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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:
08/09/2021
Test Site/Location:
PCTEST, Columbia, MD, USA
Test Report Serial No.:
1M2107130081-01.A3L
Date of Issue:
08/10/2021

FCC ID:	**A3LSMG998U**
APPLICANT:	**SAMSUNG ELECTRONICS CO., LTD.**

Scope of Test:	Audio Band Magnetic Testing (T-Coil)
Application Type:	Class II Permissive Change
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-G998U
Additional Model(s):	SM-G998U1
Test Device Serial No.:	*Pre-Production Sample* [S/N: 0766M]
Class II Permissive Change(s):	See FCC change documents.

C63.19-2011 HAC Category:	**T3 (SIGNAL TO NOISE CATEGORY; VoNR over IMS Only)**

This report only pertains to VoNR over IMS. This wireless portable device has been shown to be hearing-aid compatible with VoNR over IMS, under the above rated category, specified in ANSI/IEEE Std. C63.19-2011 and has been tested in accordance with the specified measurement procedures. The overall category rating of the device is determined by the lowest rating obtained over all air interfaces supported by the device. 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
CERT #2041.01

REV 3.5.M
8/18/2020

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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-situ*

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

2. DUT DESCRIPTION

FCC ID:	A3LSMG998U
Applicant:	Samsung Electronics Co., Ltd. 129, Samsung-ro, Maetan dong, Yeongtong-gu, Suwon-si Gyeonggi-do 16677, Korea
Model:	SM-G998U
Additional Model(s):	SM-G998U1
Serial Number:	0766M
HW Version:	Rev1.0
SW Version:	G998USQU4AUFG
Antenna:	Internal Antenna
DUT Type:	Portable Handset

I. NR Band Selection

This device supports NR FR1 capabilities with overlapping transmission frequency ranges. When the supported frequency range of an NR Band falls completely within an NR band with a larger transmission frequency range, both NR bands have the same target power (or the band with the larger transmission frequency range has a higher target power), and both NR bands share the same transmission path and signal characteristics, HAC was only assessed for the band with the larger transmission frequency range.

Table 2-1
A3LSMG998U HAC Air Interfaces

Air-Interface	Band (MHz)	Type Transport	HAC Tested	Simultaneous But Not Tested	Name of Voice Service	Audio Codec Evaluated
CDMA	835	VO	No[4]	Yes: WIFI or BT	CMRS Voice[1]	EVRC
	1900					
	EvDO	VD	No[4]	Yes: WIFI or BT	Google Duo[2]	OPUS
GSM	850	VO	No[4]	Yes: WIFI or BT	CMRS Voice[1]	EFR
	1900					
	GPRS/EDGE	VD	No[4]	Yes: WIFI or BT	Google Duo[2]	OPUS
UMTS	850	VD	No[4]	Yes: WIFI or BT	CMRS Voice[1]	NB AMR
	1700					
	1900					
	HSPA	VD	No[4]	Yes: WIFI or BT	Google Duo[2]	OPUS
LTE (FDD)	680 (B71)	VD	No[4]	Yes: NR, WIFI, or BT	VoLTE[1], Google Duo[2]	VoLTE: NB AMR, WB AMR, EVS Google Duo: OPUS
	700 (B12)					
	780 (B13)					
	790 (B14)					
	850 (B5)					
	850 (B26)					
	1700 (B4)					
	1700 (B66)					
	1900 (B2)					
	1900 (B25)					
	2300 (B30)					
	2500 (B7)					
LTE (TDD)	2600 (B38)	VD	No[4]	Yes: NR, WIFI, or BT	VoLTE[1], Google Duo[2]	VoLTE: NB AMR, WB AMR, EVS Google Duo: OPUS
	2600 (B41)					
	3600 (B48)					
NR (FDD)	680 (n71)	VD	Yes[3,4]	Yes: LTE, WIFI, or BT	VoNR[2], Google Duo[2]	VoNR: NB AMR, WB AMR, EVS Google Duo: OPUS
	700 (n12)		Yes[4]			
	850 (n5)					
	1700 (n66)					
	1900 (n2)					
	1900 (n25)					
	2300 (n30)					
NR (TDD)	2600 (n41)	VD	Yes[4]	Yes: LTE, WIFI, or BT	VoNR[2], Google Duo[2]	VoNR: NB AMR, WB AMR, EVS Google Duo: OPUS
	3800 (n77)					
	28000 (n261)		No[4]		Google Duo[2]	Google Duo: OPUS
	39000 (n260)					
WIFI	2450	VD	No[4]	Yes: CDMA, GSM, UMTS, LTE, or NR	VoWIFI[2], Google Duo[2]	VoWIFI: NB AMR, WB AMR, EVS Google Duo: OPUS
	5200 (U-NII 1)					
	5300 (U-NII 2A)					
	5500 (U-NII 2C)					
	5800 (U-NII 3)					
	6175 (U-NII 5)					
	6475 (U-NII 6)					
	6700 (U-NII 7)					
	7000 (U-NII 8)					
BT	2450	DT	No	Yes: CDMA, GSM, UMTS, LTE, or NR	N/A	N/A

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

Notes:
1. Reference level in accordance with 7.4.2.1 of ANSI C63.19-2011 and July 2012 C63 VoLTE Interpretation.
2. Reference level is -20dBm0 in accordance with FCC KDB 285076 D02
3. NR n71, while outside the scope of ANSI C63.19 and FCC HAC regulations, was additionally tested according to the existing HAC procedures with currently available test equipment.
4. This report only pertains to NR n71/n12/n5/n66/n2/n25/n30/n41/n77 with VoNR over IMS. For full data, please refer to the Original Certification Test Report (Report S/N: 1M2009230152-21-R2.A3L).

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.

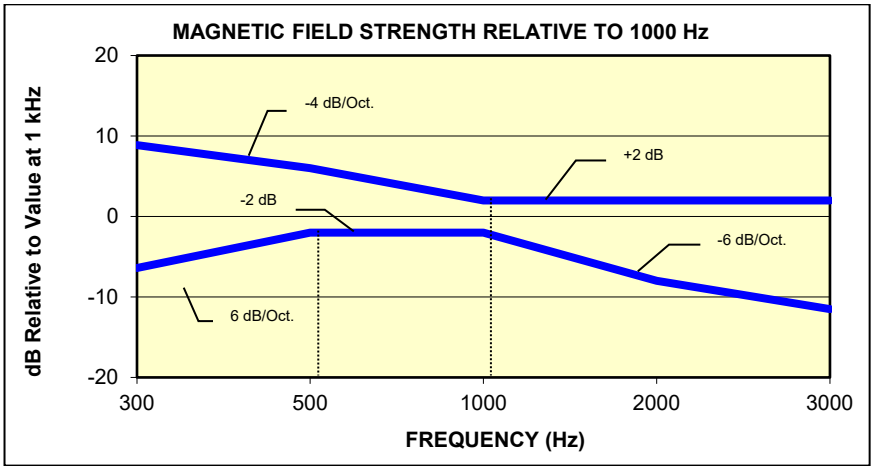


Figure 3-1
Magnetic field frequency response for Wireless Devices with an axial field ≤-15 dB(A/m) at 1 kHz

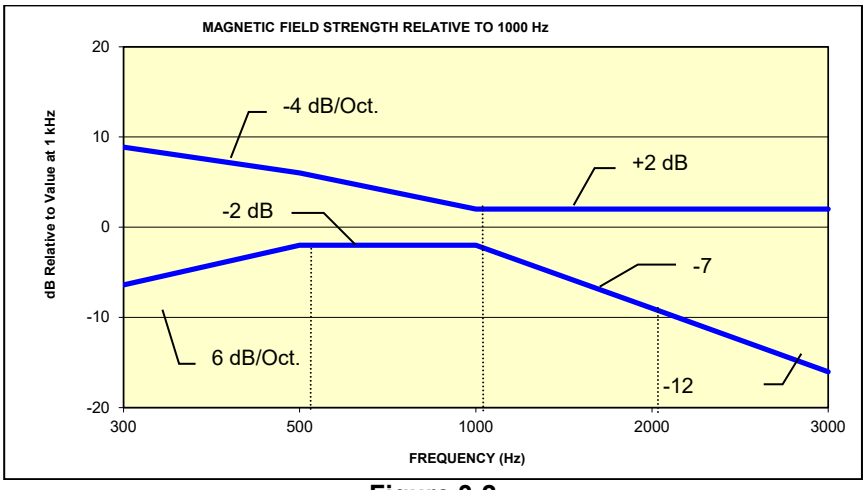


Figure 3-2
Magnetic Field frequency response for wireless devices with an axial field that exceeds -15 dB(A/m) at 1 kHz

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:

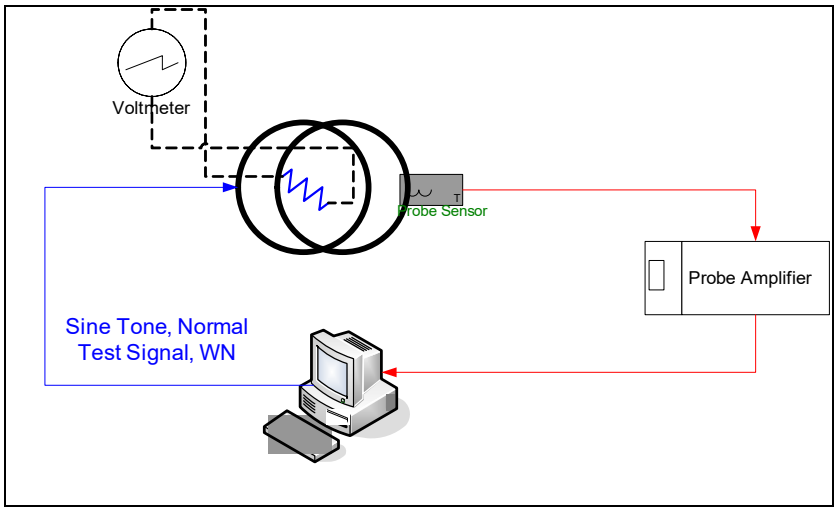


Figure 4-1
Validation Setup with Helmholtz Coil

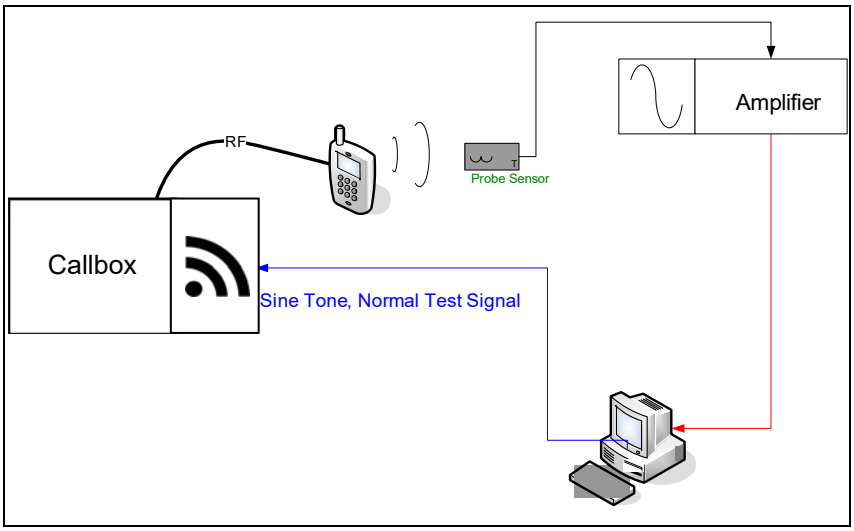


Figure 4-2
T-Coil Test Setup

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)

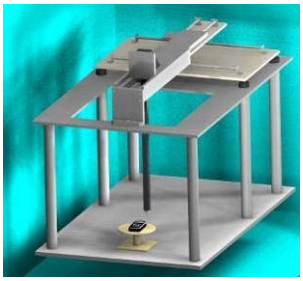


Figure 4-3
RF Near-Field Scanner

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%

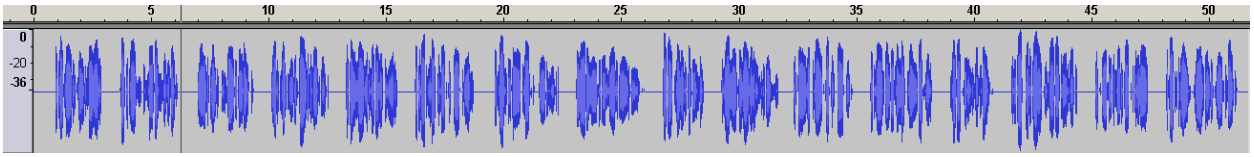
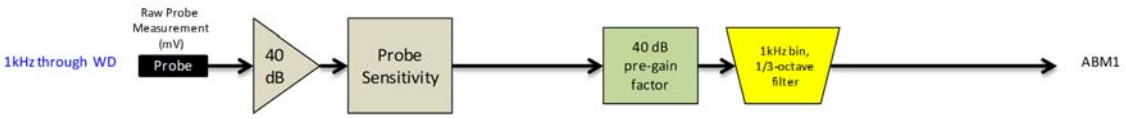


Figure 4-4
Temporal Characteristic of Normal Test Signal

ABM1 Measurement Block Diagram:



ABM2 Measurement Block Diagram:

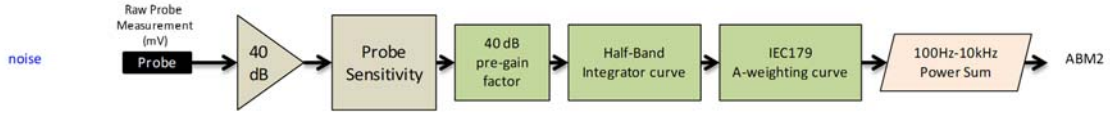


Figure 4-5 Magnetic Measurement Processing Steps

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 24).

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:

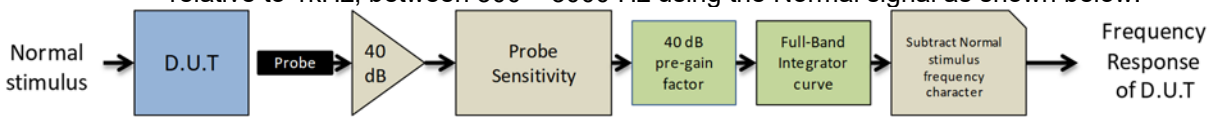


Figure 4-6 Frequency Response Validation

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

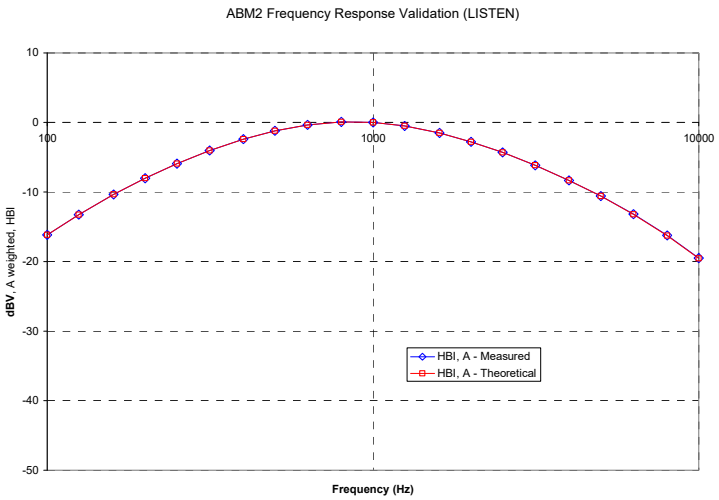


Figure 4-7
ABM2 Frequency Response Validation

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:

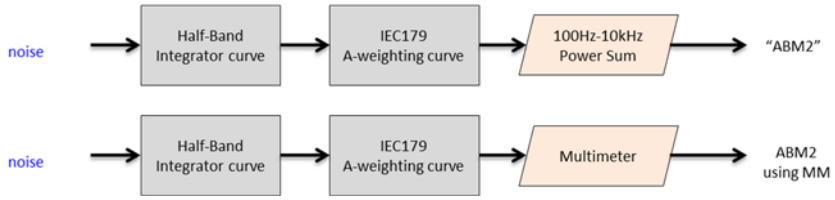


Figure 4-8
ABM2 Validation Block Diagram

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

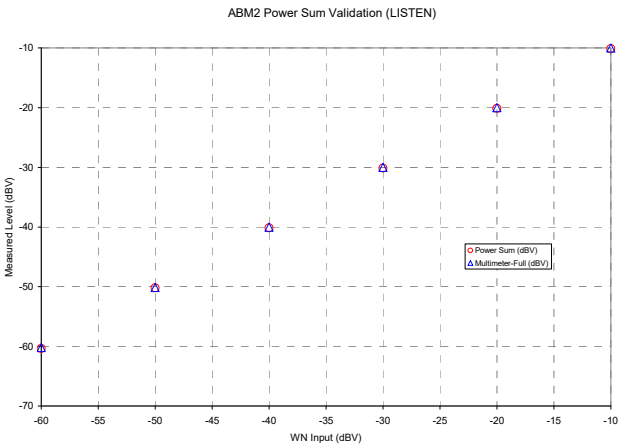


Figure 4-9
ABM2 Power Sum Validation

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):

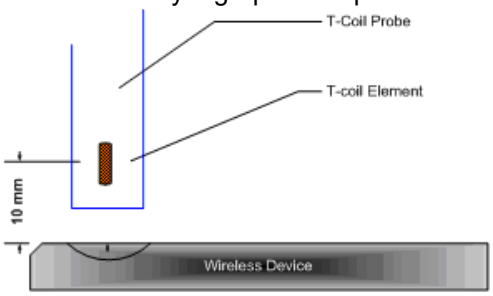


Figure 4-10
Measurement Distance

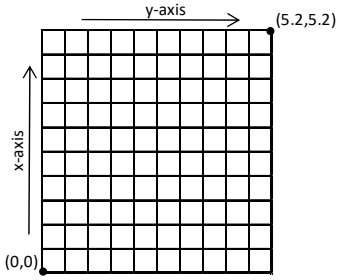


Figure 4-11
Measurement Grid

        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 4-13 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 Voice Over NR (VoNR).

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 (NR configuration information can be found in Section 5).

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

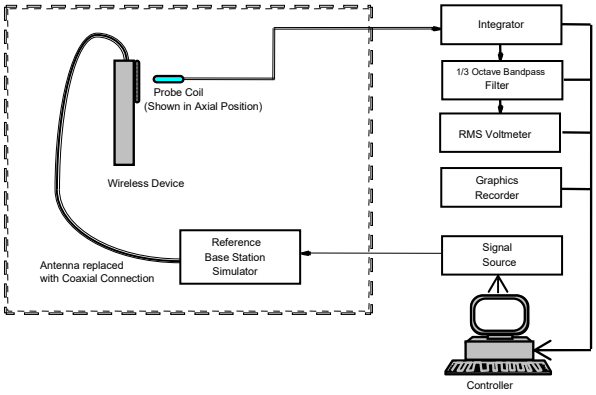


Figure 4-12
Audio Magnetic Field Test Setup

Environmental conditions such as temperature and relative humidity are monitored to ensure there are no impacts on system specifications. Proper voltage and power line frequency conditions are maintained with three phase power sources. Environmental noise and reflections are monitored through system checks.

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. See Table 2-1 for more details regarding which modes were tested.

VIII. Wireless Device Channels and Frequencies

1. 5G (NR) Modes

The middle channel for every band and bandwidth combination was tested for each probe orientation. The band and bandwidth combination from each probe orientation resulting in the worst-case SNNR was additionally tested using low and high channels for that band and bandwidth combination. Low-mid and mid-high channels are additionally tested for NR TDD. See Tables 6-2 to 6-9 for NR bandwidths and channels.

IX. Test Flow

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

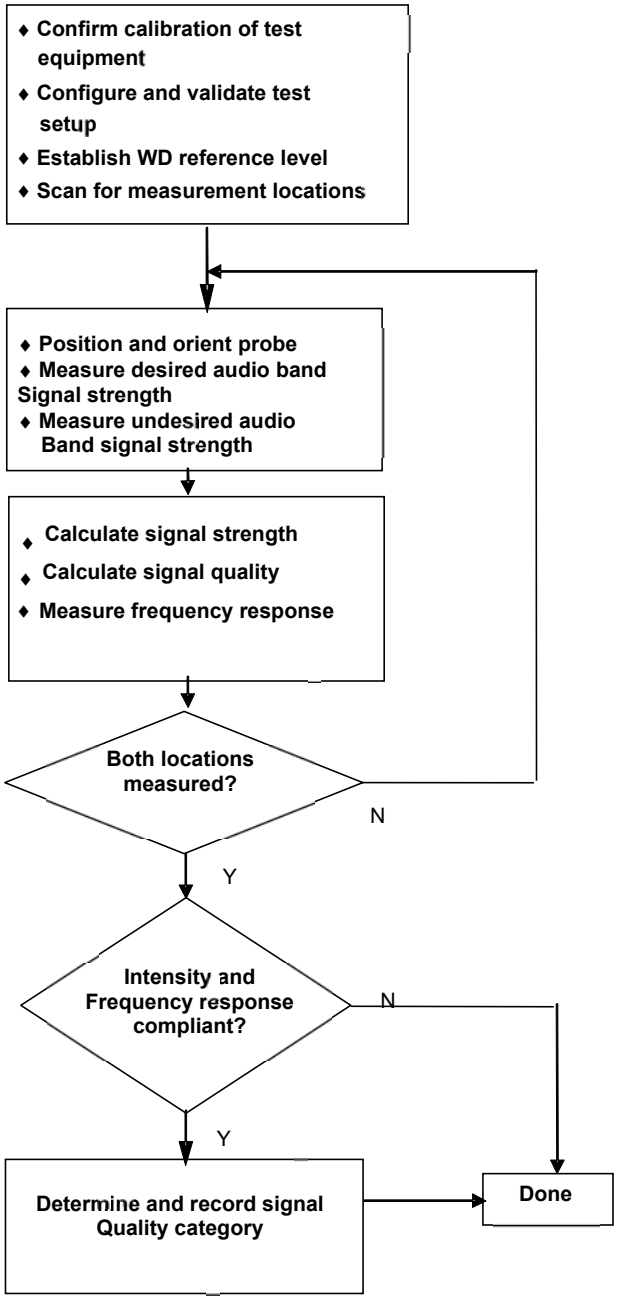


Figure 4-13
C63.19 T-Coil Signal Test Process

5. VONR TEST SYSTEM SETUP AND DUT CONFIGURATION

I. Test System Setup for VoNR over IMS T-coil Testing

1. Equipment Setup

The general test setup used for VoNR over IMS is shown below. The callboxes used when performing VoNR over IMS T-coil measurements are CMW500 and CMX500. The Data Application Unit (DAU) of the CMW500 was used to simulate the IP Multimedia Subsystem (IMS) server. The CMX500 provided the baseband signal to perform NR signaling. An external USB audio interface is used to perform the A/D conversion and ensure proper speech input level to the DUT.

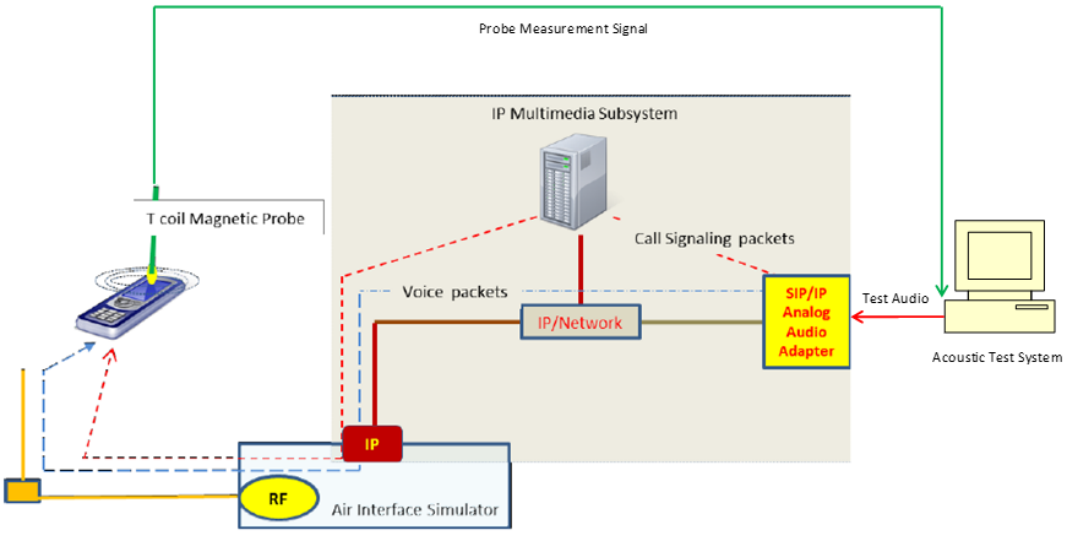


Figure 5-1
Test Setup for VoNR over IMS T-Coil Measurements

2. Audio Level Settings

According to KDB 285076 D02 released by the FCC OET regarding the appropriate audio levels to be used for VoNR over IMS T-Coil testing, -20dBm0 shall be used for the normal speech input level[2]. The acoustic test system was manually configured to ensure that the settings for speech input and full scale levels resulted in the -20dBm0 speech input level to the DUT for the VoNR over IMS connection.

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

II. DUT Configuration for VoNR over IMS T-coil Testing

1. Radio Configuration

An investigation was performed to determine the waveform, modulation, and RB configuration to be used for testing. The effects of waveform, modulation, and RB configuration were found to be independent of band and bandwidth; therefore, only one band and bandwidth were used for this investigation. DFT-s-OFDM, 16QAM, 50%RB, 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 5-1
VoNR over IMS SNNR by Radio Configuration (CP-OFDM)

Band	Frequency [MHz]	Channel	Bandwidth [MHz]	Waveform	Modulation	RB Size	RB Offset	ABM1 [dB(A/m)]	ABM2 [dB(A/m)]	SNNR [dB]
n77	3840.0	656000	100	CP-OFDM	QPSK	1	1	-6.19	-45.11	38.92
n77	3840.0	656000	100	CP-OFDM	QPSK	1	135	-6.13	-45.28	39.15
n77	3840.0	656000	100	CP-OFDM	QPSK	1	271	-6.24	-45.66	39.42
n77	3840.0	656000	100	CP-OFDM	QPSK	135	0	-6.09	-45.59	39.50
n77	3840.0	656000	100	CP-OFDM	QPSK	135	68	-6.04	-45.64	39.60
n77	3840.0	656000	100	CP-OFDM	QPSK	135	138	-6.34	-45.11	38.77
n77	3840.0	656000	100	CP-OFDM	QPSK	270	0	-6.20	-45.29	39.09
n77	3840.0	656000	100	CP-OFDM	16QAM	1	1	-6.26	-45.43	39.17
n77	3840.0	656000	100	CP-OFDM	16QAM	1	135	-5.90	-45.78	39.88
n77	3840.0	656000	100	CP-OFDM	16QAM	1	271	-6.10	-45.04	38.94
n77	3840.0	656000	100	CP-OFDM	16QAM	135	0	-6.34	-45.13	38.79
n77	3840.0	656000	100	CP-OFDM	16QAM	135	68	-6.29	-45.64	39.35
n77	3840.0	656000	100	CP-OFDM	16QAM	135	138	-6.14	-45.58	39.44
n77	3840.0	656000	100	CP-OFDM	16QAM	270	0	-6.01	-45.61	39.60
n77	3840.0	656000	100	CP-OFDM	64QAM	1	1	-6.36	-45.74	39.38
n77	3840.0	656000	100	CP-OFDM	64QAM	1	135	-6.17	-45.61	39.44
n77	3840.0	656000	100	CP-OFDM	64QAM	1	271	-6.32	-45.53	39.21
n77	3840.0	656000	100	CP-OFDM	64QAM	135	0	-6.25	-45.18	38.93
n77	3840.0	656000	100	CP-OFDM	64QAM	135	68	-6.18	-45.71	39.53
n77	3840.0	656000	100	CP-OFDM	64QAM	135	138	-6.16	-45.79	39.63
n77	3840.0	656000	100	CP-OFDM	64QAM	270	0	-5.94	-45.51	39.57
n77	3840.0	656000	100	CP-OFDM	256QAM	1	1	-6.17	-45.96	39.79
n77	3840.0	656000	100	CP-OFDM	256QAM	1	135	-5.96	-45.69	39.73
n77	3840.0	656000	100	CP-OFDM	256QAM	1	271	-6.18	-45.90	39.72
n77	3840.0	656000	100	CP-OFDM	256QAM	135	0	-6.19	-45.30	39.11
n77	3840.0	656000	100	CP-OFDM	256QAM	135	68	-6.10	-45.79	39.69
n77	3840.0	656000	100	CP-OFDM	256QAM	135	138	-5.99	-45.85	39.86
n77	3840.0	656000	100	CP-OFDM	256QAM	270	0	-6.23	-45.96	39.73

Table 5-2
VoNR over IMS SNNR by Radio Configuration (DFT-s-OFDM)

Band	Frequency [MHz]	Channel	Bandwidth [MHz]	Waveform	Modulation	RB Size	RB Offset	ABM1 [dB(A/m)]	ABM2 [dB(A/m)]	SNNR [dB]
n77	3840.0	656000	100	DFT-s-OFDM	π/2-BPSK	1	1	-6.30	-45.52	39.22
n77	3840.0	656000	100	DFT-s-OFDM	π/2-BPSK	1	135	-6.23	-45.64	39.41
n77	3840.0	656000	100	DFT-s-OFDM	π/2-BPSK	1	271	-5.94	-45.43	39.49
n77	3840.0	656000	100	DFT-s-OFDM	π/2-BPSK	135	0	-6.27	-46.03	39.76
n77	3840.0	656000	100	DFT-s-OFDM	π/2-BPSK	135	68	-6.20	-45.94	39.74
n77	3840.0	656000	100	DFT-s-OFDM	π/2-BPSK	135	138	-6.43	-46.03	39.60
n77	3840.0	656000	100	DFT-s-OFDM	π/2-BPSK	270	0	-6.28	-45.51	39.23
n77	3840.0	656000	100	DFT-s-OFDM	QPSK	1	1	-6.35	-45.49	39.14
n77	3840.0	656000	100	DFT-s-OFDM	QPSK	1	135	-5.97	-45.97	40.00
n77	3840.0	656000	100	DFT-s-OFDM	QPSK	1	271	-5.97	-45.34	39.37
n77	3840.0	656000	100	DFT-s-OFDM	QPSK	135	0	-6.30	-45.29	38.99
n77	3840.0	656000	100	DFT-s-OFDM	QPSK	135	68	-5.99	-46.03	40.04
n77	3840.0	656000	100	DFT-s-OFDM	QPSK	135	138	-6.09	-45.78	39.69
n77	3840.0	656000	100	DFT-s-OFDM	QPSK	270	0	-6.27	-45.31	39.04
n77	3840.0	656000	100	DFT-s-OFDM	16QAM	1	1	-6.29	-45.22	38.93
n77	3840.0	656000	100	DFT-s-OFDM	16QAM	1	135	-5.91	-45.56	39.65
n77	3840.0	656000	100	DFT-s-OFDM	16QAM	1	271	-6.24	-45.78	39.54
n77	3840.0	656000	100	DFT-s-OFDM	16QAM	135	0	-6.35	-44.98	**38.63**
n77	3840.0	656000	100	DFT-s-OFDM	16QAM	135	68	-6.21	-45.76	39.55
n77	3840.0	656000	100	DFT-s-OFDM	16QAM	135	138	-6.28	-45.14	38.86
n77	3840.0	656000	100	DFT-s-OFDM	16QAM	270	0	-6.34	-45.59	39.25
n77	3840.0	656000	100	DFT-s-OFDM	64QAM	1	1	-5.95	-45.64	39.69
n77	3840.0	656000	100	DFT-s-OFDM	64QAM	1	135	-5.93	-45.45	39.52
n77	3840.0	656000	100	DFT-s-OFDM	64QAM	1	271	-6.28	-45.53	39.25
n77	3840.0	656000	100	DFT-s-OFDM	64QAM	135	0	-6.21	-45.65	39.44
n77	3840.0	656000	100	DFT-s-OFDM	64QAM	135	68	-6.41	-45.36	38.95
n77	3840.0	656000	100	DFT-s-OFDM	64QAM	135	138	-6.18	-45.68	39.50
n77	3840.0	656000	100	DFT-s-OFDM	64QAM	270	0	-6.00	-45.70	39.70
n77	3840.0	656000	100	DFT-s-OFDM	256QAM	1	1	-5.95	-45.26	39.31
n77	3840.0	656000	100	DFT-s-OFDM	256QAM	1	135	-6.24	-45.63	39.39
n77	3840.0	656000	100	DFT-s-OFDM	256QAM	1	271	-6.09	-45.76	39.67
n77	3840.0	656000	100	DFT-s-OFDM	256QAM	135	0	-6.25	-45.23	38.98
n77	3840.0	656000	100	DFT-s-OFDM	256QAM	135	68	-6.20	-45.35	39.15
n77	3840.0	656000	100	DFT-s-OFDM	256QAM	135	138	-6.10	-45.37	39.27
n77	3840.0	656000	100	DFT-s-OFDM	256QAM	270	0	-6.16	-45.86	39.70

2. Codec Configuration

An investigation was performed to determine the audio codec configuration to be used for testing. The effects of codec configuration were found to be independent of radio configuration; therefore, only one radio configuration was used for this investigation. The NB AMR NB 4.75kbps setting was used for the audio codec on the CMW500 for VoNR over IMS T-coil testing. See below table for comparisons between different codecs and codec data rates:

Table 5-3
AMR Codec Investigation – VoNR over IMS

Codec Setting:	WB AMR 23.85kbps	WB AMR 6.60kbps	NB AMR 12.2kbps	NB AMR 4.75kbps	Orientation	Band / BW	Channel
ABM1 (dBA/m)	0.53	-0.44	-5.74	-5.94	Axial	NR n5 20MHz	167300
ABM2 (dBA/m)	-52.89	-53.43	-54.12	-52.24			
Frequency Response	Pass	Pass	Pass	Pass			
S+N/N (dB)	53.42	52.99	48.38	**46.30**			

- Mute on; Backlight off; Max Volume; Max Contrast
- TPC = “Max Power”

Table 5-4
EVS Codec Investigation - VoNR over IMS

Codec Setting:	EVS Primary SWB 128kbps	EVS Primary SWB 9.6kbps	EVS Primary WB 128kbps	EVS Primary WB 5.9kbps	EVS Primary NB 24.4kbps	EVS Primary NB 5.9kbps	Orientation	Band / BW	Channel
ABM1 (dBA/m)	2.60	1.89	0.86	0.56	-5.53	-5.36	Axial	NR n5 20MHz	167300
ABM2 (dBA/m)	-53.94	-53.87	-53.73	-52.79	-52.12	-53.42			
Frequency Response	Pass	Pass	Pass	Pass	Pass	Pass			
S+N/N (dB)	56.54	55.76	54.59	53.35	46.59	48.06			

- Mute on; Backlight off; Max Volume; Max Contrast
- TPC = “Max Power”

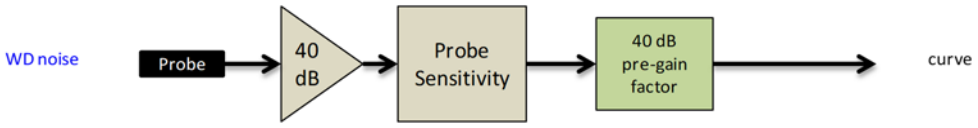


Figure 5-2
Audio Band Magnetic Curve Measurement Block Diagram

6. T-COIL TEST SUMMARY

Table 6-1
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		
NR FDD	n71	PASS	NA	PASS	PASS	PASS	PASS	-11.18	T4
	n12	PASS	NA	PASS	PASS	PASS	PASS		
	n5	PASS	NA	PASS	PASS	PASS	PASS		
	n66	PASS	NA	PASS	PASS	PASS	PASS		
	n25	PASS	NA	PASS	PASS	PASS	PASS		
	n30	PASS	NA	PASS	PASS	PASS	PASS		
NR TDD	n41 (PC2)	PASS	NA	PASS	PASS	PASS	PASS	-5.12	T3
	n77 (PC2)	PASS	NA	PASS	PASS	PASS	PASS		

I. Raw Handset Data

Table 6-2
Raw Data Results for NR n71

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
NR n71	Axial	20MHz	136100	-6.35	-53.35	-61.46	2.00	47.00	20.00	-27.00	T4	1.4, 1.2
		15MHz	136100	-6.02	-53.04		2.00	47.02	20.00	-27.02	T4	
		10MHz	136100	-6.25	-53.13		2.00	46.88	20.00	-26.88	T4	
		5MHz	136100	-6.11	-52.92		2.00	46.81	20.00	-26.81	T4	
	Radial	20MHz	136100	-13.61	-46.86	-61.70	N/A	33.25	20.00	-13.25	T4	1.4, 0.4
		15MHz	136100	-13.35	-46.70			33.35	20.00	-13.35	T4	
		10MHz	136100	-13.58	-46.81			33.23	20.00	-13.23	T4	
		5MHz	136100	-13.68	-46.82			33.14	20.00	-13.14	T4	

Table 6-3
Raw Data Results for NR n12

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
NR n12	Axial	15MHz	141500	-6.02	-53.83	-61.46	2.00	47.81	20.00	-27.81	T4	1.4, 1.2
		10MHz	141500	-6.17	-52.89		2.00	46.72	20.00	-26.72	T4	
		5MHz	141500	-6.14	-53.14		2.00	47.00	20.00	-27.00	T4	
	Radial	15MHz	141500	-13.78	-46.18	-61.70	N/A	32.40	20.00	-12.40	T4	1.4, 0.4
		10MHz	141500	-13.75	-46.58			32.83	20.00	-12.83	T4	
		5MHz	141500	-13.49	-46.85			33.36	20.00	-13.36	T4	

Table 6-4
Raw Data Results for NR n5

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
NR n5	Axial	20MHz	167300	-6.15	-52.59	-61.46	2.00	46.44	20.00	-26.44	T4	1.4, 1.2
		15MHz	167300	-6.05	-52.87		2.00	46.82	20.00	-26.82	T4	
		10MHz	167300	-6.31	-52.39		2.00	46.08	20.00	-26.08	T4	
		5MHz	167300	-6.28	-52.63		2.00	46.35	20.00	-26.35	T4	
	Radial	20MHz	167300	-13.33	-46.93	-61.70	N/A	33.60	20.00	-13.60	T4	1.4, 0.4
		15MHz	167300	-13.41	-46.73			33.32	20.00	-13.32	T4	
		10MHz	167300	-13.71	-46.69			32.98	20.00	-12.98	T4	
		5MHz	167300	-13.70	-46.97			33.27	20.00	-13.27	T4	

Table 6-5
Raw Data Results for NR n66

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
NR n66	Axial	40MHz	352000	-6.41	-50.33	-61.46	2.00	43.92	20.00	-23.92	T4	1.4, 1.2
		40MHz	349000	-6.28	-50.30		2.00	44.02	20.00	-24.02	T4	
		40MHz	346000	-6.45	-51.90		2.00	45.45	20.00	-25.45	T4	
		30MHz	349000	-6.12	-51.92		2.00	45.80	20.00	-25.80	T4	
		20MHz	349000	-6.41	-51.82		2.00	45.41	20.00	-25.41	T4	
		15MHz	349000	-6.42	-51.63		2.00	45.21	20.00	-25.21	T4	
		10MHz	349000	-6.08	-50.76		2.00	44.68	20.00	-24.68	T4	
		5MHz	349000	-6.49	-52.69		2.00	46.20	20.00	-26.20	T4	
	Radial	40MHz	349000	-13.60	-45.87	-61.70	N/A	32.27	20.00	-12.27	T4	1.4, 0.4
		30MHz	353000	-13.42	-44.60			31.18	20.00	-11.18	T4	
		30MHz	349000	-13.59	-45.44			31.85	20.00	-11.85	T4	
		30MHz	345000	-13.63	-46.30			32.67	20.00	-12.67	T4	
		20MHz	349000	-13.88	-45.79			31.91	20.00	-11.91	T4	
		15MHz	349000	-13.38	-46.43			33.05	20.00	-13.05	T4	
		10MHz	349000	-13.36	-46.15			32.79	20.00	-12.79	T4	
		5MHz	349000	-13.63	-46.32			32.69	20.00	-12.69	T4	

Table 6-6
Raw Data Results for NR n25

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
NR n25	Axial	40MHz	376500	-6.30	-52.61	-61.46	2.00	46.31	20.00	-26.31	T4	1.4, 1.2
		30MHz	376500	-6.40	-52.78		2.00	46.38	20.00	-26.38	T4	
		25MHz	376500	-6.10	-52.16		2.00	46.06	20.00	-26.06	T4	
		20MHz	376500	-6.10	-51.91		2.00	45.81	20.00	-25.81	T4	
		15MHz	376500	-6.33	-51.56		2.00	45.23	20.00	-25.23	T4	
		10MHz	376500	-6.34	-51.93		2.00	45.59	20.00	-25.59	T4	
		5MHz	376500	-6.17	-53.74		2.00	47.57	20.00	-27.57	T4	
	Radial	40MHz	376500	-13.63	-46.40	-61.70	N/A	32.77	20.00	-12.77	T4	1.4, 0.4
		30MHz	376500	-13.47	-46.44			32.97	20.00	-12.97	T4	
		25MHz	376500	-13.49	-45.88			32.39	20.00	-12.39	T4	
		20MHz	376500	-13.67	-46.47			32.80	20.00	-12.80	T4	
		15MHz	376500	-13.39	-46.46			33.07	20.00	-13.07	T4	
		10MHz	376500	-13.45	-46.48			33.03	20.00	-13.03	T4	
		5MHz	376500	-13.64	-46.47			32.83	20.00	-12.83	T4	

Table 6-7
Raw Data Results for NR n30

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
NR n30	Axial	10MHz	462000	-6.24	-53.67	-61.46	2.00	47.43	20.00	-27.43	T4	1.4, 1.2
		5MHz	462000	-6.53	-52.47		2.00	45.94	20.00	-25.94	T4	
	Radial	10MHz	462000	-13.39	-45.76	-61.70	N/A	32.37	20.00	-12.37	T4	1.4, 0.4
		5MHz	462000	-13.48	-45.47			31.99	20.00	-11.99	T4	

Table 6-8
Raw Data Results for NR n41 Power Class 2

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
NR n41 (PC2)	Axial	100MHz	518598	-6.39	-43.71	-61.46	2.00	37.32	20.00	-17.32	T4	1.4, 1.2
		90MHz	518598	-6.14	-44.58		2.00	38.44	20.00	-18.44	T4	
		80MHz	518598	-6.56	-44.77		2.00	38.21	20.00	-18.21	T4	
		60MHz	518598	-6.17	-44.85		2.00	38.68	20.00	-18.68	T4	
		50MHz	518598	-6.36	-44.98		2.00	38.62	20.00	-18.62	T4	
		40MHz	518598	-6.06	-45.44		2.00	39.38	20.00	-19.38	T4	
		30MHz	518598	-6.40	-45.61		2.00	39.21	20.00	-19.21	T4	
		20MHz	518598	-6.13	-45.60		2.00	39.47	20.00	-19.47	T4	
	Radial	100MHz	518598	-13.62	-39.00	-61.70	N/A	25.38	20.00	-5.38	T3	1.4, 0.4
		90MHz	528996	-13.28	-39.20			25.92	20.00	-5.92	T3	
		90MHz	523800	-13.22	-39.02			25.80	20.00	-5.80	T3	
		90MHz	518598	-13.54	-38.72			25.18	20.00	-5.18	T3	
		90MHz	513402	-13.20	-38.86			25.66	20.00	-5.66	T3	
		90MHz	508200	-13.53	-38.65			25.12	20.00	-5.12	T3	
		80MHz	518598	-13.65	-38.88			25.23	20.00	-5.23	T3	
		60MHz	518598	-13.70	-39.25			25.55	20.00	-5.55	T3	
		50MHz	518598	-13.66	-40.50			26.84	20.00	-6.84	T3	
		40MHz	518598	-13.63	-40.77			27.14	20.00	-7.14	T3	
		30MHz	518598	-13.88	-40.96			27.08	20.00	-7.08	T3	
		20MHz	518598	-13.41	-40.51			27.10	20.00	-7.10	T3	

Table 6-9
Raw Data Results for NR n77 Power Class 2

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
NR n77 (PC2)	Axial	100MHz	662000	-6.45	-44.79	-61.46	2.00	38.34	20.00	-18.34	T4	1.4, 1.2
		100MHz	659000	-6.40	-44.73		2.00	38.33	20.00	-18.33	T4	
		100MHz	656000	-6.45	-43.33		2.00	36.88	20.00	-16.88	T4	
		100MHz	653000	-6.14	-44.64		2.00	38.50	20.00	-18.50	T4	
		100MHz	650000	-6.38	-45.23		2.00	38.85	20.00	-18.85	T4	
		90MHz	656000	-6.37	-44.55		2.00	38.18	20.00	-18.18	T4	
		80MHz	656000	-6.34	-45.63		2.00	39.29	20.00	-19.29	T4	
		70MHz	656000	-6.25	-45.19		2.00	38.94	20.00	-18.94	T4	
		60MHz	656000	-6.41	-45.79		2.00	39.38	20.00	-19.38	T4	
		50MHz	656000	-6.46	-45.61		2.00	39.15	20.00	-19.15	T4	
		40MHz	656000	-6.06	-46.36		2.00	40.30	20.00	-20.30	T4	
		30MHz	656000	-6.38	-46.47		2.00	40.09	20.00	-20.09	T4	
		20MHz	656000	-6.30	-46.40		2.00	40.10	20.00	-20.10	T4	
	Radial	100MHz	656000	-13.26	-40.83	-61.70	N/A	27.57	20.00	-7.57	T3	1.4, 0.4
		90MHz	656000	-13.55	-39.93			26.38	20.00	-6.38	T3	
		80MHz	656000	-13.22	-40.27			27.05	20.00	-7.05	T3	
		70MHz	656000	-13.44	-39.89			26.45	20.00	-6.45	T3	
		60MHz	656000	-13.45	-40.07			26.62	20.00	-6.62	T3	
		50MHz	656000	-13.31	-40.22			26.91	20.00	-6.91	T3	
		40MHz	656000	-13.53	-40.41			26.88	20.00	-6.88	T3	
		30MHz	656000	-13.55	-40.18			26.63	20.00	-6.63	T3	
		20MHz	656000	-13.57	-40.36			26.79	20.00	-6.79	T3	

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→Other Call Settings→Hearing Aid Compatibility**) was set to ON for Frequency Response compliance
4. Speech Signal: 3GPP2 Normal Test Signal
5. Bluetooth and WIFI were disabled while testing 5G modes.
6. The Margin from FCC limit column indicates a margin from the FCC limit for compliance (T3).

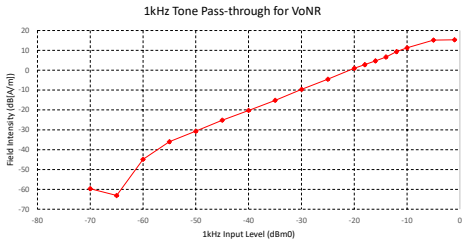
B. NR FDD

1. Power Configuration: TPC = “Max Power”
2. Radio Configuration: DFT-s-OFDM, 16QAM, 50%RB, 0RB offset
3. Vocoder Configuration: NB AMR 4.75kbps
4. The worst-case band and bandwidth combination for each probe orientation is additionally tested on the low and high channels for those combinations. NR n66 at 40MHz is the worst-case for the Axial probe orientation. NR n66 at 30MHz is the worst-case for the Radial probe orientation.

C. NR TDD

1. Power Configuration: TPC = “Max Power”
2. Radio Configuration: DFT-s-OFDM, 16QAM, 50%RB, 0RB offset
3. Vocoder Configuration: NB AMR 4.75kbps
4. The worst-case band and bandwidth combination for each probe orientation is additionally tested on the low, low-mid, high-mid, and high channels for those combinations. NR n77 (Power Class 2) at 100MHz is the worst-case for the Axial probe orientation. NR n41 (Power Class 2) at 90MHz is the worst-case for the Radial probe orientation.

III. 1 kHz Vocoder Application Check



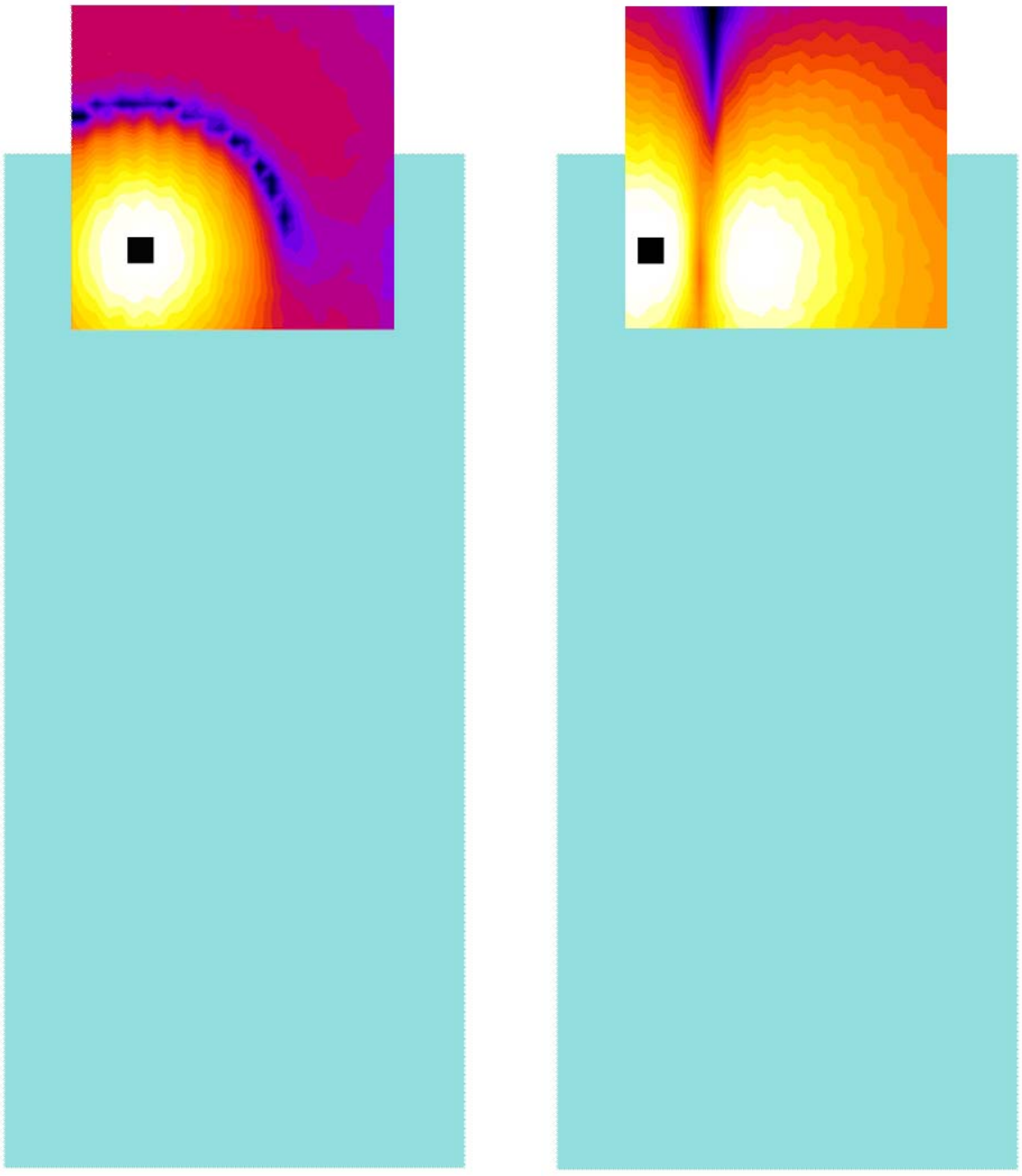
This model was verified to be within the linear region for ABM1 measurements at -20 dBm0 for VoNR over IMS. This measurement was taken in the axial configuration above the maximum location.

IV. T-Coil Validation Test Results

Table 6-10
Helmholtz Coil Validation Table of Results

Item	Target	Result	Verdict
Axial			
Magnetic Intensity, -10 dBA/m	*-10 ± 0.5 dB*	-10.489	**PASS**
Environmental Noise	< -58 dBA/m	-61.46	**PASS**
Frequency Response, from limits	*> 0 dB*	0.70	**PASS**
Radial			
Magnetic Intensity, -10 dBA/m	*-10 ± 0.5 dB*	-10.467	**PASS**
Environmental Noise	< -58 dBA/m	-61.70	**PASS**
Frequency Response, from limits	*> 0 dB*	0.70	**PASS**

V. ABM1 Magnetic Field Distribution Scan Overlays



Axial Radial (Transverse)

Figure 6-1
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.

7. MEASUREMENT UNCERTAINTY

Table 7-1
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.

8. EQUIPMENT LIST

Table 8-1
Equipment List

Manufacturer	Model	Description	Cal Date	Cal Interval	Cal Due	Serial Number
Control Company	4040	Therm./ Clock/ Humidity Monitor	3/12/2021	Biennial	3/12/2023	210202053
Listen	Fireface UC	Acoustic Analyzer External Audio Interface	3/29/2021	Biennial	3/29/2023	23857555
Listen	SoundConnect	Microphone Power Supply	3/29/2021	Biennial	3/29/2023	PS3099
Rohde & Schwarz	CMW500	Wideband Radio Communication tester	5/2/2019	Annual	9/2/2021	167286
Rohde & Schwarz	CMX500	Radio Communication Tester	N/A		N/A	100298
Seekonk	NC-100	Torque Wrench (8" lb)	8/4/2020	Biennial	8/4/2022	N/A
TEM		HAC System Controller with Software	N/A		N/A	N/A
TEM		HAC Positioner	N/A		N/A	N/A
TEM	Helmholtz Coil	Helmholtz Coil	3/29/2021	Biennial	3/29/2023	925
TEM	Axial T-Coil Probe	Axial T-Coil Probe	3/29/2021	Biennial	3/29/2023	TEM-1139
TEM	Radial T-Coil Probe	Radial T-Coil Probe	3/29/2021	Biennial	3/29/2023	TEM-1133
YellowTec	YT4211	USB Audio Interface	N/A		N/A	20000365

9. TEST DATA

PCTEST Hearing-Aid Compatibility Facility

DUT: HH Coil – SN: 925

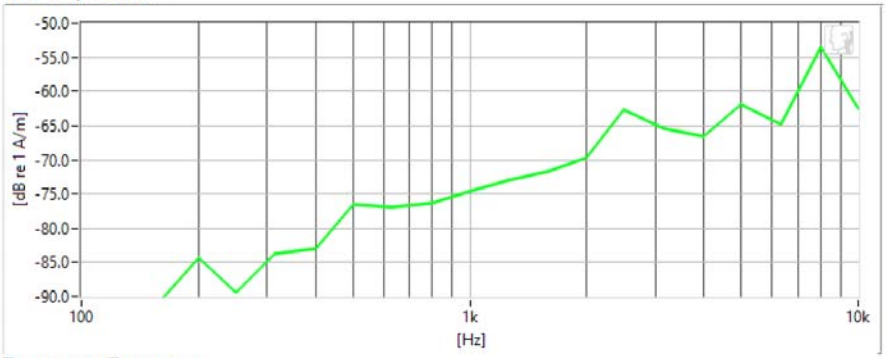
Type: HH Coil
Serial: 925

Measurement Standard: ANSI C63.19-2011

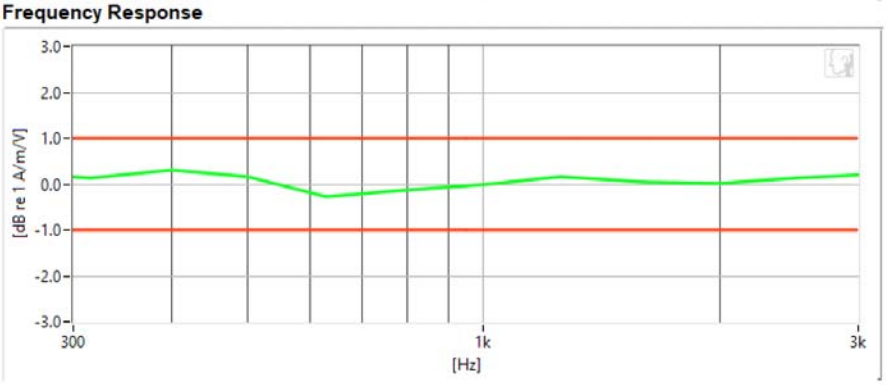
Equipment:

- Probe: Axial T-Coil Probe – SN: TEM-1139; Calibrated: 3/29/2021
- Helmholtz Coil – SN: 925; Calibrated: 3/29/2021

Noise Spectrum



Frequency Response



Results

Verification 1kHz Intensity	-10.489 dB	✓	Max/Min	-9.5/-10.5
Verification ABM2	-61.46 dB	✓	Maximum	-58.0
Frequency Response Margin	700m dB	✓	Tolerance curves	Aligned Data

PCTEST Proud to be part of element

PCTEST Hearing-Aid Compatibility Facility

DUT: HH Coil – SN: 925

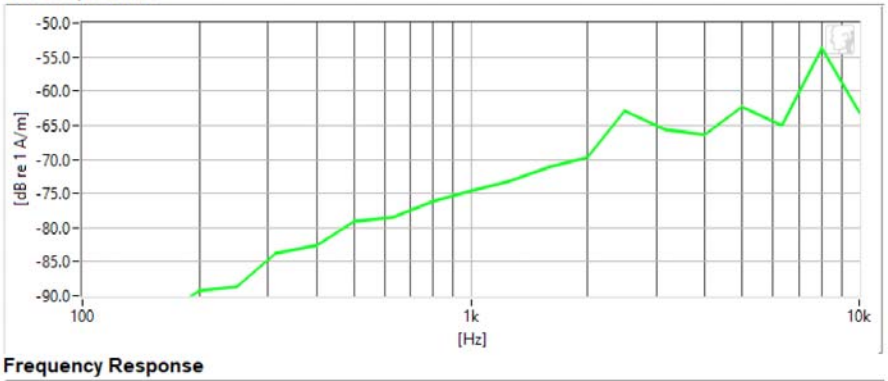
Type: HH Coil
Serial: 925

Measurement Standard: ANSI C63.19-2011

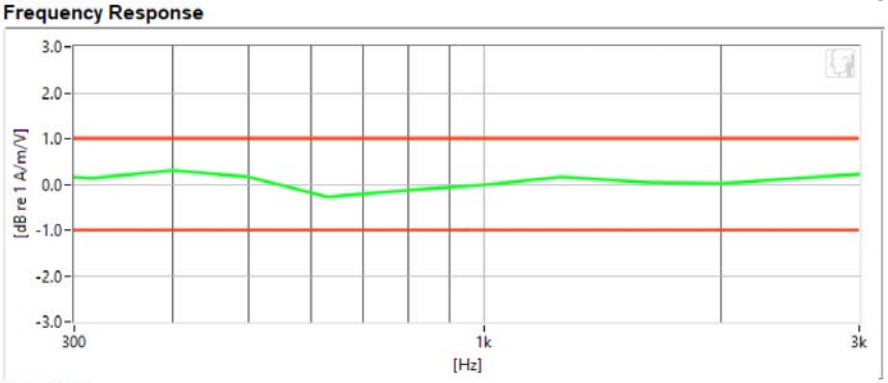
Equipment:

- Probe: Radial T-Coil Probe – SN: TEM-1133; Calibrated: 3/29/2021
- Helmholtz Coil – SN: 925; Calibrated: 3/29/2021

Noise Spectrum



Frequency Response



Results

Verification 1kHz Intensity	-10.467 dB	✓	Max/Min	-9.5/-10.5
Verification ABM2	-61.7 dB	✓	Maximum	-58.0
Frequency Response Margin	700m dB	✓	Tolerance curves	Aligned Data

PCTEST Proud to be part of element

PCTEST Hearing-Aid Compatibility Facility

DUT: A3LSMG998U

Type: Portable Handset
Serial: 0766M

Measurement Standard: ANSI C63.19-2011

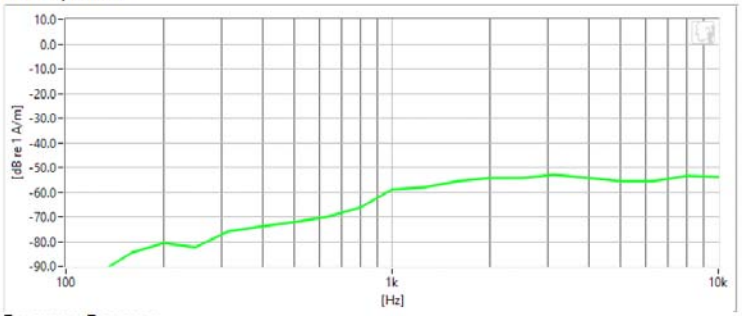
Equipment:

- Probe: Axial T-Coil Probe – SN: TEM-1139; Calibrated: 3/29/2021

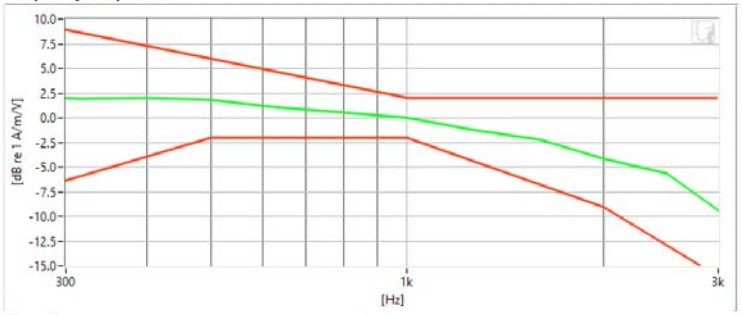
Test Configuration:

- Mode: NR FDD n66
- Bandwidth: 40MHz
- Channel: 352000
- Speech Signal: 3GPP2 Normal Test Signal

Noise Spectrum



Frequency Response



Results

ABM1	-6.41 dB	✓	Minimum	-18.0
ABM2	-50.33 dB	✓	Maximum	0.0
SNNR	43.92 dB	✓	Minimum	20.0
Aligned Response - Normal	2 dB	✓	Tolerance curves	Aligned Data

PCTEST Proud to be part of element

PCTEST Hearing-Aid Compatibility Facility

DUT: A3LSMG998U

Type: Portable Handset
Serial: 0766M

Measurement Standard: ANSI C63.19-2011

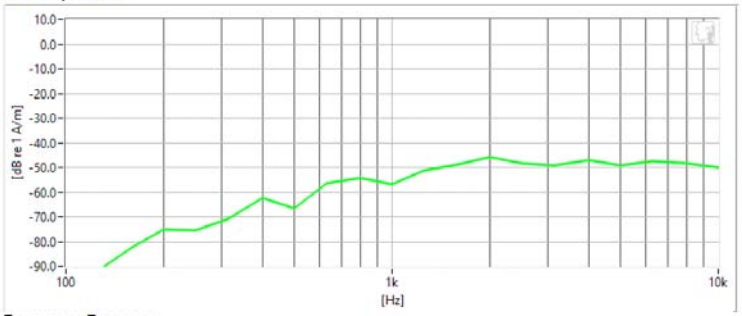
Equipment:

- Probe: Axial T-Coil Probe – SN: TEM-1139; Calibrated: 3/29/2021

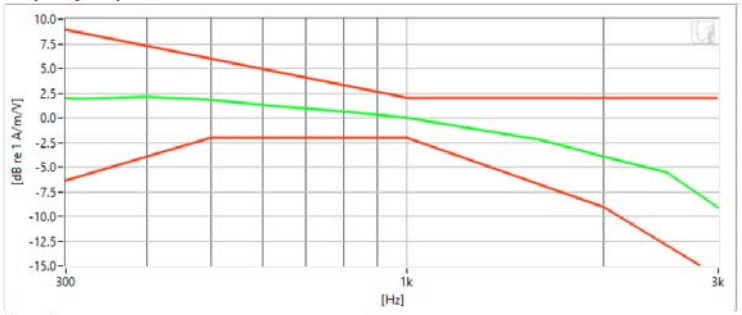
Test Configuration:

- Mode: NR TDD n77 (PC2)
- Bandwidth: 100MHz
- Channel: 656000
- Speech Signal: 3GPP2 Normal Test Signal

Noise Spectrum



Frequency Response



Results

ABM1	-6.45 dB	✓	Minimum	-18.0
ABM2	-43.34 dB	✓	Maximum	0.0
SNNR	36.88 dB	✓	Minimum	20.0
Aligned Response - Normal	2 dB	✓	Tolerance curves	Aligned Data

PCTEST Proud to be part of element

PCTEST Hearing-Aid Compatibility Facility

DUT: A3LSMG998U

Type: Portable Handset
Serial: 0766M

Measurement Standard: ANSI C63.19-2011

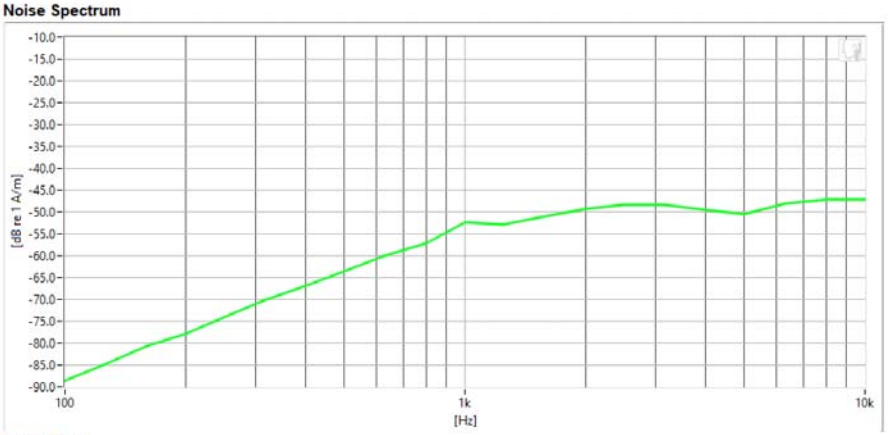
Equipment:

- Probe: Radial T-Coil Probe – SN: TEM-1133; Calibrated: 3/29/2021

Test Configuration:

- Mode: NR FDD n66
- Bandwidth: 30MHz
- Channel: 353000

Noise Spectrum



Results

ABM1	-13.42 dB	✓	Minimum	-18.0
ABM2	-44.61 dB	✓	Maximum	0.0
SNNR	31.18 dB	✓	Minimum	20.0

PCTEST Proud to be part of element

PCTEST Hearing-Aid Compatibility Facility

DUT: A3LSMG998U

Type: Portable Handset
Serial: 0766M

Measurement Standard: ANSI C63.19-2011

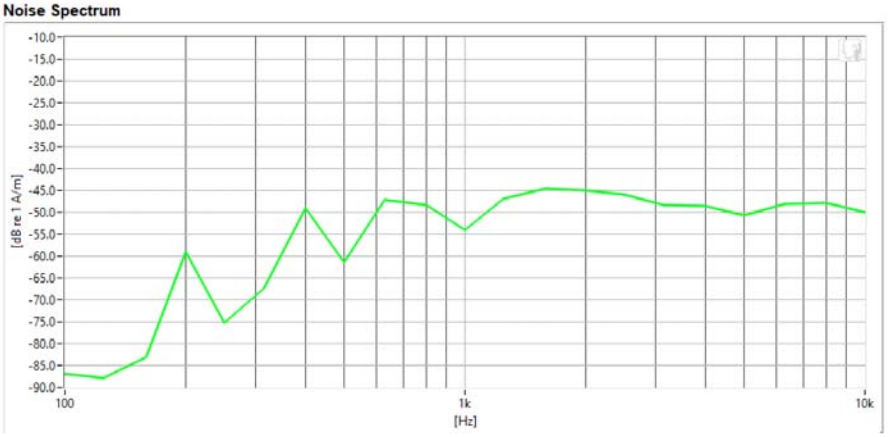
Equipment:

- Probe: Radial T-Coil Probe – SN: TEM-1133; Calibrated: 3/29/2021

Test Configuration:

- Mode: NR TDD n41 (PC2)
- Bandwidth: 90MHz
- Channel: 508200

Noise Spectrum



Results

ABM1	-13.53 dB	✓	Minimum	-18.0
ABM2	-38.65 dB	✓	Maximum	0.0
SNNR	25.12 dB	✓	Minimum	20.0

10. CALIBRATION CERTIFICATES

West Caldwell Calibration Laboratories Inc.

Certificate of Calibration

for

AXIAL T COIL PROBE

Manufactured by:	TEM CONSULTING, LP
Model No:	AXIAL T COIL PROBE
Serial No:	TEM-1139
Calibration Recall No:	31813

VaA
4/7/2021

Submitted By:

Customer:	ANDREW HARWELL
Company:	PCTEST ENGINEERING LAB
Address:	7185 OAKLAND MILLS ROAD
	COLUMBIA MD 21046

The subject instrument was calibrated to the indicated specification using standards traceable to the SI through 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.
The information supplied relates to the calibrated item listed above and statement of conformance for ALL given specifications and standards fall under the decision rule: A= (L-(U95)*M), where A is acceptance limit, L is manufacturer specifications, U95 is confidence level of 95% at k=2, and M is managed guard-band mulitiplier. The guard-band multiplier increases false-accept risk in favor of decreasing false-reject risk. Although the false accept risk increases, it is still below the Z540.3 2% risk requirement. The decision rule has been communicated and approved by customer during contract review.

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 9001:2015, and ISO 17025

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

Approved by:

James Zhu

Quality Manager
ISO/IEC 17025:2017

Calibration Date: 29-Mar-21

Certificate No: 31813 -3

QA Doc. #1051 Rev. 3.0 5/29/20

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: 2017
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-1139**
Company: PCTest Engineering Lab **I. D. No.: XXXX**

Calibration results:

Probe Sensitivity measured with Helmholtz Coil

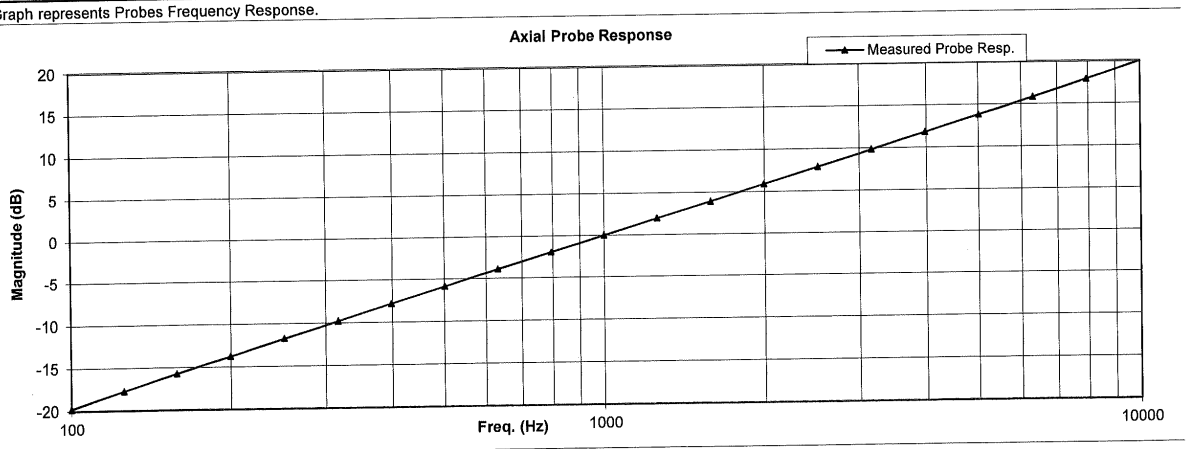
Helmholtz Coil;		
the number of turns on each coil;	10	No.
the radius of each coil, in meters;	0.204	m
the current in the coils, in amperes.;	0.08	A
Helmholtz Coil Constant;	7.09	A/m/V
Helmholtz Coil magnetic field;	5.92	A/m
Probe Sensitivity at	1000	Hz.
was	-60.26	dBV/A/m
	0.970	mV/A/m
Probe resistance	873	Ohms

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

Laboratory Environment:		
Ambient Temperature:	20.4	°C
Ambient Humidity:	29.3	% RH
Ambient Pressure:	99.394	kPa
Calibration Date:	29-Mar-2021	
Calibration Due:		
Report Number:		31813 -3
Control Number:		31813

The above listed instrument meets or exceeds the tested manufacturer's specifications.
This Calibration is traceable through NIST test numbers: 684.07/O-0000001126-20
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 9001:2015, ISO 17025

Cal. Date: 29-Mar-2021
Calibrated on WCCL system type 9700

Measurements performed by: .....
James Zhu
Rev. 7.0 Jan. 24, 2014 Doc. # 1038 HCATEMC

HCATEMC_TEM-1139_Mar-29-2021.xls

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-1139
Company: PCTest Engineering Lab

Test	Function	Tolerance		Measured values		
				Before	Out	Remarks
1.0	Probe Sensitivity at	1000 Hz.	dBV/A/m	-60.26		
2.0	Probe Level Linearity		dB			
		Ref. (0 dB)	6	5.94		
			0	0.00		
			-6	-6.03		
			-12	-12.04		
3.0	Probe Frequency Response		Hz			
			100	-19.8		
			126	-17.8		
			158	-15.7		
			200	-13.8		
			251	-11.8		
			316	-9.8		
			398	-7.8		
			501	-5.9		
			631	-3.9		
			794	-2.0		
		Ref. (0 dB)	1000	0.0		
			1259	2.0		
			1585	3.9		
			1995	5.9		
			2512	7.9		
			3162	9.8		
			3981	11.8		
			5012	13.8		
			6310	15.8		
			7943	17.9		
			10000	20.0		

Instruments used for calibration:			Date of Cal.	Traceablity No.	Due Date
HP	34401A	S/N US360641	2-Jul-2020	,610119	2-Jul-2021
HP	34401A	S/N US361024	2-Jul-2020	,610119	2-Jul-2021
HP	33120A	S/N US360437	2-Jul-2020	,610119	2-Jul-2021
B&K	2133	S/N 1583254	1-Jul-2020	684.07/O-0000001126-20	1-Jul-2021

Cal. Date: 29-Mar-2021 — Tested by: James Zhu

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, LP**
Model No:	**RADIAL T COIL PROBE**
Serial No:	**TEM-1133**
Calibration Recall No:	**31813**

Submitted By:

4/7/2021

Customer:	**ANDREW HARWELL**
Company:	**PCTEST ENGINEERING LAB**
Address:	**7185 OAKLAND MILLS ROAD**
	COLUMBIA MD 21046

The subject instrument was calibrated to the indicated specification using standards traceable to the SI through 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**)

tolerance of the indicated specification. See attached Report of Calibration.
The information supplied relates to the calibrated item listed above and statement of conformance for ALL given specifications and standards fall under the decision rule: A= (L-(U95)*M), where A is acceptance limit, L is manufacturer specifications, U95 is confidence level of 95% at k=2, and M is managed guard-band mulitiplier. The guard-band multiplier increases false-accept risk in favor of decreasing false-reject risk. Although the false accept risk increases, it is still below the Z540.3 2% risk requirement. The decision rule has been communicated and approved by customer during contract review.

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 9001:2015, and ISO 17025

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

Approved by:

James Zhu

Quality Manager
ISO/IEC 17025:2017

Calibration Date: **29-Mar-21**

Certificate No: **31813** - 2

QA Doc. #1051 Rev. 3.0 5/29/20

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

ISO/IEC 17025: 2017

West Caldwell Calibration Laboratories, Inc.
uncompromised calibration

ACCREDITED
Calibration Lab. Cert. # 1533.01

1575 State Route 96, Victor NY 14564

REPORT OF CALIBRATION

for

TEM Consulting LP Radial T Coil Probe **Model No.: Radial T Coil Probe** **Serial No.: TEM-1133**
Company: PCTest Engineering Lab **I. D. No.: XXXX**

Calibration results:

Probe Sensitivity measured with Helmholtz Coil

Helmholtz Coil;		
the number of turns on each coil;	10	No.
the radius of each coil, in meters;	0.204	m
the current in the coils, in amperes.;	0.09	A
Helmholtz Coil Constant;	7.09	A/m/V
Helmholtz Coil magnetic field;	5.97	A/m
Probe Sensitivity at	1000	Hz.
was	-60.18	dBV/A/m
	0.980	mV/A/m
Probe resistance	896	Ohms

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

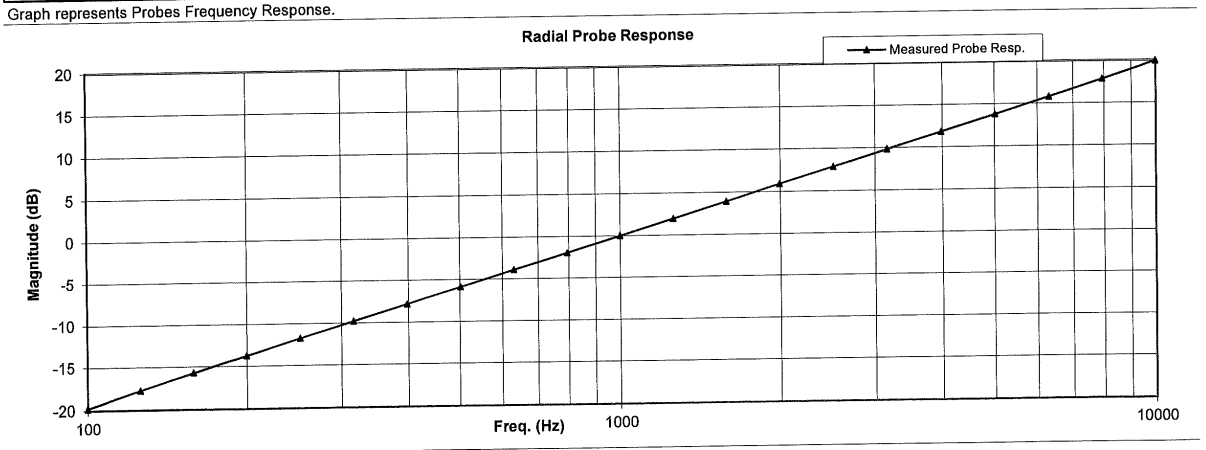
Laboratory Environment:		
Ambient Temperature:	20.4	°C
Ambient Humidity:	29.3	% RH
Ambient Pressure:	99.394	kPa
Calibration Date:	29-Mar-2021	
Re-calibration Due:		
Report Number:		31813 -2
Control Number:		31813

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

This Calibration is traceable through NIST test numbers: 684.07/O-0000001126-20

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 9001:2015, ISO 17025

Cal. Date: 29-Mar-2021

Calibrated on WCCL system type 9700

Measurements performed by: .....
James Zhu
Rev. 7.0 Jan. 24, 2014 Doc. # 1038 HCRTEMC

HCRTEMC_TEM-1133_Mar-29-2021.xls

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-1133
Company: PCTest Engineering Lab

Test	Function	Tolerance		Measured values		
				Before	Out	Remarks
1.0	Probe Sensitivity at	1000 Hz.	dBV/A/m	-60.18		
			dB			
2.0	Probe Level Linearity		6	6.04		
		Ref. (0 dB)	0	0.00		
			-6	-6.03		
			-12	-12.06		
			Hz			
3.0	Probe Frequency Response		100	-19.8		
			126	-17.8		
			158	-15.7		
			200	-13.8		
			251	-11.8		
			316	-9.8		
			398	-7.8		
			501	-5.9		
			631	-3.9		
			794	-2.0		
		Ref. (0 dB)	1000	0.0		
			1259	2.0		
			1585	3.9		
			1995	5.9		
			2512	7.8		
			3162	9.8		
			3981	11.8		
			5012	13.8		
			6310	15.8		
			7943	17.8		
			10000	20.0		

Instruments used for calibration:			Date of Cal.	Traceability No.	Due Date
HP	34401A	S/N US360641	2-Jul-2020	,610119	2-Jul-2021
HP	34401A	S/N US361024	2-Jul-2020	,610119	2-Jul-2021
HP	33120A	S/N US360437	2-Jul-2020	,610119	2-Jul-2021
B&K	2133	S/N 1583254	1-Jul-2020	684.07/O-0000001126-20	1-Jul-2021

Cal. Date: 29-Mar-2021 — Tested by: James Zhu

Calibrated on WCCL system type 9700

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

11. 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 for VoNR over IMS. 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.

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