43.77	-63.60	2.00	52.35	20.00	-32.35	T4	2.2, 2.6
	Radial	6	0.69	-47.65	-64.53	N/A	48.34	20.00	-28.34	T4	2.6, 1.4
WLAN 802.11g	Axial	1	8.68	-44.23	-63.60	2.00	52.91	20.00	-32.91	T4	2.2, 2.6
		6	8.58	-43.17		2.00	51.75	20.00	-31.75	T4	
		11	8.50	-43.95		2.00	52.45	20.00	-32.45	T4	
	Radial	1	0.70	-44.24	-64.53	N/A	44.94	20.00	-24.94	T4	2.6, 1.4
		6	1.06	-44.85			45.91	20.00	-25.91	T4	
		11	0.83	-44.22			45.05	20.00	-25.05	T4	
WLAN 802.11n	Axial	6	8.77	-44.96	-63.60	1.90	53.73	20.00	-33.73	T4	2.2, 2.6
	Radial	6	1.09	-45.77	-64.53	N/A	46.86	20.00	-26.86	T4	2.6, 1.4

Table 7-11
Raw Data Results for 5GHz WIFI 802.11a (OTT VoIP)

Mode	Orientation	Bandwidth	U-NII	Channel	ABM1 [dB(A/m)]	ABM2 [dB(A/m)]	Ambient Noise [dB(A/m)]	Frequency Response Margin (dB)	S+N/N (dB)	FCC Limit (dB)	Margin from FCC Limit (dB)	C63.19-2011 Rating	Test Coordinates
802.11a	Axial	20MHz	1	40	8.48	-47.78	-63.60	2.00	56.26	20.00	-36.26	T4	2.2, 2.6
		20MHz	2A	56	8.53	-49.86		2.00	58.39	20.00	-38.39	T4	
		20MHz	2C	100	8.95	-50.44		2.00	59.39	20.00	-39.39	T4	
		20MHz	2C	116	8.85	-46.44		2.00	55.29	20.00	-35.29	T4	
		20MHz	2C	140	8.63	-49.10		1.82	57.73	20.00	-37.73	T4	
		20MHz	3	157	8.67	-49.95		2.00	58.62	20.00	-38.62	T4	
	Radial	20MHz	1	40	1.18	-42.96	-64.53	N/A	44.14	20.00	-24.14	T4	2.6, 1.4
		20MHz	2A	56	0.71	-41.83			42.54	20.00	-22.54	T4	
		20MHz	2C	100	1.19	-40.42			41.61	20.00	-21.61	T4	
		20MHz	2C	116	0.84	-39.99			40.83	20.00	-20.83	T4	
		20MHz	2C	140	1.10	-41.71			42.81	20.00	-22.81	T4	
		20MHz	3	157	0.80	-41.75			42.55	20.00	-22.55	T4	

Table 7-12
Raw Data Results for 5GHz WIFI 802.11n (OTT VoIP)

Mode	Orientation	Bandwidth	U-NII	Channel	ABM1 [dB(A/m)]	ABM2 [dB(A/m)]	Ambient Noise [dB(A/m)]	Frequency Response Margin (dB)	S+N/N (dB)	FCC Limit (dB)	Margin from FCC Limit (dB)	C63.19-2011 Rating	Test Coordinates
802.11n	Axial	40MHz	1	38	8.61	-51.13	-63.60	1.82	59.74	20.00	-39.74	T4	2.2, 2.6
		20MHz	1	40	8.82	-51.15		2.00	59.97	20.00	-39.97	T4	
	Radial	40MHz	1	38	0.57	-47.66	-64.53	N/A	48.23	20.00	-28.23	T4	2.6, 1.4
		20MHz	1	40	0.42	-46.14			46.56	20.00	-26.56	T4	

Table 7-13
Raw Data Results for 5GHz WIFI 802.11ac (OTT VoIP)

Mode	Orientation	Bandwidth	U-NII	Channel	ABM1 [dB(A/m)]	ABM2 [dB(A/m)]	Ambient Noise [dB(A/m)]	Frequency Response Margin (dB)	S+N/N (dB)	FCC Limit (dB)	Margin from FCC Limit (dB)	C63.19-2011 Rating	Test Coordinates
802.11ac	Axial	40MHz	1	38	9.00	-52.44	-63.60	2.00	61.44	20.00	-41.44	T4	2.2, 2.6
		20MHz	1	40	8.58	-52.79		2.00	61.37	20.00	-41.37	T4	
	Radial	40MHz	1	38	0.81	-46.62	-64.53	N/A	47.43	20.00	-27.43	T4	2.6, 1.4
		20MHz	1	40	0.26	-46.87			47.13	20.00	-27.13	T4	

II. Test Notes

A. General

1. Phone Condition: Mute on; Backlight off; Max Volume; Max Contrast
2. 'Radial' orientation refers to radial transverse.
3. Hearing Aid Mode (**Phone→Settings→More Settings→Hearing aids**) was set to ON for Frequency Response compliance
4. Speech Signal: 3GPP2 Normal Test Signal
5. Bluetooth and WIFI were disabled while testing 2G/3G/4G modes.
6. Licensed data modes and Bluetooth were disabled while testing WIFI modes while testing.
7. The Margin from FCC limit column indicates a margin from the FCC limit for compliance (T3).

B. CDMA

1. Power Configuration: Power Control Bits = "All Up"
2. Vocoder Configuration: RC1/SO3 (CDMA – EVRC)

C. GSM

1. Power Configuration: GSM850: PCL=5, GSM1900: PCL=0;
2. Vocoder Configuration: EFR (GSM);

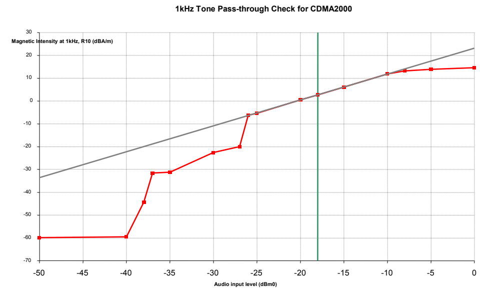
D. UMTS

1. Power Configuration: TPC= "All 1s";
2. Vocoder Configuration: AMR 12.2 kbps (UMTS);

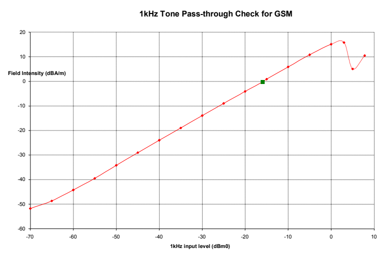
E. OTT VoIP

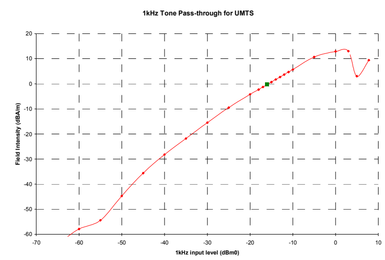
1. Vocoder Configuration: 6kbps
2. EvDO Configuration
    a. Revision: A
3. EDGE Configuration
    a. MCS Index: 7
    b. Number of TX slots: 2
4. HSPA Configuration:
    a. Release: 6
    b. 3GPP 34.121 Subtest 1
5. LTE FDD Configuration:
    a. Power Configuration: TPC = “Max Power”
    b. Radio Configuration: 16QAM, 1RB, 0RB offset
    c. LTE Band 13 was the worst-case band from Table 5-7 and was used to test both Axial and Radial probe orientations.
    d. The worst-case bandwidth for each probe orientation is additionally tested on the low and high channels for those bandwidths. LTE Band 13 at 10MHz is the worst-case for both the Axial and Radial probe orientations, but that configuration only supports one channel. Therefore, no additional testing was performed.
6. LTE TDD Configuration:
    a. Power Configuration: TPC = “Max Power”
    b. Radio Configuration: 16QAM, 1RB, 0RB offset
    c. Power Class 3 Uplink-Downlink configuration: 2
    d. The worst-case bandwidth for each probe orientation is additionally tested on the low, low-mid, high-mid, and high channels for those bandwidths. LTE Band 41 (Power Class 3) at 20MHz is the worst-case for the Axial probe orientation and LTE Band 41 (Power Class 3) at 10MHz is the Radial probe orientation.
7. WIFI Configuration:
    a. Radio Configuration
        i. 802.11b: DSSS, 2Mbps
        ii. 802.11g/a: BPSK, 6Mbps
        iii. 802.11n/ac 20MHz: 16-QAM, 39Mbps
        iv. 802.11n/ac 40MHz: 64-QAM, 108Mbps
    b. The worst-case standard for 2.4GHz WIFI in each probe orientation is additionally tested on the low and high channels. 802.11g is the worst-case for both the Axial and Radial probe orientations.
    c. The worst-case standard for 5GHz WIFI in each probe orientation is additionally tested on higher U-NII bands as well as applicable low and high channels. 802.11a (U-NII 2C) is the worst-case for both the Axial and Radial probe orientations.

III. 1 kHz Vocoder Application Check

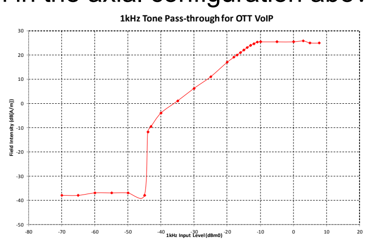


This model was verified to be within the linear region for ABM1 measurements at -18 dBm0 for CDMA. This measurement was taken in the axial configuration above the maximum location.





This model was verified to be within the linear region for ABM1 measurements at -16 dBm0 for GSM and UMTS. This measurement was taken in the axial configuration above the maximum location.



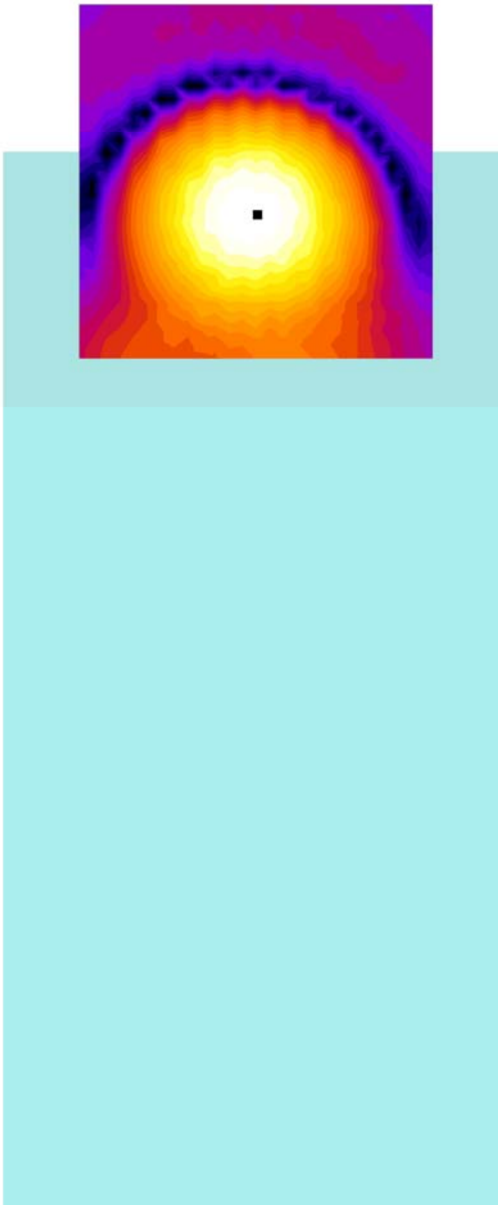
This model was verified to be within the linear region for ABM1 measurements at -20 dBm0 for OTT VoIP. This measurement was taken in the axial configuration above the maximum location.

IV. T-Coil Validation Test Results

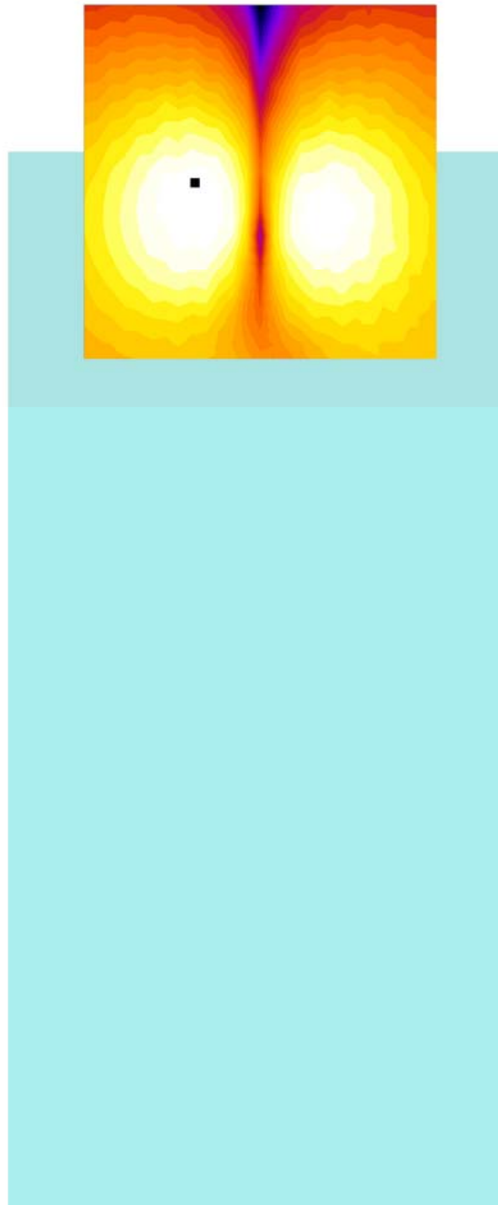
Table 7-14
Helmholtz Coil Validation Table of Results

Item	Target	Result	Verdict
Axial			
Magnetic Intensity, -10 dBA/m	-10 ± 0.5 dB	-10.171	PASS
Environmental Noise	< -58 dBA/m	-63.60	PASS
Frequency Response, from limits	> 0 dB	0.70	PASS
Radial			
Magnetic Intensity, -10 dBA/m	-10 ± 0.5 dB	-10.275	PASS
Environmental Noise	< -58 dBA/m	-64.53	PASS
Frequency Response, from limits	> 0 dB	0.70	PASS

V. ABM1 Magnetic Field Distribution Scan Overlays



Axial



Radial (Transverse)

Figure 7-1
T-Coil Scan Overlay Magnetic Field Distributions

Notes:
1. Final measurement locations are indicated by a cursor on the contour plots.
2. See Test Setup Photographs for actual WD overlay.

8. MEASUREMENT UNCERTAINTY

Table 8-1
Uncertainty Estimation Table

Contribution	Data +/- %	Data +/- dB	Data Type	Probability distribution	Divisor	Standard uncertainty	Standard Uncertainty (dB)
ABM Noise	7.0%	0.29	Std. Dev.	Normal k=1	1.00	7.0%	
RF Reflections	4.7%	0.20	Specification	Rectangular	1.73	2.7%	
Reference Signal Level	12.2%	0.50	Specification	Rectangular	1.73	7.0%	
Positioning Accuracy	10.0%	0.41	Uncertainty	Rectangular	1.73	5.8%	
Probe Coil Sensitivity	12.2%	0.50	Specification	Rectangular	1.73	7.0%	
Probe Linearity	2.4%	0.10	Std. Dev.	Normal k=1	1.00	2.4%	
Cable Loss	2.8%	0.12	Specification	Rectangular	1.73	1.6%	
Frequency Analyzer	5.0%	0.21	Specification	Rectangular	1.73	2.9%	
System Repeatability	5.0%	0.21	Std. Dev.	Normal k=1	1.00	5.0%	
WD Repeatability	9.0%	0.37	Std. Dev.	Normal k=1	1.00	9.0%	
Positioner Accuracy	1.0%	0.04	Specification	Rectangular	1.73	0.6%	
Combined standard uncertainty, uc (k=1)						17.7%	0.71
Expanded uncertainty (k=2), 95% confidence level						35.3%	1.31

Notes:

1. Test equipments are calibrated according to techniques outlined in NIS81, NIS3003 and NIST Tech Note 1297.
2. All equipments have traceability according to NIST. Measurement Uncertainties are defined in further detail in NIS 81 and NIST Tech Note 1297 and UKAS M3003.

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

9. EQUIPMENT LIST

Table 9-1
Equipment List

Manufacturer	Model	Description	Cal Date	Cal Interval	Cal Due	Serial Number
Dell	Latitude E6540	SoundCheck Acoustic Analyzer Laptop	4/11/2017	Biennial	4/11/2019	7BFNM32
Listen	SoundConnect	Microphone Power Supply	N/A		N/A	0899-PS150
Listen	SoundConnect	Microphone Power Supply	12/2/2016	Biennial	12/2/2018	PS2612
RME	Fireface UC	Soundcheck Acoustic Analyzer External Audio Interface	4/11/2017	Biennial	4/11/2019	23528889
Rohde & Schwarz	CMW500	Wideband Radio Communication Tester	1/19/2018	Annual	1/19/2019	162125
Rohde & Schwarz	CMW500	Radio Communication tester	7/14/2017	Annual	7/14/2018	140144
Seekonk	NC-100	Torque Wrench (8" lb)	9/1/2016	Biennial	9/1/2018	21053
TEM	C63.19	Helmholtz Coil	12/7/2016	Biennial	12/7/2018	925
TEM	Radial T-Coil Probe	Radial T-Coil Probe	12/7/2016	Biennial	12/7/2018	TEM-1130
TEM	Axial T-Coil Probe	Axial T-Coil Probe	12/7/2016	Biennial	12/7/2018	TEM-1124
TEM		HAC System Controller with Software	N/A		N/A	N/A
TEM		HAC Positioner	N/A		N/A	N/A

10. TEST DATA

PCTEST Hearing-Aid Compatibility Facility

DUT: HH Coil – SN: 925

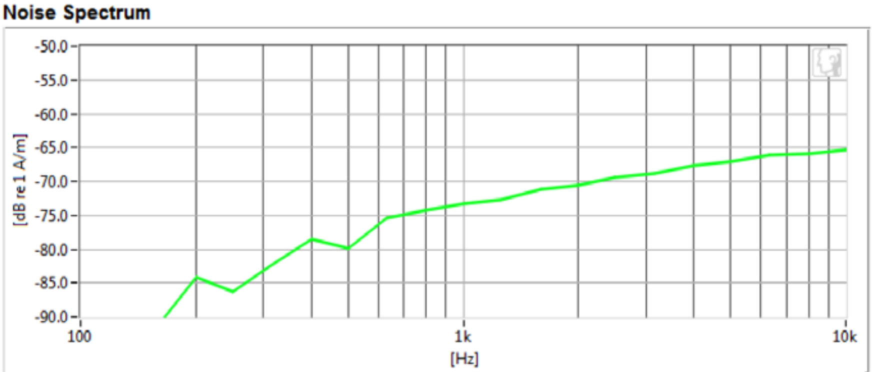
Type: HH Coil
Serial: 925

Measurement Standard: ANSI C63.19-2011

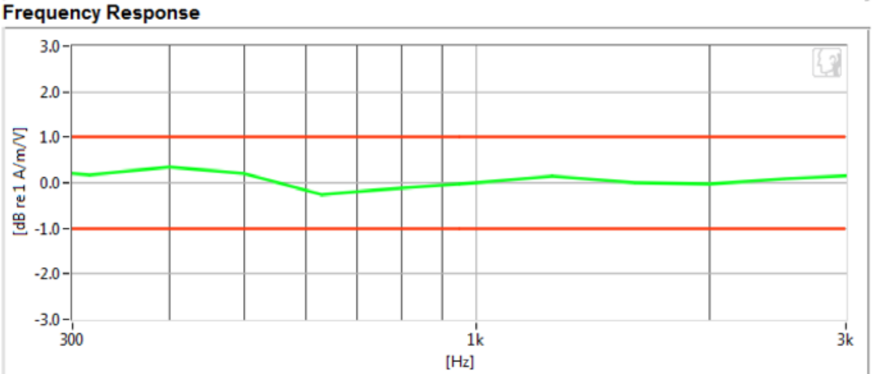
Equipment:

- Probe: Axial T-Coil Probe – SN: TEM-1124; Calibrated: 12/07/2016
- Helmholtz Coil – SN: 925; Calibrated: 12/07/2016

Noise Spectrum



Frequency Response



Results

Verification 1kHz Intensity	-10.171 dB	✔	Max/Min	-9.5/-10.5
Verification ABM2	-63.6 dB	✔	Maximum	-58.0
Frequency Response Margin	700m dB	✔	Tolerance curves	Aligned Data

PCTEST 2018

PCTEST Hearing-Aid Compatibility Facility

DUT: HH Coil – SN: 925

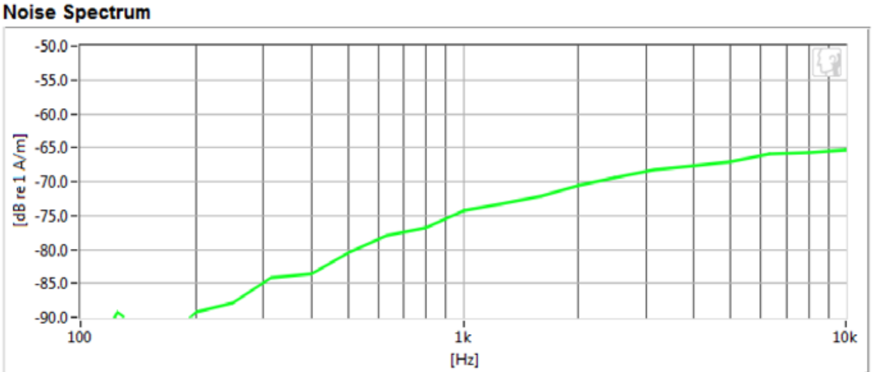
Type: HH Coil
Serial: 925

Measurement Standard: ANSI C63.19-2011

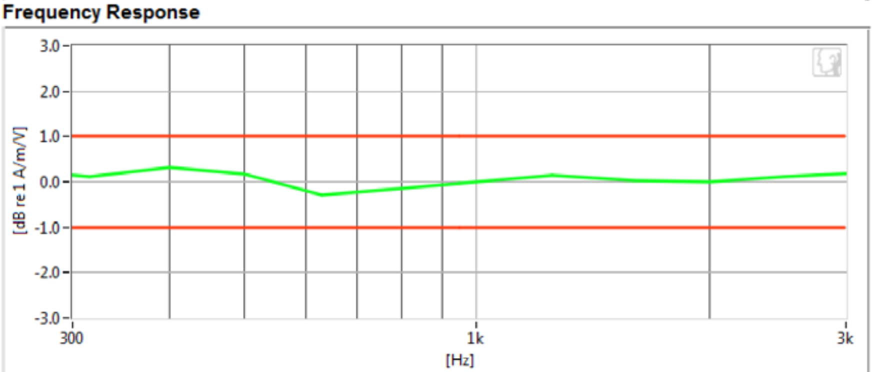
Equipment:

- Probe: Radial T-Coil Probe – SN: TEM-1130; Calibrated: 12/07/2016
- Helmholtz Coil – SN: 925; Calibrated: 12/07/2016

Noise Spectrum



Frequency Response



Results

Verification 1kHz Intensity	-10.275 dB	✔	Max/Min	-9.5/-10.5
Verification ABM2	-64.53 dB	✔	Maximum	-58.0
Frequency Response Margin	700m dB	✔	Tolerance curves	Aligned Data

PCTEST ENGINEERING LABORATORY, INC.

PCTEST Hearing-Aid Compatibility Facility

DUT: A3LSMN9600

Type: Portable Handset
Serial: 32928

Measurement Standard: ANSI C63.19-2011

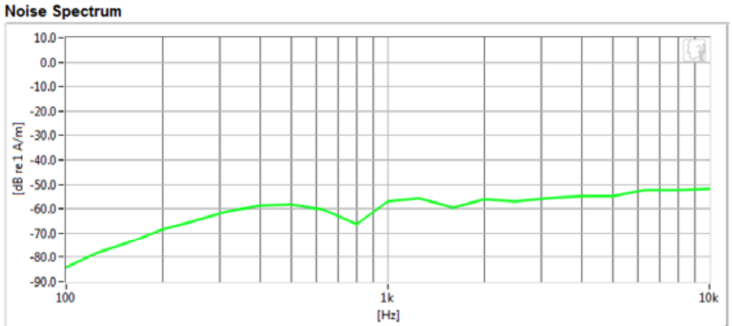
Equipment:

- Probe: Axial T-Coil Probe – SN: TEM-1124; Calibrated: 12/07/2016

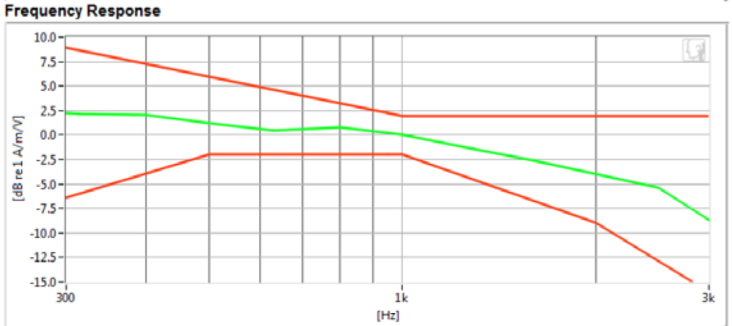
Test Configuration:

- Mode: Cellular CDMA
- Channel: 777
- Speech Signal: 3GPP2 Normal Test Signal

Noise Spectrum



Frequency Response



Results

ABM1	1.26	dB	✓	Minimum	-18.0
ABM2	-47.72	dB	✓	Maximum	0.0
SNNR	48.98	dB	✓	Minimum	20.0
Aligned Response - Normal	2	dB	✓	Tolerance curves	Aligned Data

PCTEST 2018

PCTEST Hearing-Aid Compatibility Facility

DUT: A3LSMN9600

Type: Portable Handset
Serial: 32928

Measurement Standard: ANSI C63.19-2011

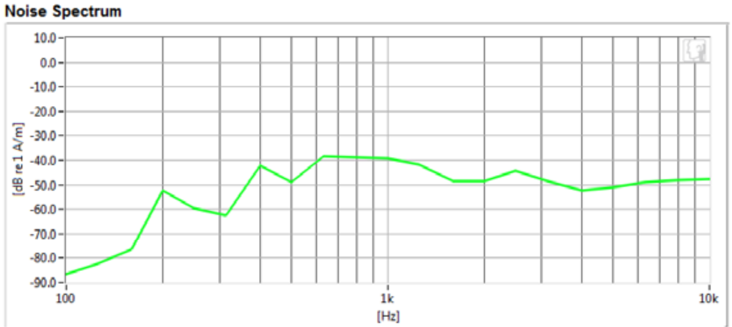
Equipment:

- Probe: Axial T-Coil Probe – SN: TEM-1124; Calibrated: 12/07/2016

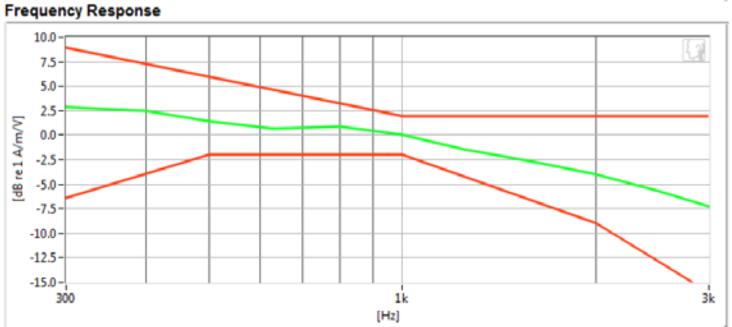
Test Configuration:

- Mode: GSM850
- Channel: 128
- Speech Signal: 3GPP2 Normal Test Signal

Noise Spectrum



Frequency Response



Results

ABM1	3.15	dB	✔	Minimum	-18.0
ABM2	-31.4	dB	✔	Maximum	0.0
SNNR	34.54	dB	✔	Minimum	20.0
Aligned Response - Normal	2	dB	✔	Tolerance curves	Aligned Data

PCTEST Hearing-Aid Compatibility Facility

DUT: A3LSMN9600

Type: Portable Handset
Serial: 32928

Measurement Standard: ANSI C63.19-2011

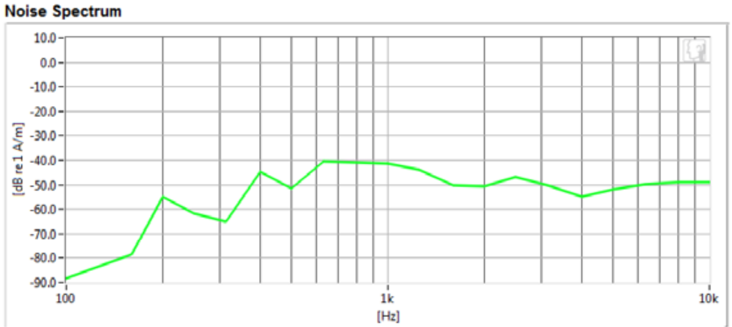
Equipment:

- Probe: Axial T-Coil Probe – SN: TEM-1124; Calibrated: 12/07/2016

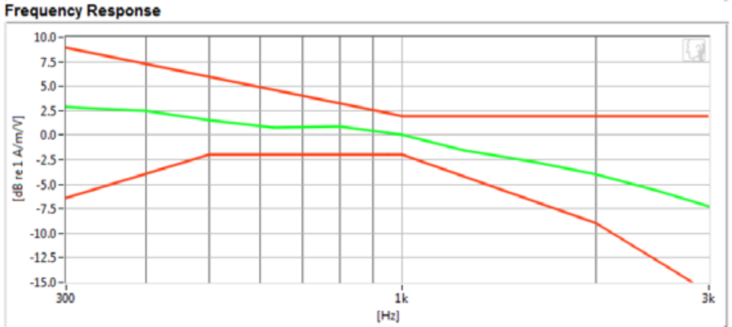
Test Configuration:

- Mode: GSM1900
- Channel: 810
- Speech Signal: 3GPP2 Normal Test Signal

Noise Spectrum



Frequency Response



Results

ABM1	3.1 dB	✔	Minimum	-18.0
ABM2	-33.64 dB	✔	Maximum	0.0
SNNR	36.74 dB	✔	Minimum	20.0
Aligned Response - Normal	2 dB	✔	Tolerance curves	Aligned Data

PCTEST 2018

PCTEST Hearing-Aid Compatibility Facility

DUT: A3LSMN9600

Type: Portable Handset
Serial: 32928

Measurement Standard: ANSI C63.19-2011

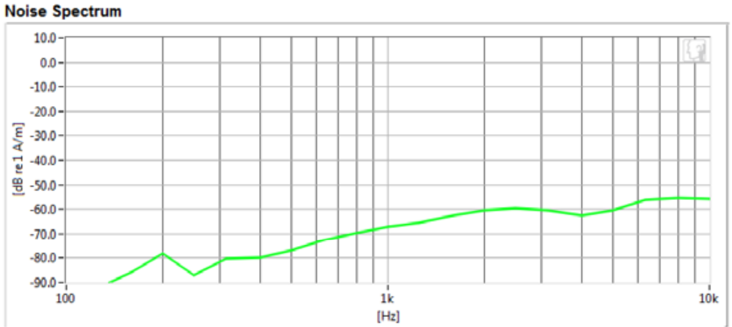
Equipment:

- Probe: Axial T-Coil Probe – SN: TEM-1124; Calibrated: 12/07/2016

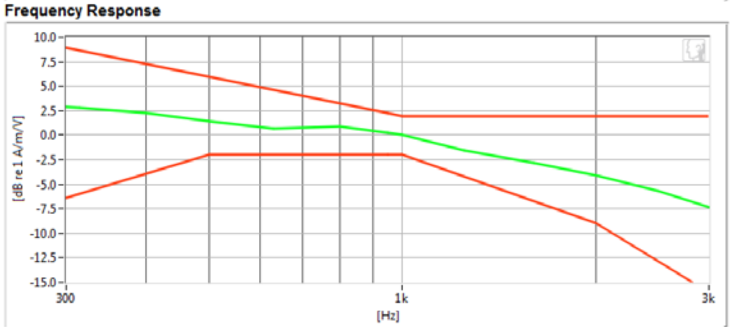
Test Configuration:

- Mode: UMTS V
- Channel: 4183
- Speech Signal: 3GPP2 Normal Test Signal

Noise Spectrum



Frequency Response



Results

ABM1	2.8 dB	✔	Minimum	-18.0
ABM2	-56.39 dB	✔	Maximum	0.0
SNNR	59.18 dB	✔	Minimum	20.0
Aligned Response - Normal	2 dB	✔	Tolerance curves	Aligned Data

PCTEST Hearing-Aid Compatibility Facility

DUT: A3LSMN9600

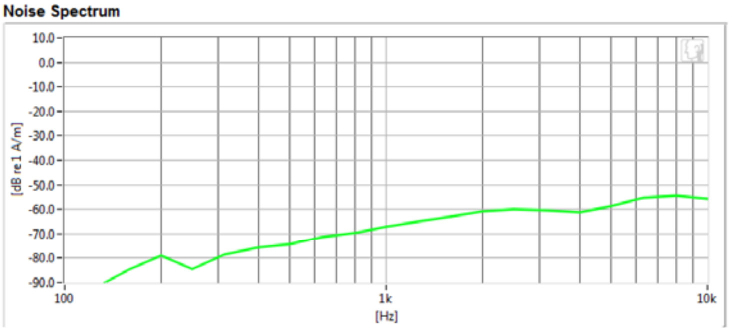
Type: Portable Handset
Serial: 32928

Measurement Standard: ANSI C63.19-2011

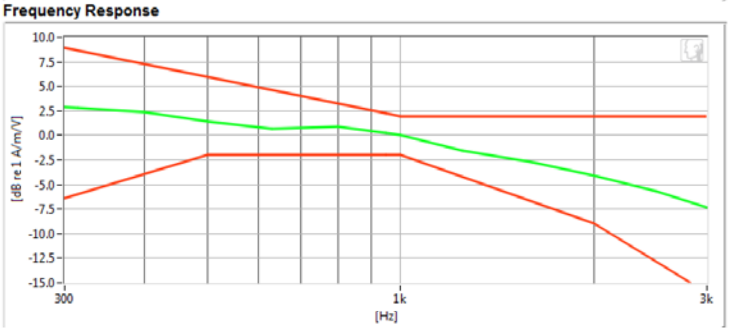
Equipment:
- Probe: Axial T-Coil Probe – SN: TEM-1124; Calibrated: 12/07/2016

Test Configuration:
- Mode: UMTS IV
- Channel: 1513
- Speech Signal: 3GPP2 Normal Test Signal

Noise Spectrum



Frequency Response



Results

ABM1	2.81	dB	✔	Minimum	-18.0
ABM2	-56.15	dB	✔	Maximum	0.0
SNNR	58.96	dB	✔	Minimum	20.0
Aligned Response - Normal	2	dB	✔	Tolerance curves	Aligned Data

PCTEST 2018

PCTEST Hearing-Aid Compatibility Facility

DUT: A3LSMN9600

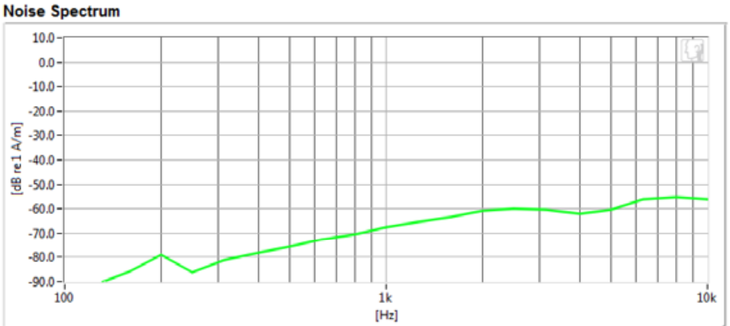
Type: Portable Handset
Serial: 32928

Measurement Standard: ANSI C63.19-2011

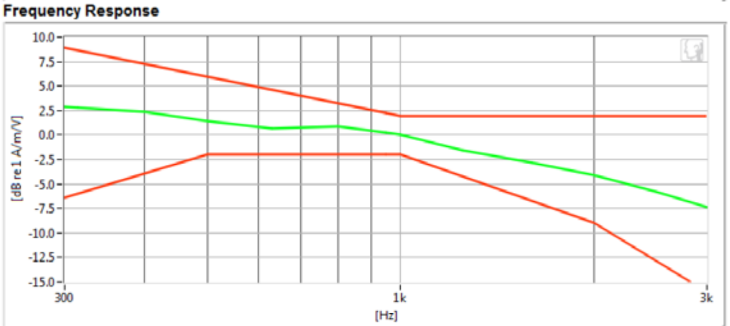
Equipment:
- Probe: Axial T-Coil Probe – SN: TEM-1124; Calibrated: 12/07/2016

Test Configuration:
- Mode: UMTS II
- Channel: 9262
- Speech Signal: 3GPP2 Normal Test Signal

Noise Spectrum



Frequency Response



Results

ABM1	2.81	dB	✔	Minimum	-18.0
ABM2	-56.63	dB	✔	Maximum	0.0
SNNR	59.44	dB	✔	Minimum	20.0
Aligned Response - Normal	2	dB	✔	Tolerance curves	Aligned Data

PCTEST 2018

PCTEST Hearing-Aid Compatibility Facility

DUT: A3LSMN9600

Type: Portable Handset
Serial: 32928

Measurement Standard: ANSI C63.19-2011

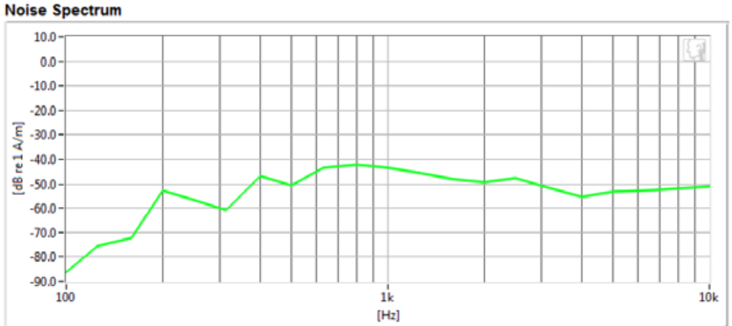
Equipment:

- Probe: Axial T-Coil Probe – SN: TEM-1124; Calibrated: 12/07/2016

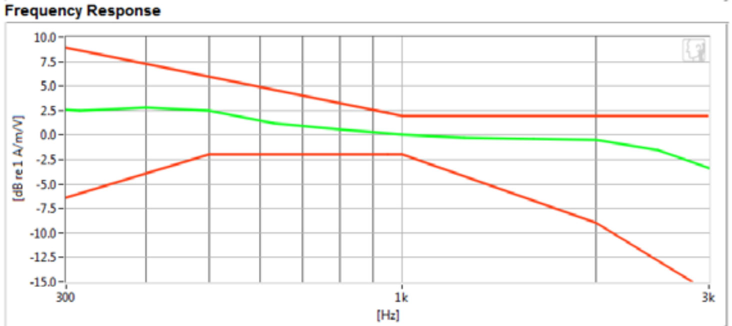
Test Configuration:

- VoIP Application: Google Duo
- Mode: EDGE850
- Channel: 190
- Speech Signal: 3GPP2 Normal Test Signal

Noise Spectrum



Frequency Response



Results

ABM1	6.82 dB	✔	Minimum	-18.0
ABM2	-35.29 dB	✔	Maximum	0.0
SNNR	42.11 dB	✔	Minimum	20.0
Aligned Response - Normal	2 dB	✔	Tolerance curves	Aligned Data

PCTEST ENGINEERING LABORATORY, INC.

PCTEST Hearing-Aid Compatibility Facility

DUT: A3LSMN9600

Type: Portable Handset
Serial: 32928

Measurement Standard: ANSI C63.19-2011

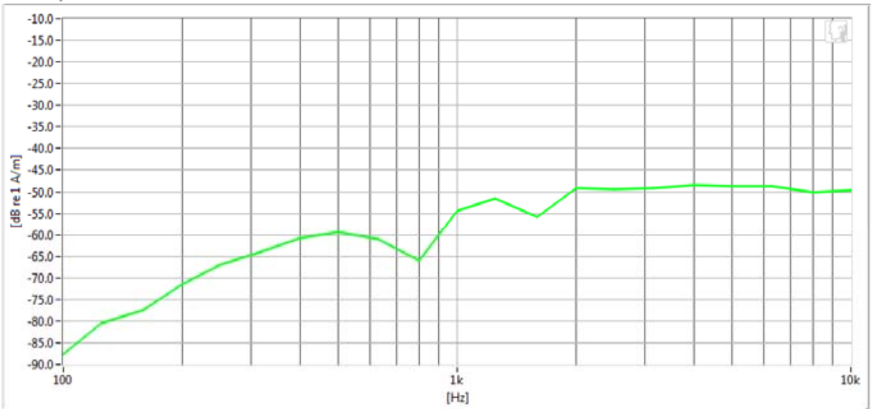
Equipment:

- Probe: Radial T-Coil Probe – SN: TEM-1130; Calibrated: 12/07/2016

Test Configuration:

- Mode: Cellular CDMA
- Channel: 1013

Noise Spectrum



Results

ABM1	-7.04 dB	✓	Minimum	-18.0
ABM2	-45.11 dB	✓	Maximum	0.0
SNNR	38.06 dB	✓	Minimum	20.0

PCTEST 2018

6/4/2018

PCTEST Hearing-Aid Compatibility Facility

DUT: A3LSMN9600

Type: Portable Handset
Serial: 32928

Measurement Standard: ANSI C63.19-2011

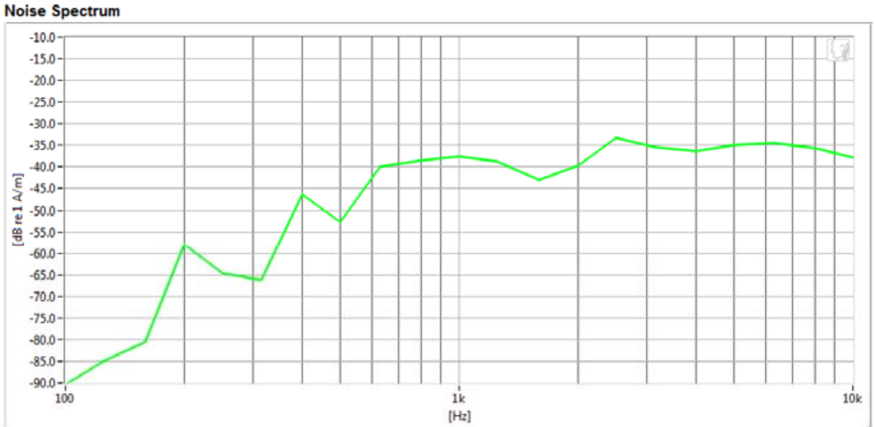
Equipment:

- Probe: Radial T-Coil Probe – SN: TEM-1130; Calibrated: 12/07/2016

Test Configuration:

- Mode: GSM850
- Channel: 128

Noise Spectrum



Results

ABM1	-4.29	dB	✓	Minimum	-18.0
ABM2	-30.06	dB	✓	Maximum	0.0
SNNR	25.77	dB	✓	Minimum	20.0

PCTEST 2018

PCTEST ENGINEERING LABORATORY, INC.

PCTEST Hearing-Aid Compatibility Facility

DUT: A3LSMN9600

Type: Portable Handset
Serial: 32928

Measurement Standard: ANSI C63.19-2011

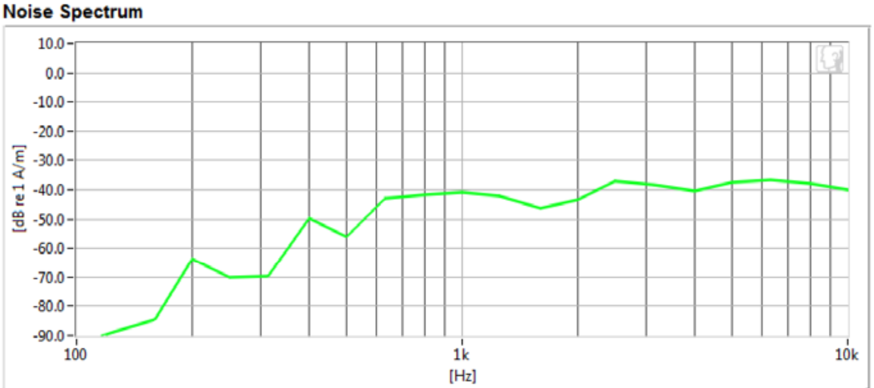
Equipment:

- Probe: Radial T-Coil Probe – SN: TEM-1130; Calibrated: 12/07/2016

Test Configuration:

- Mode: GSM1900
- Channel: 810

Noise Spectrum



Results

ABM1	-4.3 dB	✔	Minimum	-18.0
ABM2	-33.28 dB	✔	Maximum	0.0
SNNR	28.98 dB	✔	Minimum	20.0

PCTEST Hearing-Aid Compatibility Facility

DUT: A3LSMN9600

Type: Portable Handset
Serial: 32928

Measurement Standard: ANSI C63.19-2011

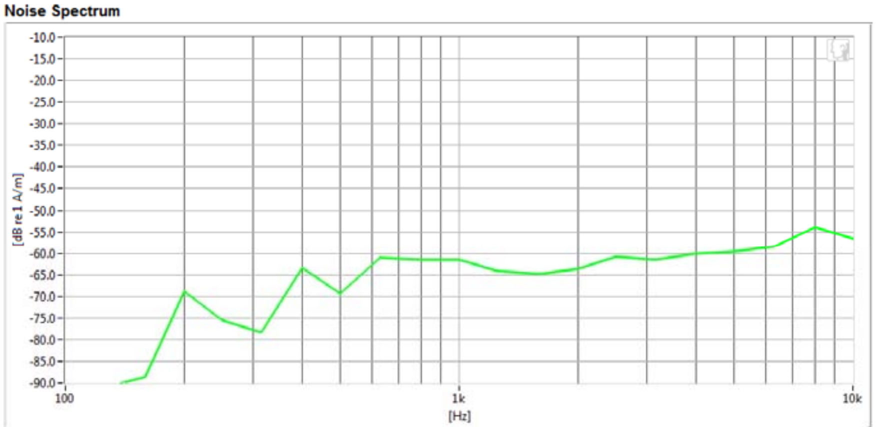
Equipment:

- Probe: Radial T-Coil Probe – SN: TEM-1130; Calibrated: 12/07/2016

Test Configuration:

- Mode: UMTS V
- Channel: 4233

Noise Spectrum



Results

ABM1	-4.48 dB	✓	Minimum	-18.0
ABM2	-52.65 dB	✓	Maximum	0.0
SNNR	48.17 dB	✓	Minimum	20.0

6/4/2018

PCTEST Hearing-Aid Compatibility Facility

DUT: A3LSMN9600

Type: Portable Handset
Serial: 32928

Measurement Standard: ANSI C63.19-2011

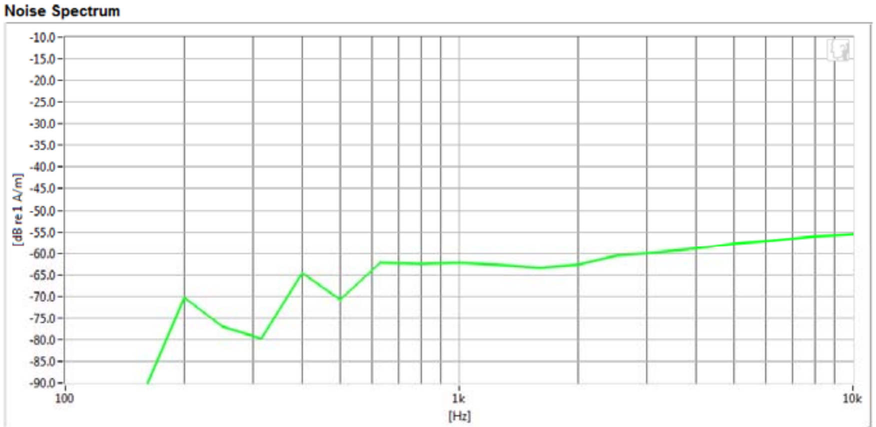
Equipment:

- Probe: Radial T-Coil Probe – SN: TEM-1130; Calibrated: 12/07/2016

Test Configuration:

- Mode: UMTS IV
- Channel: 1312

Noise Spectrum



Results

ABM1	-4.43	dB	✔	Minimum	-18.0
ABM2	-53.08	dB	✔	Maximum	0.0
SNNR	48.65	dB	✔	Minimum	20.0

PCTEST 2018

PCTEST Hearing-Aid Compatibility Facility

DUT: A3LSMN9600

Type: Portable Handset
Serial: 32928

Measurement Standard: ANSI C63.19-2011

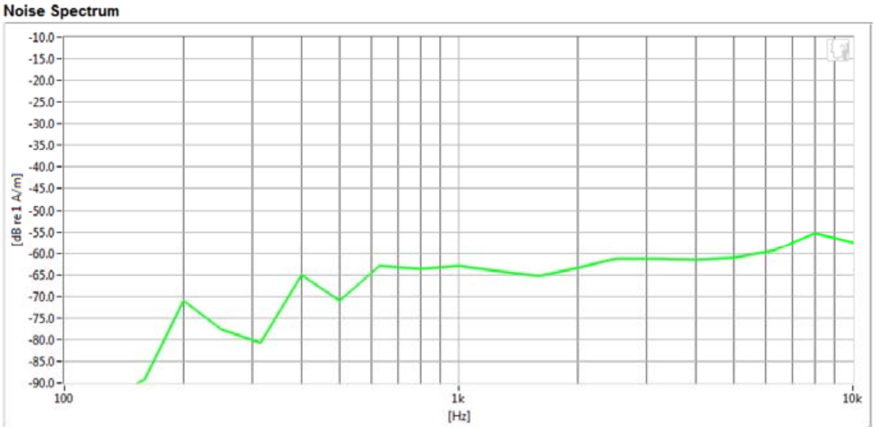
Equipment:

- Probe: Radial T-Coil Probe – SN: TEM-1130; Calibrated: 12/07/2016

Test Configuration:

- Mode: UMTS II
- Channel: 9538

Noise Spectrum



Results

ABM1	-4.42 dB	✔	Minimum	-18.0
ABM2	-54 dB	✔	Maximum	0.0
SNNR	49.58 dB	✔	Minimum	20.0

PCTEST Hearing-Aid Compatibility Facility

DUT: A3LSMN9600

Type: Portable Handset
Serial: 32928

Measurement Standard: ANSI C63.19-2011

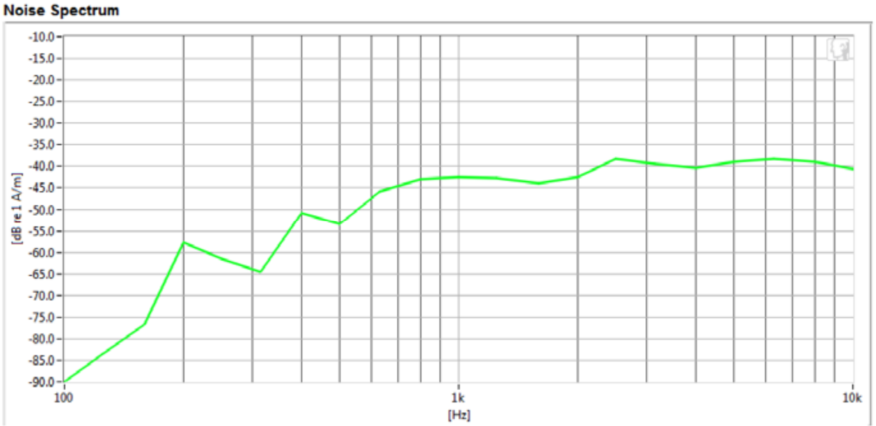
Equipment:

- Probe: Radial T-Coil Probe – SN: TEM-1130; Calibrated: 12/07/2016

Test Configuration:

- VoIP Application: Google Duo
- Mode: EDGE850
- Channel: 190

Noise Spectrum



Results

ABM1	420m dB	✔	Minimum	-18.0
ABM2	-34.38 dB	✔	Maximum	0.0
SNNR	34.8 dB	✔	Minimum	20.0

PCTEST 2018

11. CALIBRATION CERTIFICATES

West Caldwell Calibration Laboratories Inc.

Certificate of Calibration

for

AXIAL T COIL PROBE

Manufactured by:	TEM CONSULTING
Model No:	AXIAL T COIL PROBE
Serial No:	TEM-1124
Calibration Recall No:	27068

Submitted By:

Customer:	ANDREW HARWELL
Company:	PCTEST ENGINEERING LAB
Address:	6660-B DOBBIN ROAD
	COLUMBIA MD 21045

The subject instrument was calibrated to the indicated specification using standards traceable to the National Institute of Standards and Technology or to accepted values of natural physical constants. This document certifies that the instrument met the following specification upon its return to the submitter.

West Caldwell Calibration Laboratories Procedure No. AXIAL T C TEM C

Upon receipt for Calibration, the instrument was found to be:

Within (X)

tolerance of the indicated specification. See attached Report of Calibration.

West Caldwell Calibration Laboratories' calibration control system meets the following requirements, ISO 10012-1 MIL STD 45662A, ANSI/NCSL Z540-1, IEC Guide 25, ISO 9001:2008 and ISO 17025

Note: With this Certificate, Report of Calibration is Included.

Approved by:

Calibration Date: 07-Dec-16

Certificate No: 27068 - 3

Felix Christopher (QA Mgr.)

ISO/IEC 17025:2005

QA Doc. #1051 Rev. 2.0 10/1/01

Certificate Page 1 of 1

West Caldwell Calibration Laboratories, Inc.

uncompromised calibration

1575 State Route 96, Victor, NY 14564, U.S.A.

ACCREDITED

Calibration Lab. Cert. # 1533.01

West Caldwell Calibration Laboratories, Inc.
uncompromised calibration
1575 State Route 96, Victor NY 14564

ISO/IEC 17025: 2005
ACCREDITED
Calibration Lab. Cert. # 1533.01

REPORT OF CALIBRATION

for

TEM Consulting LP Axial T Coil Probe **Model No.: Axial T Coil Probe** **Serial No.: TEM 1124**

Company : PCTEST Engineering Lab. **I. D. No: 80578**

Calibration results:

Probe Sensitivity measured with Helmholtz Coil

Helmholtz Coil; Before & after data same: ...X......

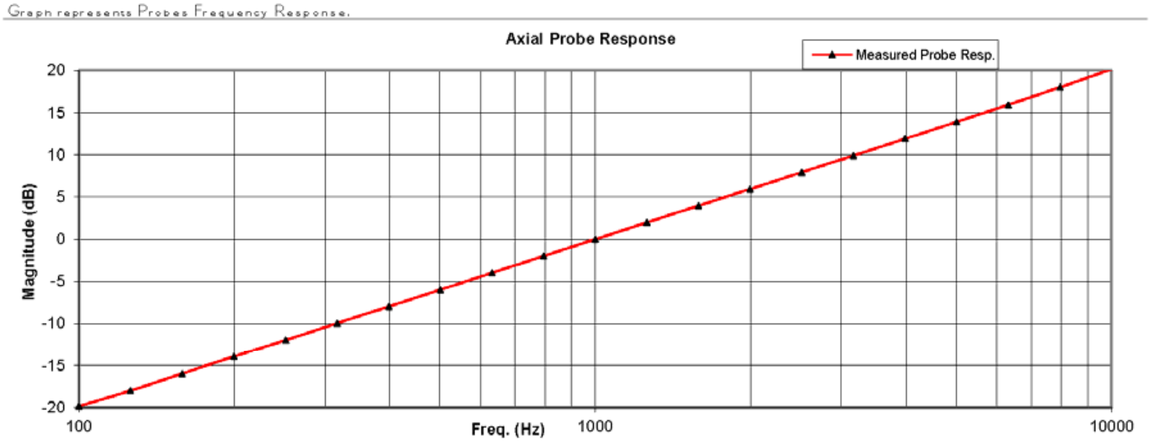
the number of turns on each coil;	10	No.			
the radius of each coil, in meters;	0.204	m	Laboratory Environment:		
the current in the coils, in amperes.;	0.09	A	Ambient Temperature:	20.2	°C
Helmholtz Coil Constant;	7.09	A/m/V	Ambient Humidity:	31.4	% RH
Helmholtz Coil magnetic field;	5.98	A/m	Ambient Pressure:	99.1	kPa
			Calibration Date:	7-Dec-16	
Probe Sensitivity at	1000	Hz.			
was	-60.23	dBV/A/m	Report Number:	27068	-3
	0.974	mV/A/m	Control Number:	27068	
Probe resistance	904	Ohms			

The above listed instrument meets or exceeds the tested manufacturer's specifications.

This Calibration is traceable through NIST test numbers: 683/284413-14

The expanded uncertainty of calibration: 0.30dB at 95% confidence level with a coverage factor of k=2.

Graph represents Probes Frequency Response.



The above listed instrument was checked using calibration procedure documented in West Caldwell Calibration Laboratories Inc. procedure : **Rev. 7.0 Jan. 24, 2014 Doc. # 1038 HCATEMC**

Calibration was performed by West Caldwell Calibration Laboratories Inc. under Operating Procedures intended to implement the requirements of ISO10012-1, IEC Guide 25, ANSI/NCSL Z540-1, (MIL-STD-45662A) and ISO 9001:2008, ISO 17025

Cal. Date: 7-Dec-2016 Measurements performed by: FC

Calibrated on WCCL system type 9700 **Felix Christopher**

Rev. 7.0 Jan. 24, 2014 Doc. # 1038 HCATEMC

Page 1 of 2

West Caldwell Calibration Laboratories Inc.
1575 State Route 96, Victor NY 14564
Tel. (585) 586-3900 FAX (585) 586-4327

Calibration Data Record

for

TEM Consulting LP Axial T Coil Probe **Model No.: Axial T Coil Probe** **Serial No.: TEM 1124**

Company : PCTEST Engineering Lab.

Test	Function		Tolerance	Measured values Before	Out	Remarks
1.0	Probe Sensitivity at	1000 Hz.	dBV/A/m	-60.23		
			dB			
2.0	Probe Level Linearity		6	6.03		
		Ref. (0 dB)	0	0.00		
			-6	-6.03		
			-12	-12.05		
			Hz			
3.0	Probe Frequency Response		100	-19.8		
			126	-18.0		
			158	-16.0		
			200	-13.9		
			251	-12.0		
			316	-9.9		
			398	-8.0		
			501	-6.0		
			631	-4.0		
			794	-2.0		
		Ref. (0 dB)	1000	0.0		
			1259	2.0		
			1585	4.0		
			1995	6.0		
			2512	7.9		
			3162	9.9		
			3981	11.9		
			5012	13.9		
			6310	15.9		
			7943	18.0		
			10000	20.2		

Instruments used for calibration:			Date of Cal.	Traceability No.	Due Date
HP	34401A	S/N 36064102	1-Oct-2016	,287708	1-Oct-2017
HP	34401A	S/N 36102471	1-Oct-2016	,287708	1-Oct-2017
HP	33120A	S/N 36043716	1-Oct-2016	,287708	1-Oct-2017
B&K	2133	S/N 1583254	1-Oct-2016	683/284413-14	1-Oct-2017

Cal. Date: 7-Dec-2016 Tested by: Felix Christopher

Calibrated on WCCL system type 9700

Rev. 7.0 Jan. 24, 2014 Doc. # 1038 HCATEMC

West Caldwell Calibration Laboratories Inc.

Certificate of Calibration

for

RADIAL T COIL PROBE

Manufactured by:	TEM CONSULTING
Model No:	RADIAL T COIL PROBE
Serial No:	TEM-1130
Calibration Recall No:	27068

Submitted By:

Customer:	ANDREW HARWELL
Company:	PCTEST ENGINEERING LAB
Address:	6660-B DOBBIN ROAD
	COLUMBIA MD 21045

The subject instrument was calibrated to the indicated specification using standards traceable to the National Institute of Standards and Technology or to accepted values of natural physical constants. This document certifies that the instrument met the following specification upon its return to the submitter.

West Caldwell Calibration Laboratories Procedure No. RADIAL T TEM C

Upon receipt for Calibration, the instrument was found to be:

Within (X)

12/29/2016

tolerance of the indicated specification. See attached Report of Calibration.

West Caldwell Calibration Laboratories' calibration control system meets the following requirements, ISO 10012-1 MIL STD 45662A, ANSI/NCSL Z540-1, IEC Guide 25, ISO 9001:2008 and ISO 17025

Note: With this Certificate, Report of Calibration is included.

Approved by:

Calibration Date: 07-Dec-16

FC

Certificate No: 27068 - 2

Felix Christopher (QA Mgr.)

ISO/IEC 17025:2005

QA Doc. #1051 Rev. 2.0 10/1/01

Certificate Page 1 of 1

West Caldwell Calibration Laboratories, Inc.

uncompromised calibration

1575 State Route 96, Victor, NY 14564, U.S.A.

ACCREDITED

Calibration Lab. Cert. # 1533.01

West Caldwell Calibration Laboratories, Inc.
uncompromised calibration
1575 State Route 96, Victor NY 14564

ISO/IEC 17025: 2005
ACCREDITED
Calibration Lab. Cert. # 1533.01

REPORT OF CALIBRATION

for

TEM Consulting LP Radial T Coil Probe **Model No.: Radial T Coil Probe** **Serial No.: TEM-1130**

Company : PCTEST Engineering Lab. **I. D. No: 80579**

Calibration results:

Probe Sensitivity measured with Helmholtz Coil

Before & after data same: ...X......

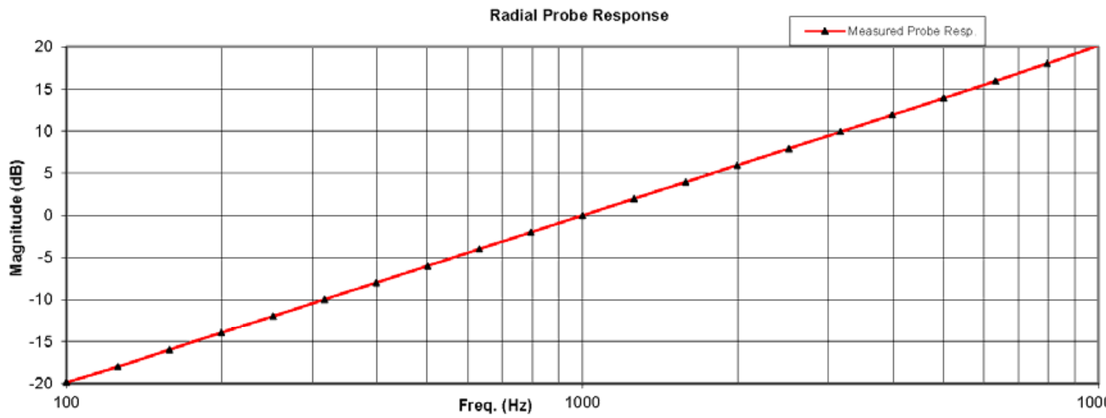
Helmholtz Coil;					
the number of turns on each coil;	10	No.	Laboratory Environment:		
the radius of each coil, in meters;	0.204	m			
the current in the coils, in amperes.;	0.09	A	Ambient Temperature:	20.2	ºC
Helmholtz Coil Constant;	7.09	A/m/V	Ambient Humidity:	31.4	% RH
Helmholtz Coil magnetic field;	5.98	A/m	Ambient Pressure:	99.1	kPa
			Calibration Date:	7-Dec-16	
Probe Sensitivity at	1000	Hz.			
was	-60.27	dBV/A/m	Report Number:	27068	-2
	0.969	mV/A/m	Control Number:	27068	
Probe resistance	902	Ohms			

The above listed instrument meets or exceeds the tested manufacturer's specifications.

This Calibration is traceable through NIST test numbers: 683/284413-14

The expanded uncertainty of calibration: 0.30dB at 95% confidence level with a coverage factor of k=2.

Graph represents Probes Frequency Response.



The above listed instrument was checked using calibration procedure documented in West Caldwell Calibration Laboratories Inc. procedure : **Rev. 7.0 Jan. 24, 2014 Doc. # 1038 HCRTEMC**

Calibration was performed by West Caldwell Calibration Laboratories Inc. under Operating Procedures intended to implement the requirements of ISO10012-1, IEC Guide 25, ANSI/NCSL Z540-1, (MIL-STD-45662A) and ISO 9001:2008, ISO 17025

Cal. Date: 7-Dec-2016

Calibrated on WCCL system type 9700

Measurements performed by: FC

Felix Christopher

Rev. 7.0 Jan. 24, 2014 Doc. # 1038 HCRTEMC

Page 1 of 2

West Caldwell Calibration Laboratories Inc.
1575 State Route 96, Victor NY 14564
Tel. (585) 586-3900 FAX (585) 586-4327

Calibration Data Record

for

TEM Consulting LP Radial T Coil Probe **Model No.: Radial T Coil Probe** **Serial No.: TEM-1130**

Company : PCTEST Engineering Lab.

Test	Function		Tolerance	Measured values: Before	Out	Remarks
1.0	Probe Sensitivity at	1000 Hz.	dBV/A/m	-60.27		
			dB			
2.0	Probe Level Linearity		6	6.03		
		Ref. (0 dB)	0	0.00		
			-6	-6.03		
			-12	-12.06		
			Hz			
3.0	Probe Frequency Response		100	-19.9		
			126	-18.0		
			158	-16.0		
			200	-13.9		
			251	-12.0		
			316	-10.0		
			398	-8.0		
			501	-6.0		
			631	-4.0		
			794	-2.0		
		Ref. (0 dB)	1000	0.0		
			1259	2.0		
			1585	4.0		
			1995	6.0		
			2512	7.9		
			3162	9.9		
			3981	11.9		
			5012	13.9		
			6310	15.9		
			7943	18.0		
			10000	20.2		

Instruments used for calibration:			Date of Cal.	Traceability No.	Due Date
HP	34401A	S/N 36064102	1-Oct-2016	,287708	1-Oct-2017
HP	34401A	S/N 36102471	1-Oct-2016	,287708	1-Oct-2017
HP	33120A	S/N 36043716	1-Oct-2016	,287708	1-Oct-2017
B&K	2133	S/N 1583254	1-Oct-2016	683/284413-14	1-Oct-2017

Cal. Date: 7-Dec-2016 Tested by: Felix Christopher

Calibrated on WCCL system type 9700

Rev. 7.0 Jan. 24, 2014 Doc. # 1038 HCRTEMC

12. CONCLUSION

The measurements indicate that the wireless communications device complies with the HAC limits specified in accordance with the ANSI C63.19 Standard and FCC WT Docket No. 01-309 RM-8658. Precise laboratory measures were taken to assure repeatability of the tests. The tested device complies with the requirements in respect to all parameters specific to the test. The test results and statements relate only to the item(s) tested.

The measurement system and techniques presented in this evaluation are proposed in the ANSI standard as a means of best approximating wireless device compatibility with a hearing-aid. The literature is under continual re-construction.

13. REFERENCES

1. ANSI C63.19-2011, American National Standard for Methods of Measurement of Compatibility between Wireless communication devices and Hearing Aids.", New York, NY, IEEE, May 2011

2. FCC Office of Engineering and Technology KDB, "285076 D01 HAC Guidance v05," September 13, 2017

3. FCC Office of Engineering and Technology KDB, "285076 D02 T-Coil Testing for CMRS IP v03," September 13, 2017

4. FCC Public Notice DA 06-1215, *Wireless Telecommunications Bureau and Office of Engineering and Technology Clarify Use of Revised Wireless Phone Hearing Aid Compatibility Standard*, June 6, 2006

5. FCC 3G Review Guidance, Laboratory Division OET FCC, May/June 2006

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