HAC T-Coil Evaluation Report for FCC

Applicant Name	:	**PepperlFuchs SE**
Applicant Address	:	**Lilienthalstrasse 200, 68307 Mannheim, Germany**
Product Name	:	**Phone**
Brand Name	:	**PEPPERL+FUCHS**
Model Number	:	**Smart-Ex 03**
FCC ID	:	**2AXZAS03GR01**
Report Number	:	**USSC236135003**
Compliant Standards	:	**FCC 47 CFR §20.19**
		ANSI C63.19-2011
HAC Category	:	**T3**
Sample Received Date	:	**Apr. 20, 2023**
Date of Testing	:	**Oct. 06 ~ Nov. 15, 2023**
Report Issue Date	:	**Nov. 28, 2023**

*The above equipment has been tested by **Eurofins E&E Wireless Taiwan Co., Ltd.**, and found compliance with the requirement of the above standards. The test record, data evaluation & Device Under Test (DUT) configurations represented herein are true and accurate accounts of the measurements of the sample's characteristics under the conditions specified in this report.*

Note:

1. *The test results are valid only for samples provided by customers and under the test conditions described in this report.*
2. *This report shall not be reproduced except in full, without the written approval of Eurofins E&E Wireless Taiwan Co., Ltd.*
3. *The relevant information is provided by customers in this test report. According to the correctness, appropriateness or completeness of the information provided by the customer, if there is any doubt or error in the information which affects the validity of the test results, the laboratory does not take the responsibility.*

Approved By：

Roy Wu / SAR Technical Director

ilac-MRA

TAF Testing Laboratory 1330

Table of Contents

Revision History

Rev.	Issue Date	Description	Revised by
00	Nov. 28, 2023	Initial release	Rowan Hsieh

1. Compliance Statement

This device (FCC ID: ***2AXZAS03GR01***) has been tested by ***Eurofins E&E Wireless Taiwan Co., Ltd.*** in accordance with the measurement procedures specified in ANSI C63.19 and FCC KDB procedures, and the results shown in below are capable of demonstrating compliance for Hearing Aid Compatibility (HAC) for minimum criteria of ***T3*** rating specified in *FCC 47 CFR §20.19*.

Technology	Band	HAC Category (T Rating)				
		CMRS	VoLTE	VoNR	VoWiFi	OTT
GSM	850	T3	N/A	N/A	N/A	N/A
GSM	1900	T4	N/A	N/A	N/A	N/A
WCDMA	Band 2	T4	N/A	N/A	N/A	N/A
WCDMA	Band 4	T4	N/A	N/A	N/A	N/A
WCDMA	Band 5	T4	N/A	N/A	N/A	N/A
LTE	B2	N/A	T4	N/A	N/A	N/A
LTE	B4	N/A	T4	N/A	N/A	N/A
LTE	B5	N/A	T4	N/A	N/A	N/A
LTE	B7	N/A	T4	N/A	N/A	N/A
LTE	B12	N/A	T4	N/A	N/A	N/A
LTE	B13	N/A	T4	N/A	N/A	N/A
LTE	B14	N/A	T4	N/A	N/A	N/A
LTE	B17	N/A	T4	N/A	N/A	N/A
LTE	B25	N/A	T4	N/A	N/A	N/A
LTE	B26	N/A	T4	N/A	N/A	N/A
LTE	B30	N/A	T4	N/A	N/A	N/A
LTE	B38	N/A	T4	N/A	N/A	N/A
LTE	B40	N/A	T4	N/A	N/A	N/A
LTE	B41	N/A	T4	N/A	N/A	N/A
LTE	B42	N/A	T4	N/A	N/A	N/A
LTE	B48	N/A	T4	N/A	N/A	N/A
LTE	B66	N/A	T4	N/A	N/A	N/A
LTE	B71	N/A	T4	N/A	N/A	N/A
5G NR	n2	N/A	N/A	T4	N/A	N/A
5G NR	n5	N/A	N/A	T4	N/A	N/A
5G NR	n7	N/A	N/A	T4	N/A	N/A
5G NR	n12	N/A	N/A	T4	N/A	N/A
5G NR	n13	N/A	N/A	T4	N/A	N/A
5G NR	n14	N/A	N/A	T4	N/A	N/A
5G NR	n25	N/A	N/A	T4	N/A	N/A
5G NR	n30	N/A	N/A	T4	N/A	N/A
5G NR	n38	N/A	N/A	T3	N/A	N/A
5G NR	n41	N/A	N/A	T3	N/A	N/A
5G NR	n48	N/A	N/A	T3	N/A	N/A
5G NR	n66	N/A	N/A	T4	N/A	N/A
5G NR	n71	N/A	N/A	T4	N/A	N/A
5G NR	n77	N/A	N/A	T3	N/A	N/A
5G NR	n78	N/A	N/A	T3	N/A	N/A
WLAN	2.4G	N/A	N/A	N/A	T4	N/A
WLAN	5G	N/A	N/A	N/A	T4	N/A
WLAN	6G	N/A	N/A	N/A	T4	N/A

2. Test Regulations

2.1. Reference Standard and Guidance

The Specific Absorption Rate (SAR) testing documented in this report were performed in accordance with following FCC published KDB guidance and standard：

KDB Publication 285076 D01 – HAC Guidance v06r04

KDB Publication 285076 D02 – T-Coil Testing for CMRS IP v04

KDB Publication 285076 D03 – HAC FAQ v01r06

2.2. HAC Performance Criteria

The FCC uses a technical standard to determine whether a handset is hearing aid-compatible. The HAC technical standard is known as the standard of ***ANSI C63.19-2011***, and devices that meet it will be simply labelled as "hearing aid-compatible." The standard uses an M/T rating system. The ***"M" rating*** is for reducing interference with hearing aids operating in acoustic mode – from ***M1*** to ***M4***, with ***M4*** being the best. The ***"T" rating*** is for their ability to operate with hearing aids that contain a telecoil (a tightly wrapped piece of wire that converts sounds into electromagnetic signals) and operate in inductive coupling mode – from ***T1*** to ***T4***, with ***T4*** being the best. The FCC considers a handset to be hearing aid-compatible if it is rated at least an ***M3*** (for acoustic coupling) and at least a ***T3*** (for inductive coupling).

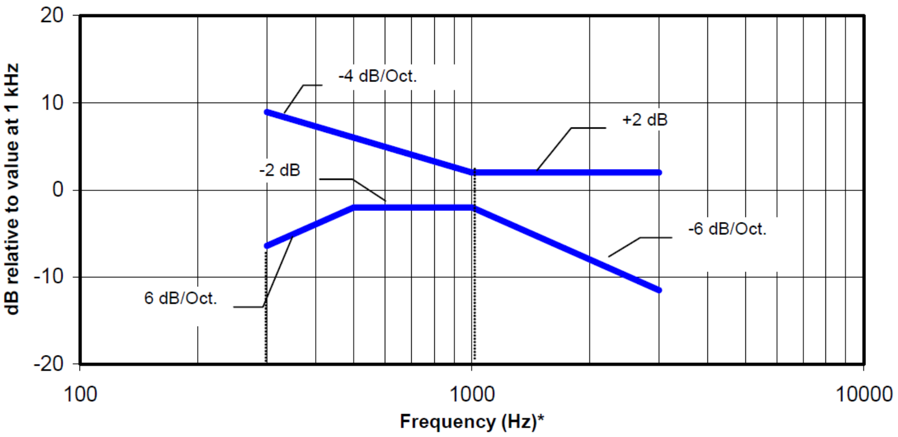
Field Intensity

The T-Coil signal shall be ≥ –18 dB (A/m) at 1 kHz, in a 1/3 octave band filter for all orientations.

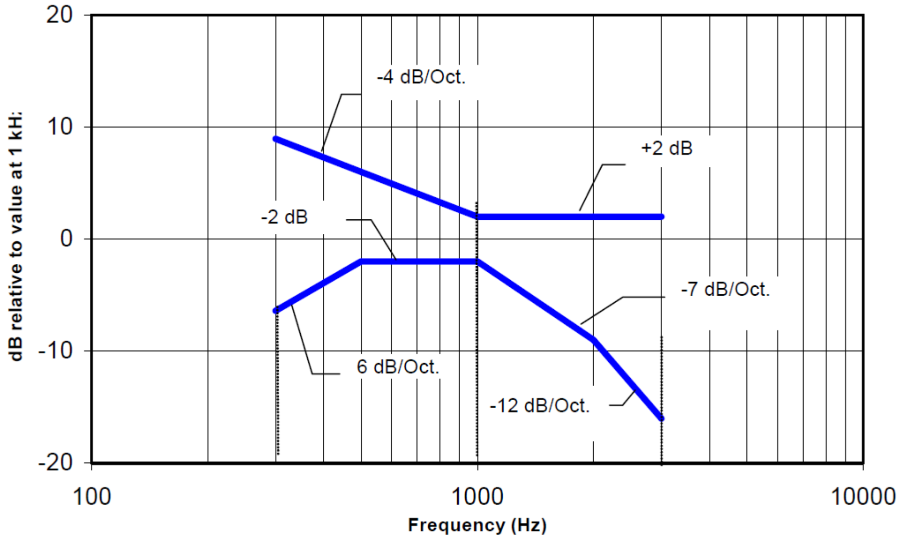
Frequency Response

The frequency response of the axial component of the magnetic field, measured in 1/3 octave bands, shall follow the below response curve, over the frequency range 300 Hz to 3000 Hz. The following figures provide the boundaries for the specified frequency. These response curves are for true field strength measurements of the T-Coil signal. Thus the 6 dB/octave probe response has been corrected from the raw readings.

Magnetic Field Frequency Response for DUT with Field Strength ≤ -15 dB (A/m) at 1 kHz



Magnetic Field Frequency Response for DUT with Field Strength > -15 dB (A/m) at 1 kHz



Signal Quality (Signal to Noise)

This subclause specifies the signal-to-noise quality requirement for the intended T-Coil signal from a WD. The worst signal to noise of the two T-Coil signal measurements shall be used to determine the T-Coil mode category per following table.

T-Coil Signal-to-Noise Categories Specified in ANSI C63.19-2011

Categories	*DUT Signal Quality [(Signal + Noise) – Noise Ratio in Decibels]*
Category T1	**0 dB ~ 10 dB**
Category T2	**10 dB ~ 20 dB**
Category T3	**20 dB ~ 30 dB**
Category T4	**> 30 dB**

3. Information of Testing Laboratory

Test Facilities

Company Name: Eurofins E&E Wireless Taiwan Co., Ltd.
Address No.: 140-1, Changan Street, Bade District, Taoyuan City 334025, Taiwan
Website: https://www.atl.com.tw
Telephone: +886-3-271-0188
Fax: +886-3-271-0190
E-mail: infoEETW@eurofins.com

Test Site Location

■ No. 140-1, Changan Street, Bade District, Taoyuan City 334025, Taiwan
□ No. 2, Wuquan 5th Rd. Wugu Dist., New Taipei City, Taiwan

Laboratory Accreditation

Location	TAF	FCC	ISED
No. 140-1, Changan Street, Bade District, Taoyuan City 334025, Taiwan	Accreditation No.: 1330	Designation No.: TW0010	Company No.: 7381A CAB ID: TW1330
No. 2, Wuquan 5th Rd. Wugu Dist., New Taipei City, Taiwan	Accreditation No.: 1330	Designation No.: TW0034	Company No.: 28922 CAB ID: TW1330

4. DUT (Device Under Test) Information

4.1. Device Overview

Product Name	Phone
Brand Name	PEPPERL+FUCHS
Model Name	Smart-Ex 03
Variants Description	Smart-Ex 03 is provided to the end user in two variants, one with camera features and the other as a non-camera variant. The camera modules are also populated in the non-camera variant; only SW deactivation and assembling physical camera opening covers, which are not metal, are required. Therefore, the testing was completed on the DUT with the camera features only.
FCC ID	2AXZAS03GR01

	Tx Frequency (MHz)	Operating Mode
Supported Wireless Technologies	**GSM** 850 : 824.2 ~ 848.8 1900 : 1850.2 ~ 1909.8	Voice : GMSK GPRS : GMSK EDGE : 8PSK
	WCDMA Band 2 : 1852.4 ~ 1907.6 Band 4 : 1712.4 ~ 1752.6 Band 5 : 826.4 ~ 846.6	UMTS Rel. 99 (Voice / Data) HSDPA (Rel. 5) HSUPA (Rel. 6) HSPA+ (Rel. 7) DC-HSDPA (Rel. 8)
	LTE Band 2 : 1850.7 ~ 1909.3 Band 4 : 1710.7 ~ 1754.3 Band 5 : 824.7 ~ 848.3 Band 7 : 2502.5 ~ 2567.5 Band 12 : 699.7 ~ 715.3 Band 13 : 779.5 ~ 784.5 Band 14 : 790.5 ~ 795.5 Band 17 : 706.5 ~ 713.5 Band 25 : 1850.7 ~ 1914.3 Band 26 : 814.7 ~ 848.3 Band 30 : 2307.5 ~ 2312.5 Band 38 : 2572.5 ~ 2617.5 Band 40 : 2302.5 ~ 2397.5 Band 41 : 2498.5 ~ 2687.5 Band 42 : 3552.5 ~ 3597.5 Band 48 : 3552.5 ~ 3697.5 Band 66 : 1710.7 ~ 1779.3 Band 71 : 665.5 ~ 695.5	QPSK, 16QAM, 64QAM, 256QAM
	5G NR FR1 n2 : 1852.5 ~ 1907.5 n5 : 826.5 ~ 846.5 n7 : 2502.5 ~ 2567.5 n12 : 701.5 ~ 713.5 n13 : 777 ~ 787 n14 : 790.5 ~ 795.5 n25 : 1852.5 ~ 1912.5 n30 : 2307.5 ~ 2312.5 n38 : 2575 ~ 2615 n41 : 2501.01 ~ 2685, 2506.02 ~ 2679.99 n48 : 3555 ~ 3694.98 n66 : 1712.5 ~ 1777.5 n71 : 665.5 ~ 695.5 n77 : 3455.01 ~ 3645, 3705 ~ 3975 n78 : 3455.01 ~ 3544.98, 3705 ~ 3795	**DFT-s-OFDM :** π/2 BPSK, QPSK, 16QAM, 64QAM, 256QAM **CP-OFDM :** QPSK, 16QAM, 64QAM, 256QAM
	WLAN 2.4G : 2412 ~ 2472 5G : 5180 ~ 5240, 5260 ~ 5320, 5500 ~ 55720, 5745 ~ 5825, 5845 ~ 5885 6G : 5935 ~ 6415, 6435 ~ 6515, 6535 ~ 6875, 6895 ~ 7115	2.4G : 802.11b/g/n/ac/ax 5G : 802.11a/n/ac/ax 6G : 802.11a/ax
	Bluetooth 2402 ~ 2480	BR, EDR, LE

Note:

The above DUT information is declared by manufacturer and for more detailed features description please refers to the manufacturer's specifications or User's Manual.

4.2. Air Interfaces and Operating Mode

Air Interface	Bands	Transport Type	HAC Tested	Simultaneous But Not Tested	Name of Voice Service	Power Reduction
GSM	850	VO	YES	Yes: Wi-Fi or BT	CMRS Voice	No
	1900					No
	EGPRS	VD	YES	Yes: Wi-Fi or BT	N/A	No
WCDMA	2	VO	YES	Yes: Wi-Fi or BT	CMRS Voice	No
	4					No
	5					No
	HSPA	VD	YES	Yes: Wi-Fi or BT	N/A	No
LTE	2	VD	YES	Yes: NR, Wi-Fi or BT	VoLTE	No
	4					No
	5					No
	7					No
	12					No
	13					No
	14					No
	17					No
	25					No
	26					No
	30					No
	38					No
	40					No
	41					No
	42					No
	48					No
	66					No
	71					No
5G NR	n2	VD	YES	Yes: LTE, Wi-Fi or BT	VoNR	No
	n5					No
	n7					No
	n12					No
	n13					No
	n14					No
	n25					No
	n30					No
	n38					No
	n41					No
	n48					No
	n66					No
	n71					No
	n77					No
	n78					No
Wi-Fi	2.4G	VD	YES	Yes: WWAN, Wi-Fi 5G/6G	VoWiFi	No
	5.2G (UNII-1)			Yes: WWAN, Wi-Fi 2.4G, BT		No
	5.3G (UNII-2A)					No
	5.6G (UNII-2C)					No
	5.8G (UNII-3)					No
	5.9G (UNII-4)					No
	UNII-5	VD	YES(2)	Yes: WWAN, Wi-Fi 2.4G, BT	VoWiFi	No
	UNII-6		No(3)			No
	UNII-7					No
	UNII-8					No
Bluetooth	2.4G	DT	No	Yes: WWAN, Wi-Fi 5G/6G	N/A	No

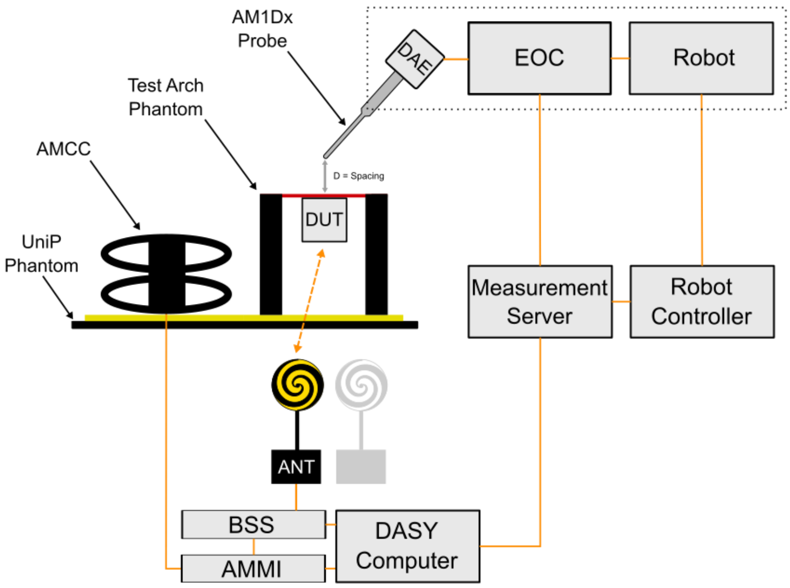
Transport Type:	***Notes:***
VO = Legacy Cellular Voice Service DT = Digital Transport Only (No Voice) VD = CMRS / IP Voice Service over Digital Transport	1. For protocols not listed in Table 7.1 of ANSI C63.19-2011 or the VoLTE interpretation, the average speech level of -20 dBm0 was used. 2. Wi-Fi UNII 5 was evaluated for operations which are entirely below 6 GHz. Operations partially or entirely > 6 GHz were not evaluated due to equipment limitations and being outside of the current scope of ANSI C63.19 and FCC HAC regulations. 3. Wi-Fi UNII 5 through 8 were not evaluated due to equipment limitations and being outside of the current scope of ANSI C63.19 and FCC HAC regulations. 4. NR FR2 bands are currently outside the scope of ANSI C63.19 and FCC HAC regulations therefore they were not evaluated.

5. Measurement System Description

5.1. Measurement Setup

The SPEAG DASY5 system consists of high precision robot, probe alignment sensor, phantom, robot controller, controlled measurement server and near-field probe. The robot includes six axes that can move to the precision position of the DASY5 software defined. The DASY5 software can define the area that is detected by the probe. The robot is connected to controlled box. Controlled measurement server is connected to the controlled robot box. The DAE includes amplifier, signal multiplexing, AD converter, offset measurement and surface detection. It is connected to the Electro-optical coupler (ECO). The ECO performs the conversion form the optical into digital electric signal of the DAE and transfers data to the Control PC.

SPEAG DASY5 HAC Measurement System Setup

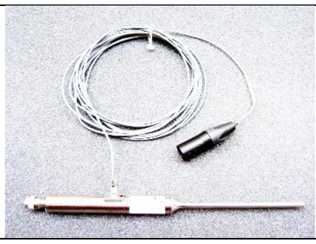


The DASY5 system for HAC measurements consists of:

- 6-axis robotic arm (Stäubli TX90XL) for positioning the probe.
- Measurement Server for handling all time-critical tasks, such as measurement data acquisition and supervision of safety features.
- EOC (Electrical to Optical Converter) for converting the optical signal from the DAE to electrical before being transmitted to the measurement server.
- LB (Light-Beam unit) for probe alignment (measurement of the exact probe length and eccentricity).
- HAC probe (EF3D probes) for measuring the E-field distribution on the HAC phantom. The audio interference distribution can be derived from the E-field measurement.
- HAC test arch phantom that can be used for easy positioning of the device under test for radiofrequency emission testing.
- DAE (Data Acquisition Electronics) for reading the probe voltages and transmitting it to the DASY5 control PC.
- Device Holder for positioning the DUT beneath the phantom.
- Control PC for running the HAC software to define/execute the measurements.
- System validation kits for system check / validation purposes.

5.1.1 Audio Magnetic Probe

Model	AM1DVx
Frequency Range	0.1 kHz to 20 kHz RF Sensitivity < -100 dB
Pre-amplifier	Symmetric, 40 dB
Dynamic Range	-50 dBA/m - 35 dBA/m
Calibration	At 1 kHz
Dimensions	Tip Diameter: 6 mm Length: 290 mm Scanning Distance: ≥ 4 mm



5.1.2 Data Acquisition Electronics (DAE)

Model	DAE3, DAE4
Construction	Signal amplifier, multiplexer, A/D converter and control logic. Serial optical link for communication with DASY embedded system (fully remote controlled). Two step probe touch detector for mechanical surface detection and emergency robot stop.
Measurement Range	-100 to +300 mV (16 bit resolution and two range settings: 4mV, 400mV)
Input Offset Voltage	< 5μV (with auto zero)
Input Bias Current	< 50 fA
Dimensions	60 x 60 x 68 mm

5.1.3 Audio Magnetic Measuring Instrument (AMMI)

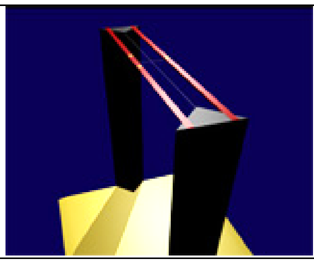
Model	AMMI
Dynamic Range	100 dB (with AM1DVx Probe)
Test Signal Generation	User selectable and pre-defined (via Control PC)
Calibration	Auto-calibration / full system calibration using AMCC with monitor output
Dimensions	482 x 65 x 270 mm

5.1.4 Audio Magnetic Calibration Coil (AMCC)

Model	AMCC
Specifications	Coil In: BNC connector, typically 50 Ohm Coil Monitor: BNO connector, 10 Ohm ±1 % (100 mV corresponding to 1 A/m)
Dimensions	370 x 370 x 196 mm

5.1.5 HAC Phantom

Model	Test Arch
Construction	Enables easy and well-defined positioning of the phone and validation dipoles as well as simple teaching of the robot.
Dimensions	Length : 370 mm Width : 370 mm Height : 370 mm



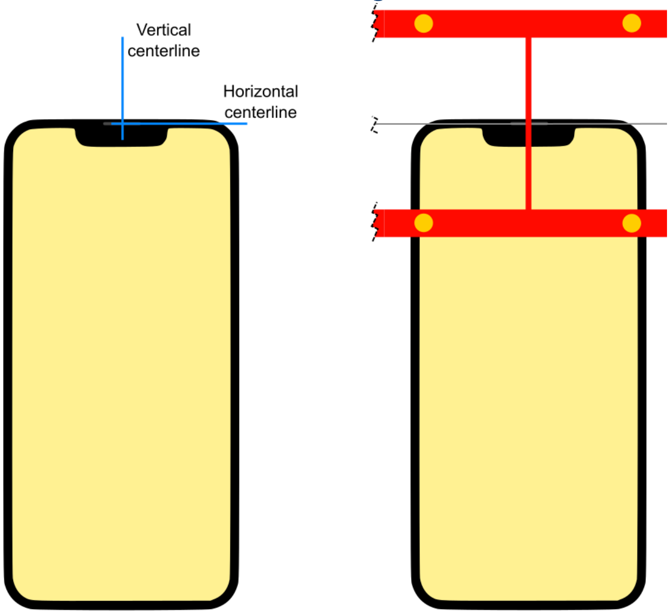
5.1.6 Device Holder

Model	Mounting Device
Construction	The Mounting Device enables the rotation of the mounted transmitter device in spherical coordinates. Rotation point is the ear opening point. Transmitter devices can be easily and accurately positioned according to ANSI C63.19.
Material	Polyoxymethylene (POM)

5.2. HAC T-Coil Measurements Points and Reference Plane

The DUT is mounted in the device holder in a similar manner as for dosimetric measurements. The earpiece of the DUT should correspond to the center point of the Test Arch (see below Figure). The DUT is moved vertically towards the frame of the Test Arch by using the adjustable DUT holder. The DUT is moved upwards towards the underside of the Test Arch until it touches the frame. Large corrections in the X, Y direction can be achieved by sliding the device holder along the surface while minor adjustments are available on the device holder itself.

Device Under Test Positioning under the Test Arch



Below Figure illustrates the standard probe orientations. Position 1 is the perpendicular (axial) orientation of the probe coil. Orientation 2 is the transverse (radial) orientation. The space between the measurement positions is not fixed. It is recommended that a scan of the DUT be done for each probe coil orientation and that the maximum level recorded be used as the reading for that orientation of the probe coil.

[1] The reference plane is the planar area that contains the highest point in the area of the phone that normally rests against the user's ear. It is parallel to the centerline of the receiver area of the phone and is defined by the points of the receiver-end of the DUT handset that, in normal handset use, rest against the ear.

[2] The measurement plane is parallel to, and 10 mm in front of the reference plane.

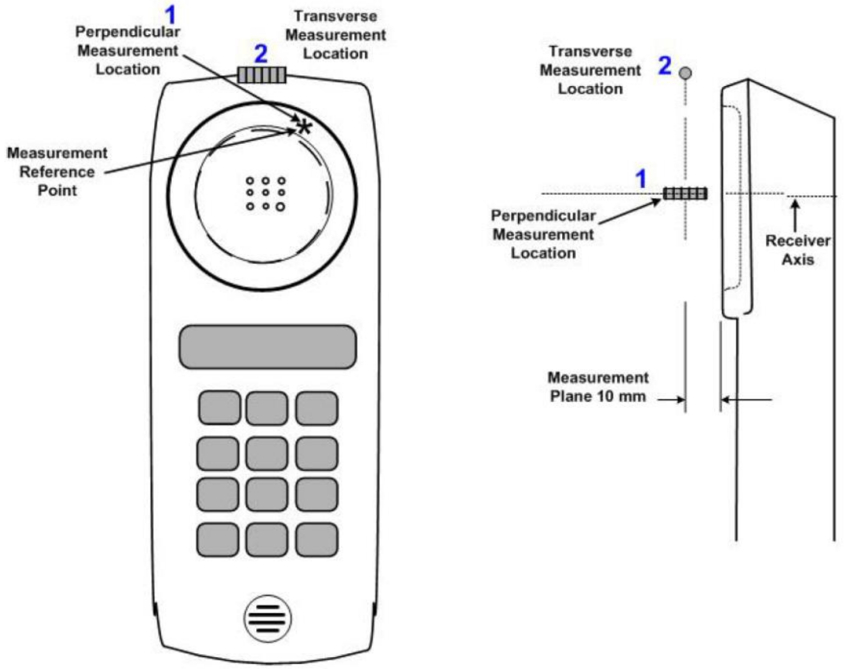
[3] The reference axis is normal to the reference plane and passes through the center of the receiver speaker section or it may be centered on a secondary inductive source.

[4] The measurement points may be located where the perpendicular (axial) and transverse (radial) field intensity measurements are optimum with regard to the requirements. However, the measurement points should be near the acoustic output of the DUT and shall be located in the same half of the phone as the DUT receiver. In DUT handset with a centered receiver and a circularly symmetrical magnetic field, the measurement axis and the reference axis would coincide.

[5] The relative spacing of each measurement orientations is not fixed. The perpendicular (axial) and transverse (radial) orientations should be chosen to select the optimal position.

[6] The measurement point for the axial position is located 10 mm from the reference plane on the measurement axis.

Axis and Planes for DUT Audio-Frequency Magnetic Field Measurement



5.3. HAC T-Coil Test Procedure

The T-Coil test procedure for wireless communications device is as below.

[1] Position the DUT in the test setup and connect the DUT RF connector to a base station simulator.

[2] The drive level to the DUT is set such that the reference input level specified in Table 7.1 is input to the base station simulator in the 1 kHz, 1/3 octave band. This drive level shall be used for the T-Coil signal test (ABM1) at f = 1 kHz. Either a sine wave at 1025 Hz or a voice-like signal, band-limited to the 1 kHz 1/3 octave, as defined in 7.4.2, shall be used for the reference audio signal. If interference is found at 1025 Hz, an alternate nearby reference audio signal frequency may be used. The same drive level will be used for the ABM1 frequency response measurements at each 1/3 octave band center frequency. The EUT volume control may be set at any level up to maximum, provided that a signal at any frequency at maximum modulation would not result in clipping or signal overload.

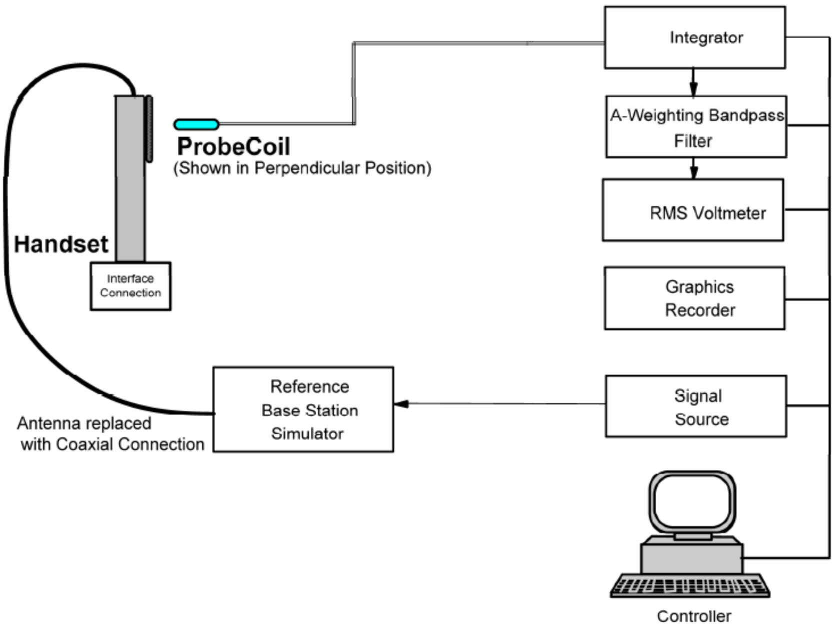
[3] Determine the magnetic measurement locations for the DUT, if not already specified by the manufacturer, as described in 7.4.4.1.1 and 7.4.4.2.

[4] At each measurement location, measure and record the desired T-Coil magnetic signals (ABM1 at fi) as described in 7.4.4.2 in each individual ISO 266-1975 R10 standard 1/3 octave band. The desired audio band input frequency (fi) shall be centered in each 1/3 octave band maintaining the same drive level as determined in Step 2 and the reading taken for that band. Equivalent methods of determining the frequency response may also be employed, such as fast Fourier transform (FFT) analysis using noise excitation or input–output comparison using simulated speech. The full-band integrated or half-band integrated probe output, as described in D.9, may be used, as long as the appropriate calibration curve is applied to the measured result, so as to yield an accurate measurement of the field magnitude. (The resulting measurement shall be an accurate measurement in dB A/m.) All measurements of the desired signal shall be shown to be of the desired signal and not of an undesired signal. This may be shown by turning the desired signal on and off with the probe measuring the same location. If the scanning method is used, the scans shall show that all measurement points selected for the ABM1 measurement meet the ambient and test system noise criterion in 7.3.1.

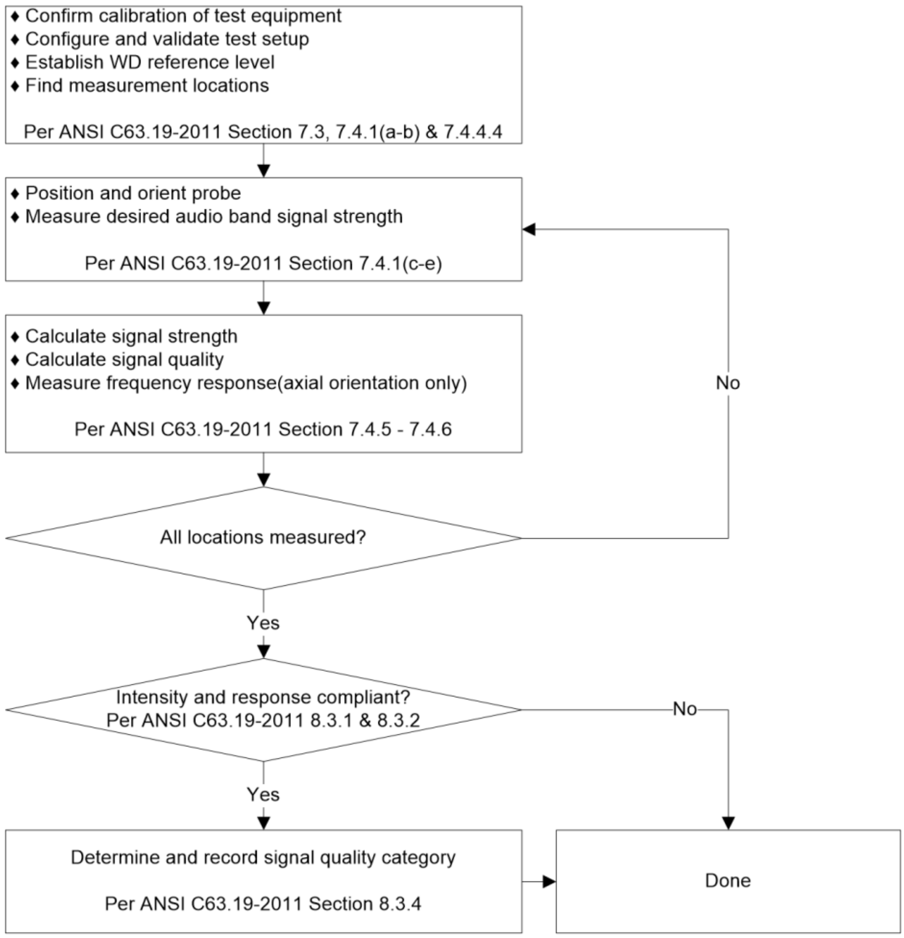
[5] At the measurement location for each orientation, measure and record the undesired broadband audio magnetic signal (ABM2) as described in 7.4.4.4 with no audio signal applied (or digital zero applied, if appropriate) using A-weighting, and the half-band integrator. Calculate the ratio of the desired to undesired signal strength (i.e., signal quality).

[6] Determine the category that properly classifies the signal quality based on Table 8.5.

T-Coil Signal Measurement Test Setup



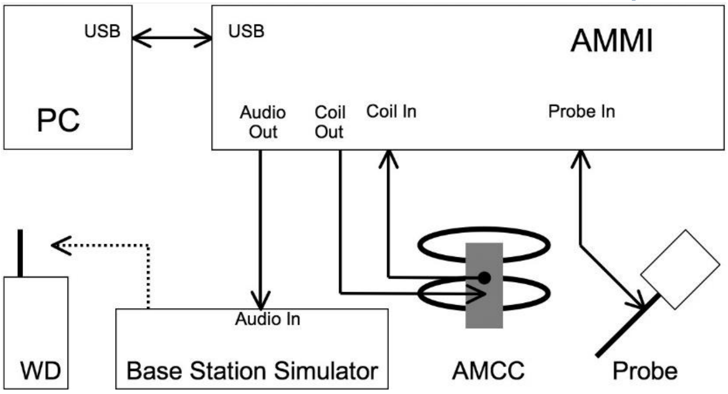
DUT T-Coil Signal Test Flowchart



5.4. Measurements Test Setup

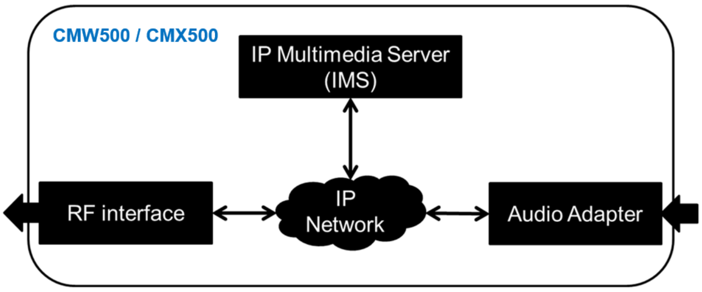
For ***CMRS*** voice calling, the test setup shown in below is to extend DASY5 system with the capability of Audio Band Magnetic (ABM) measurements according to standard ANSI C63.19-2011. Together with the HAC RF extension, it permits complete characterization of the emissions of DUT. The signals measured during these tests represent the field picked up by the T-Coil of a hearing aid. Using DASY's test software, these orthogonal axes can be scanned with a probe incorporating a single sensor coil. The DUT was mounted on the Test Arch Phantom. The acoustic center of the DUT was mounted in such a way that it is centered, and this represents the reference for the combination of ABM and RF field evaluation. The ABM fields of the DUT (frequency range <20 kHz) are scanned with a fully RF-shielded active 1-D probe. The probe axis is oriented in the space diagonal to the three orthogonal axes, and its single sensor can be oriented to the axes by 120-degree rotation. The probe signal is evaluated by an Audio Magnetic Measurement Instrument (AMMI) which is interfaced to the Control PC via USB. The AMMI also provides test and calibration signals and interfaces to the Helmholtz Audio Magnetic Calibration Coil (AMCC). Through the connector at the AMMI, predefined or user-definable audio signals are available for injection into the DUT during the test.

Hardware Connections and T-Coil Test Setup



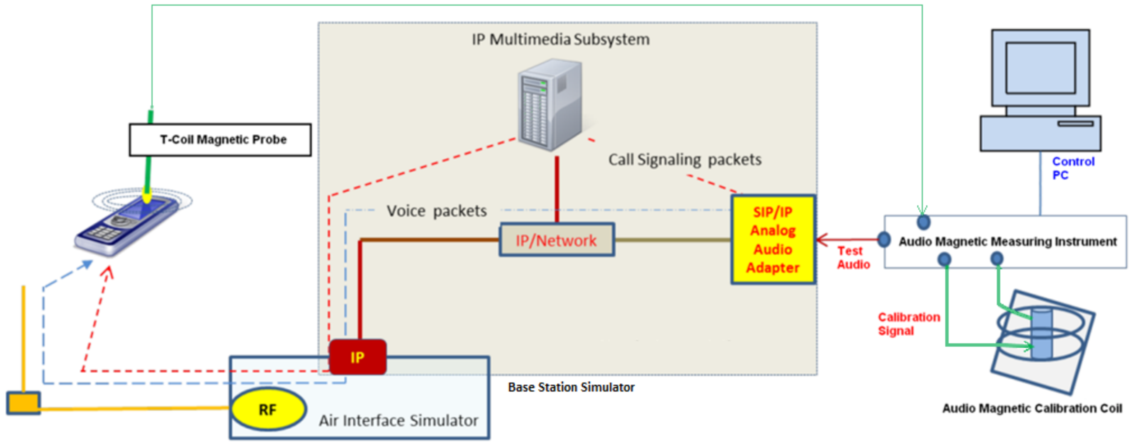
Per KDB 285076 D02, T-Coil testing for ***VoLTE***, ***VoNR*** and ***VoWiFi*** requires test instrumentation that can (1) for the system to be able to establish an IP call from/to the handset under test, (2) through an IMS (IP Multimedia Subsystem) and SIP/IP server, (3) to an analog audio adapter containing the permissible set of codecs used by the device under test, and (4) inject the necessary C63.19 test tones at the average speech level for the measurement. The system simulator as R&S CMW500 was used for VoLTE and VoWiFi and CMX500 was used for VoNR testing. The DAU (Data Application Unit) in CMW500 and CMX500 integrates IMS and SIP/IP server that can establish VoLTE, VoNR and VoWiFi calling, and transport the test tones from AMMI (Audio Magnetic Measuring Instrument) to DUT.

Diagram for Base Station Simulator in Establishing VoLTE, VoNR and VoWiFi Calls



The general test setup used for VoLTE, VoNR and VoWiFi is shown below. The CMW500 was used when performing VoLTE and VoWiFi over IMS T-Coil measurements. The DAU (Data Application Unit) of the CMW500 was used to simulate the IMS (IP Multimedia Subsystem) server. Similar architecture, the CMX500 was used for VoNR connection and an external media endpoint as CMX-ZG180A is a soundcard for NR audio interface which is used to perform the A/D conversion and ensure proper speech input level to the DUT.

Test Setup for VoLTE, VoNR and VoWiFi Calls



5.5. Audio Input Level and Gain Measurements

Per KDB 285076 D02 and ANSI C63.19-2011, the applied reference input level applied at the calibrated reference point for legacy protocols fixed to specific air-interfaces are defined in 7.4.2.1 Table 7.1 of ANSI C63.19-2011 or the ANSI C63.19-2011 VoLTE interpretation of July 2012 with −16 dBm0. The normal speech input level for HAC T-coil tests shall be set to -16 dBm0 for GSM, WCDMA and VoLTE. The technical description below shows a possibility to evaluate and set the correct level with the HAC T-Coil setup with an R&S communication tester with codec.

For protocols not listed in Table 7.1 of ANSI C63.19-2011 or the ANSI C63.19-2011 VoLTE interpretation, the average speech level of −20 dBm0 should be used. For VoWiFi and OTT Calling, the average speech level of -20 dBm0 was used for testing.

Reference Audio Input Level:
-16 dBm0 is used for ***GSM***, ***WCDMA***, ***VoLTE***, and ***VoNR***
-20 dBm0 is used for ***VoWiFi***, and ***OTT Calling***

The gain setting for other signal types needs to be adjusted to achieve the same average level. Those signal types have the following differences/factors compared to the 1 kHz sine signal:

Signal Type	Duration (s)	BWC (dB)	Required Gain Factor
1 kHz sine	-	0.0	1.00
48k_voice_1kHz	1	0.16	**4.33**
48k_voice_300-3000	2	10.8	**8.48**

The speech levels with the settings at the AF connector of R&S CMW500 or CMX500 have been calibrated, and it can be set manually to ensure the specific full-scale speech level during T-Coil testing. For an example, the gain setting for -16 dBm0 and -20 dBm0 has been calculated as below.

Audio Input Level (dBm0)	Full-Scale Voltage	AMMI Audio Out (dBV, RMS)	Gain Setting (dB)	Gain Setting (Linear)
3.14	1.0	-3.01		
9.07		2.92	40	100
-16.0			14.93	**5.58**
-20.0			10.93	**3.52**

Audio Input Level (dBm0)	Signal Type	Gain Setting For 1 kHz sine	Gain Factor	Gain Setting (Linear)
-16.0	48k_voice_1kHz	5.58	4.33	**24.16**
-16.0	48k_voice_300-3000	5.58	8.48	**47.32**
-20.0	48k_voice_1kHz	3.52	4.33	**15.24**
-20.0	48k_voice_300-3000	3.52	8.48	**29.85**

6. HAC T-Coil Measurement

6.1. Test Result for GSM CMRS

Codec Investigation

Band	Codec	Channel	Orientation	ABM1 (dB A/m)	ABM2 (dB A/m)	SNR (dB)	Frequency Response Margin (dB)	Frequency Response
GSM850	FR V1	189	Axial (Z)	-5.11	-29.57	24.46	1.47	Pass
GSM850	AMR-NB FR	189	Axial (Z)	-4.81	-30.2	25.39	1.32	Pass
GSM850	AMR-WB FR	189	Axial (Z)	-0.95	-29.72	28.77	1.5	Pass

Air Interface Investigation

Index.	Air Interface	Codec	Channel	Orientation	ABM1 (dB A/m)	ABM2 (dB A/m)	SNR (dB)	Frequency Response Margin (dB)	Frequency Response	Ambient Noise (dB A/m)	T-Rating
1	GSM850	FR V1	189	Axial (Z)	-5.11	-29.57	24.46	1.47	Pass	-50.85	T3
	GSM850	FR V1	189	Radial (Y)	-14.47	-44.69	30.22			-46.41	T4
2	GSM1900	FR V1	661	Axial (Z)	-4.42	-36.24	31.82	1.36	Pass	-50.85	T4
	GSM1900	FR V1	661	Radial (Y)	-14.12	-44.36	30.24			-46.41	T4

6.2. Test Result for WCDMA CMRS

Codec Investigation

Band	Codec	Channel	Orientation	ABM1 (dB A/m)	ABM2 (dB A/m)	SNR (dB)	Frequency Response Margin (dB)	Frequency Response
WCDMA V	NB_AMR 4.75kbps	4182	Axial (Z)	-4.31	-49.62	45.31	0.66	Pass
WCDMA V	NB_AMR 12.2kbps	4182	Axial (Z)	-3.86	-48.68	44.82	1.47	Pass
WCDMA V	WB_AMR 6.6kbps	4182	Axial (Z)	-2.15	-49.63	47.48	1.87	Pass
WCDMA V	WB_AMR 23.85kbps	4182	Axial (Z)	-0.43	-48.91	48.48	1.57	Pass

Air Interface Investigation

Index.	Air Interface	Codec	Channel	Orientation	ABM1 (dB A/m)	ABM2 (dB A/m)	SNR (dB)	Frequency Response Margin (dB)	Frequency Response	Ambient Noise (dB A/m)	T-Rating
3	WCDMA II	NB_AMR 12.2kbps	9400	Axial (Z)	-3.91	-49.95	46.04	1.4	Pass	-50.85	T4
	WCDMA II	NB_AMR 12.2kbps	9400	Radial (Y)	-10.3	-45.16	34.86			-46.41	T4
4	WCDMA IV	NB_AMR 12.2kbps	1413	Axial (Z)	-3.97	-51.16	47.19	1.31	Pass	-50.85	T4
	WCDMA IV	NB_AMR 12.2kbps	1413	Radial (Y)	-10.69	-45.68	34.99			-46.41	T4
5	WCDMA V	NB_AMR 12.2kbps	4182	Axial (Z)	-3.86	-48.68	44.82	1.47	Pass	-50.85	T4
	WCDMA V	NB_AMR 12.2kbps	4182	Radial (Y)	-10.19	-44.56	34.37			-46.41	T4

6.3. Test Result for VoLTE

Radio Configuration Investigation

FDD

Band	Codec	Channel	Bandwidth (MHz)	Modulation	RB Size	RB Offset	Orientation	ABM1 (dB A/m)	ABM2 (dB A/m)	SNR (dB)	Frequency Response Margin (dB)	Frequency Response
LTE B2	AMR NB 4.75kbps	18900	20	QPSK	100	0	Axial (Z)	-4.41	-49.11	44.7	1.44	Pass
LTE B2	AMR NB 12.2kbps	18900	20	QPSK	100	0	Axial (Z)	-3.55	-49.33	45.78	1.47	Pass
LTE B2	AMR WB 6.6kbps	18900	20	QPSK	100	0	Axial (Z)	-1.52	-49.94	48.42	1.73	Pass
LTE B2	AMR WB 23.85kbps	18900	20	QPSK	100	0	Axial (Z)	-1.22	-50.22	49	1.48	Pass
LTE B2	EVS NB 5.9kbps	18900	20	QPSK	100	0	Axial (Z)	-4.31	-49.83	45.52	1.84	Pass
LTE B2	EVS NB 24.4kbps	18900	20	QPSK	100	0	Axial (Z)	-3.72	-50.66	46.94	1.44	Pass
LTE B2	EVS WB 5.9kbps	18900	20	QPSK	100	0	Axial (Z)	-5.28	-50.72	45.44	1.02	Pass
LTE B2	EVS WB 24.4kbps	18900	20	QPSK	100	0	Axial (Z)	-4.04	-50.87	46.83	1.47	Pass
LTE B2	EVS SWB 9.6kbps	18900	20	QPSK	100	0	Axial (Z)	-0.2	-50.52	50.32	2	Pass
LTE B2	EVS SWB 24.4kbps	18900	20	QPSK	100	0	Axial (Z)	-0.45	-50.88	50.43	1.72	Pass
LTE B2	EVS NB-WB 5.9kbps	18900	20	QPSK	100	0	Axial (Z)	-5.15	-51.26	46.11	1.54	Pass
LTE B2	EVS NB-WB 24.4kbps	18900	20	QPSK	100	0	Axial (Z)	-0.07	-50.6	50.53	1.67	Pass
LTE B2	EVS NB-SWB 9.6kbps	18900	20	QPSK	100	0	Axial (Z)	-0.16	-50.71	50.55	1.99	Pass
LTE B2	EVS NB-SWB 24.4kbps	18900	20	QPSK	100	0	Axial (Z)	-0.12	-50.75	50.63	1.82	Pass

TDD

Band	Codec	Channel	Bandwidth (MHz)	Modulation	RB Size	RB Offset	Orientation	ABM1 (dB A/m)	ABM2 (dB A/m)	SNR (dB)	Frequency Response Margin (dB)	Frequency Response
LTE B41	AMR NB 4.75kbps	40620	20	QPSK	100	0	Axial (Z)	-4.45	-48.99	44.54	1.01	Pass
LTE B41	AMR NB 12.2kbps	40620	20	QPSK	100	0	Axial (Z)	-3.89	-48.8	44.91	1.54	Pass
LTE B41	AMR WB 6.6kbps	40620	20	QPSK	100	0	Axial (Z)	-1.31	-48.97	47.66	1.68	Pass
LTE B41	AMR WB 23.85kbps	40620	20	QPSK	100	0	Axial (Z)	-0.48	-48.06	47.58	1.48	Pass
LTE B41	EVS NB 5.9kbps	40620	20	QPSK	100	0	Axial (Z)	-4.85	-45.8	40.95	1.61	Pass
LTE B41	EVS NB 13.2kbps	40620	20	QPSK	100	0	Axial (Z)	-3.63	-40.63	37	1.62	Pass
LTE B41	EVS WB 5.9kbps	40620	20	QPSK	100	0	Axial (Z)	-3.74	-40.5	36.76	1.39	Pass
LTE B41	EVS WB 13.2kbps	40620	20	QPSK	100	0	Axial (Z)	0.5	-40.96	41.46	1.69	Pass
LTE B41	EVS SWB 9.6kbps	40620	20	QPSK	100	0	Axial (Z)	-0.36	-41.96	41.6	2	Pass
LTE B41	EVS SWB 13.2kbps	40620	20	QPSK	100	0	Axial (Z)	0.35	-44.29	44.64	1.63	Pass
LTE B41	EVS NB-WB 5.9kbps	40620	20	QPSK	100	0	Axial (Z)	-5.3	-44.9	39.6	0.96	Pass
LTE B41	EVS NB-WB 24.4kbps	40620	20	QPSK	100	0	Axial (Z)	-0.34	-42.13	41.79	1.46	Pass
LTE B41	EVS NB-SWB 9.6kbps	40620	20	QPSK	100	0	Axial (Z)	0.53	-44.28	44.81	1.96	Pass
LTE B41	EVS NB-SWB 24.4kbps	40620	20	QPSK	100	0	Axial (Z)	0.28	-44.25	44.53	1.56	Pass

Codec Investigation

Band	Codec	Channel	Bandwidth (MHz)	Modulation	RB Size	RB Offset	Orientation	ABM1 (dB A/m)	ABM2 (dB A/m)	SNR (dB)	Frequency Response Margin (dB)	Frequency Response
LTE B2	AMR NB 4.75kbps	18900	20	QPSK	1	0	Axial (Z)	-4.31	-49.74	45.43	1.33	Pass
LTE B2	AMR NB 4.75kbps	18900	20	QPSK	50	0	Axial (Z)	-4.11	-50.06	45.95	1.26	Pass
LTE B2	AMR NB 4.75kbps	18900	20	QPSK	100	0	Axial (Z)	-4.41	-49.11	44.7	1.44	Pass
LTE B2	AMR NB 4.75kbps	18900	20	16QAM	100	0	Axial (Z)	-4.07	-49.59	45.52	1.62	Pass
LTE B2	AMR NB 4.75kbps	18900	20	64QAM	100	0	Axial (Z)	-4.07	-49.54	45.47	1.02	Pass
LTE B2	AMR NB 4.75kbps	18900	20	256QAM	100	0	Axial (Z)	-4.02	-49.26	45.24	1.44	Pass
LTE B2	AMR NB 4.75kbps	18900	15	QPSK	75	0	Axial (Z)	-3.82	-48.83	45.01	0.94	Pass
LTE B2	AMR NB 4.75kbps	18900	10	QPSK	50	0	Axial (Z)	-4.09	-49.62	45.53	1.08	Pass
LTE B2	AMR NB 4.75kbps	18900	5	QPSK	25	0	Axial (Z)	-4.03	-48.86	44.83	1.86	Pass
LTE B2	AMR NB 4.75kbps	18900	3	QPSK	15	0	Axial (Z)	-4.06	-49.05	44.99	0.9	Pass
LTE B2	AMR NB 4.75kbps	18900	1.4	QPSK	6	0	Axial (Z)	-4.04	-48.17	44.13	1.28	Pass
LTE B41	EVS WB 5.9kbps	40620	20	QPSK	100	0	Axial (Z)	-5.31	-47.51	42.2	1.26	Pass
LTE B41	EVS WB 5.9kbps	40620	20	QPSK	100	0	Axial (Z)	-5.24	-46.2	40.96	0.98	Pass
LTE B41	EVS WB 5.9kbps	40620	20	QPSK	100	0	Axial (Z)	-3.35	-46.78	43.43	1.71	Pass
LTE B41	EVS WB 5.9kbps	40620	20	QPSK	100	0	Axial (Z)	-5.84	-47.48	41.64	0.55	Pass
LTE B41	EVS WB 5.9kbps	40620	20	QPSK	100	0	Axial (Z)	-5.66	-47.41	41.75	1.53	Pass
LTE B41	EVS WB 5.9kbps	40620	20	QPSK	100	0	Axial (Z)	-5.53	-47.59	42.06	1.53	Pass
LTE B41	EVS WB 5.9kbps	40620	20	QPSK	100	0	Axial (Z)	-5.17	-47.04	41.87	1.95	Pass

Air Interface Investigation

Index.	Band	Codec	Channel	Bandwidth (MHz)	Modulation	RB Size	RB Offset	Orientation	ABM1 (dB A/m)	ABM2 (dB A/m)	SNR (dB)	Frequency Response Margin (dB)	Frequency Response	Ambient Noise (dB A/m)	T-Rating
6	LTE B2	AMR NB 4.75kbps	18900	20	QPSK	100	0	Axial (Z)	-4.41	-49.11	44.7	1.44	Pass	-50.85	T4
								Radial (Y)	-10.83	-45.71	34.88			-46.41	T4
7	LTE B4	AMR NB 4.75kbps	20175	20	QPSK	100	0	Axial (Z)	-4.32	-49.7	45.38	1.67	Pass	-50.85	T4
								Radial (Y)	-10.58	-45.34	34.76			-46.41	T4
8	LTE B5	AMR NB 4.75kbps	20525	10	QPSK	50	0	Axial (Z)	-4.23	-50.05	45.82	1.19	Pass	-50.85	T4
								Radial (Y)	-10.44	-45.59	35.15			-46.41	T4
9	LTE B7	AMR NB 4.75kbps	21100	20	QPSK	100	0	Axial (Z)	-4.25	-50.13	45.88	1.74	Pass	-50.85	T4
								Radial (Y)	-10.73	-46.02	35.29			-46.41	T4
10	LTE B12	AMR NB 4.75kbps	23095	10	QPSK	50	0	Axial (Z)	-4.07	-50.34	46.27	1.19	Pass	-50.85	T4
								Radial (Y)	-10.41	-46.1	35.69			-46.41	T4
11	LTE B13	AMR NB 4.75kbps	23230	10	QPSK	50	0	Axial (Z)	-4.15	-50.49	46.34	1.84	Pass	-50.85	T4
								Radial (Y)	-10.45	-46.55	36.1			-46.41	T4
12	LTE B14	AMR NB 4.75kbps	23330	10	QPSK	50	0	Axial (Z)	-4.11	-50.35	46.24	1.73	Pass	-50.85	T4
								Radial (Y)	-10.52	-47.29	36.77			-46.41	T4
13	LTE B25	AMR NB 4.75kbps	26365	20	QPSK	100	0	Axial (Z)	-4.29	-49.22	44.93	1.03	Pass	-50.85	T4
								Radial (Y)	-10.62	-46.66	36.04			-46.41	T4
14	LTE B26	AMR NB 4.75kbps	26865	15	QPSK	75	0	Axial (Z)	-4.16	-49	44.84	1.51	Pass	-50.85	T4
								Radial (Y)	-10.44	-46.23	35.79			-46.41	T4
15	LTE B30	AMR NB 4.75kbps	27710	10	QPSK	50	0	Axial (Z)	-4.42	-50.32	45.9	1.33	Pass	-50.85	T4
								Radial (Y)	-10.66	-47.33	36.67			-46.41	T4
16	LTE B66	AMR NB 4.75kbps	132322	20	QPSK	100	0	Axial (Z)	-4.27	-50.99	46.72	1.82	Pass	-50.85	T4
								Radial (Y)	-10.76	-46.88	36.12			-46.41	T4
17	LTE B71	AMR NB 4.75kbps	133297	20	QPSK	100	0	Axial (Z)	-4.03	-51.42	47.39	1.7	Pass	-50.85	T4
								Radial (Y)	-10.54	-47.29	36.75			-46.41	T4
18	LTE B38	EVS WB 5.9kbps	38000	20	QPSK	100	0	Axial (Z)	-6.83	-48.88	42.05	1.46	Pass	-52.41	T4
								Radial (Y)	-10.44	-45.89	35.45			-47.25	T4
19	LTE B40	EVS WB 5.9kbps	39150	20	QPSK	100	0	Axial (Z)	-4.19	-49.08	44.89	1.12	Pass	-52.41	T4
								Radial (Y)	-12.93	-46.33	33.4			-47.25	T4
20	LTE B41	EVS WB 5.9kbps	40620	20	QPSK	100	0	Axial (Z)	-3.57	-48.5	44.93	1.93	Pass	-52.41	T4
								Radial (Y)	-10.31	-45.64	35.33			-47.25	T4
21	LTE B42	EVS WB 5.9kbps	42590	20	QPSK	100	0	Axial (Z)	-3.69	-48.44	44.75	1.1	Pass	-52.41	T4
								Radial (Y)	-10.3	-45.54	35.24			-47.25	T4
22	LTE B48	EVS WB 5.9kbps	56210	20	QPSK	100	0	Axial (Z)	-4.55	-47.81	43.26	0.68	Pass	-52.41	T4
								Radial (Y)	-9.97	-45.61	35.64			-47.25	T4

6.4. Test Result for VoNR

Radio Configuration Investigation

FDD

Band	Codec	Channel	Bandwidth (MHz)	Modulation	RB Size	RB Offset	Orientation	ABM1 (dB A/m)	ABM2 (dB A/m)	SNR (dB)	Frequency Response Margin (dB)	Frequency Response
FR1 n2	AMR NB 4.75kbps	376000	20	DFTS-QPSK	100	0	Axial (Z)	-5.1	-40.23	35.13	1.46	Pass
FR1 n2	AMR NB 12.2kbps	376000	20	DFTS-QPSK	100	0	Axial (Z)	-4.9	-40.96	36.06	1.33	Pass
FR1 n2	AMR WB 6.6kbps	376000	20	DFTS-QPSK	100	0	Axial (Z)	-4.31	-44	39.69	2	Pass
FR1 n2	AMR WB 23.85kbps	376000	20	DFTS-QPSK	100	0	Axial (Z)	-3.27	-42.66	39.39	1.41	Pass
FR1 n2	EVS NB 5.9kbps	376000	20	DFTS-QPSK	100	0	Axial (Z)	-4.96	-36.37	31.41	0.51	Pass
FR1 n2	EVS NB 24.4kbps	376000	20	DFTS-QPSK	100	0	Axial (Z)	-5.66	-40.53	34.87	1.5	Pass
FR1 n2	EVS WB 5.9kbps	376000	20	DFTS-QPSK	100	0	Axial (Z)	-1.97	-39	37.03	1.28	Pass
FR1 n2	EVS WB 24.4kbps	376000	20	DFTS-QPSK	100	0	Axial (Z)	-2.17	-40.82	38.65	1.41	Pass
FR1 n2	EVS SWB 9.6kbps	376000	20	DFTS-QPSK	100	0	Axial (Z)	-0.86	-40.39	39.53	1.72	Pass
FR1 n2	EVS SWB 24.4kbps	376000	20	DFTS-QPSK	100	0	Axial (Z)	-1.16	-39.65	38.49	1.85	Pass
FR1 n2	EVS NB-WB 5.9kbps	376000	20	DFTS-QPSK	100	0	Axial (Z)	-3.35	-39.25	35.9	1.95	Pass
FR1 n2	EVS NB-WB 24.4kbps	376000	20	DFTS-QPSK	100	0	Axial (Z)	-2.08	-42.99	40.91	1.62	Pass
FR1 n2	EVS NB-SWB 9.6kbps	376000	20	DFTS-QPSK	100	0	Axial (Z)	-0.31	-40.94	40.63	1.75	Pass
FR1 n2	EVS NB-SWB 24.4kbps	376000	20	DFTS-QPSK	100	0	Axial (Z)	-0.86	-40.46	39.6	1.8	Pass

TDD

Band	Codec	Channel	Bandwidth (MHz)	Modulation	RB Size	RB Offset	Orientation	ABM1 (dB A/m)	ABM2 (dB A/m)	SNR (dB)	Frequency Response Margin (dB)	Frequency Response
FR1 n78	AMR NB 4.75kbps	645619	100	DFTS-QPSK	270	0	Axial (Z)	-5	-40.02	35.02	1.43	Pass
FR1 n78	AMR NB 12.2kbps	645619	100	DFTS-QPSK	270	0	Axial (Z)	-4.44	-40.83	36.39	1.26	Pass
FR1 n78	AMR WB 6.6kbps	645619	100	DFTS-QPSK	270	0	Axial (Z)	-1.99	-33.48	31.49	1.74	Pass
FR1 n78	AMR WB 23.85kbps	645619	100	DFTS-QPSK	270	0	Axial (Z)	-1.61	-33.47	31.86	1.61	Pass
FR1 n78	EVS NB 5.9kbps	645619	100	DFTS-QPSK	270	0	Axial (Z)	-6.9	-37.84	30.94	1	Pass
FR1 n78	EVS NB 24.4kbps	645619	100	DFTS-QPSK	270	0	Axial (Z)	-6.11	-41.02	34.91	1.52	Pass
FR1 n78	EVS WB 5.9kbps	645619	100	DFTS-QPSK	270	0	Axial (Z)	-3.11	-39.06	35.95	1.25	Pass
FR1 n78	EVS WB 24.4kbps	645619	100	DFTS-QPSK	270	0	Axial (Z)	-2.25	-39.59	37.34	1.82	Pass
FR1 n78	EVS SWB 9.6kbps	645619	100	DFTS-QPSK	270	0	Axial (Z)	-0.62	-39.46	38.84	1.99	Pass
FR1 n78	EVS SWB 24.4kbps	645619	100	DFTS-QPSK	270	0	Axial (Z)	-0.96	-38.91	37.95	1.79	Pass
FR1 n78	EVS NB-WB 5.9kbps	645619	100	DFTS-QPSK	270	0	Axial (Z)	-3.69	-38.7	35.01	1.39	Pass
FR1 n78	EVS NB-WB 24.4kbps	645619	100	DFTS-QPSK	270	0	Axial (Z)	-1.26	-39.03	37.77	1.8	Pass
FR1 n78	EVS NB-SWB 9.6kbps	645619	100	DFTS-QPSK	270	0	Axial (Z)	-1.43	-39.61	38.18	1.99	Pass
FR1 n78	EVS NB-SWB 24.4kbps	645619	100	DFTS-QPSK	270	0	Axial (Z)	-0.97	-38.32	37.35	1.86	Pass

Codec Investigation

Band	Codec	Channel	Bandwidth (MHz)	Modulation	RB Size	RB Offset	Orientation	ABM1 (dB A/m)	ABM2 (dB A/m)	SNR (dB)	Frequency Response Margin (dB)	Frequency Response
FR1 n2	EVS NB 5.9kbps	376000	20	DFT-S π/2 BPSK	1	1	Axial (Z)	-4.76	-38.87	34.11	1.34	Pass
FR1 n2	EVS NB 5.9kbps	376000	20	DFT-S π/2 BPSK	25	0	Axial (Z)	-4.75	-38.82	34.07	1.17	Pass
FR1 n2	EVS NB 5.9kbps	376000	20	DFT-S π/2 BPSK	100	0	Axial (Z)	-7.68	-41.66	33.98	1.35	Pass
FR1 n2	EVS NB 5.9kbps	376000	20	DFT-S QPSK	100	0	Axial (Z)	-4.96	-36.39	31.43	0.51	Pass
FR1 n2	EVS NB 5.9kbps	376000	20	DFT-S 16QAM	100	0	Axial (Z)	-2.21	-38.72	36.51	1.65	Pass
FR1 n2	EVS NB 5.9kbps	376000	20	DFT-S 64QAM	100	0	Axial (Z)	-3.75	-37.78	34.03	1.14	Pass
FR1 n2	EVS NB 5.9kbps	376000	20	DFT-S 256QAM	100	0	Axial (Z)	-1.68	-38.11	36.43	2	Pass
FR1 n2	EVS NB 5.9kbps	376000	20	CP QPSK	100	0	Axial (Z)	-3.79	-38.97	35.18	2	Pass
FR1 n2	EVS NB 5.9kbps	376000	15	DFT-S QPSK	75	0	Axial (Z)	-3.69	-38.03	34.34	1.16	Pass
FR1 n2	EVS NB 5.9kbps	376000	10	DFT-S QPSK	50	0	Axial (Z)	-2.29	-36.95	34.66	1.31	Pass
FR1 n2	EVS NB 5.9kbps	376000	5	DFT-S QPSK	25	0	Axial (Z)	-4.47	-38.89	34.42	2	Pass
FR1 n78	EVS NB 5.9kbps	645619	100	DFT-S QPSK	270	0	Axial (Z)	-6.9	-37.84	30.94	1	Pass
FR1 n78	EVS NB 5.9kbps	645619	100	DFT-S QPSK	270	0	Axial (Z)	-5.13	-38.82	33.69	1.5	Pass
FR1 n78	EVS NB 5.9kbps	645619	100	DFT-S QPSK	270	0	Axial (Z)	-7.06	-42.51	35.45	1.2	Pass
FR1 n78	EVS NB 5.9kbps	645619	100	DFT-S QPSK	270	0	Axial (Z)	-3.53	-36.58	33.05	2	Pass
FR1 n78	EVS NB 5.9kbps	645619	100	DFT-S QPSK	270	0	Axial (Z)	-6.88	-40.43	33.55	1.15	Pass
FR1 n78	EVS NB 5.9kbps	645619	100	DFT-S QPSK	270	0	Axial (Z)	-4.41	-40.04	35.63	1.34	Pass
FR1 n78	EVS NB 5.9kbps	645619	100	DFT-S QPSK	270	0	Axial (Z)	-4.98	-40.36	35.38	1.42	Pass

Air Interface Investigation

Index.	Band	Codec	Channel	Bandwidth (MHz)	Modulation	RB Size	RB Offset	Orientation	ABM1 (dB A/m)	ABM2 (dB A/m)	SNR (dB)	Frequency Response Margin (dB)	Frequency Response	Ambient Noise (dB A/m)	T-Rating
23	FR1 n2	EVS NB 5.9kbps	376000	20	DFT-S QPSK	100	0	Axial (Z)	-4.96	-36.39	31.43	0.51	Pass	-51.87	T4
								Radial (Y)	-10.77	-41.09	30.32			-46.41	T4
24	FR1 n5	EVS NB 5.9kbps	167300	20	DFT-S QPSK	100	0	Axial (Z)	-7.45	-40.94	33.49	1.09	Pass	-51.87	T4
								Radial (Y)	-13.07	-43.34	30.27			-46.41	T4
25	FR1 n7	EVS NB 5.9kbps	507000	20	DFT-S QPSK	100	0	Axial (Z)	-5.33	-36.75	31.42	0.94	Pass	-51.87	T4
								Radial (Y)	-12.47	-44.16	31.69			-46.41	T4
26	FR1 n12	EVS NB 5.9kbps	141500	15	DFT-S QPSK	75	0	Axial (Z)	-9.08	-42.68	33.6	0.79	Pass	-51.87	T4
								Radial (Y)	-11.42	-42.03	30.61			-46.41	T4
27	FR1 n13	EVS NB 5.9kbps	156400	10	DFT-S QPSK	50	0	Axial (Z)	-5.14	-39.21	34.07	0.33	Pass	-51.87	T4
								Radial (Y)	-11.65	-43.87	32.22			-46.41	T4
28	FR1 n14	EVS NB 5.9kbps	158600	10	DFT-S QPSK	50	0	Axial (Z)	-8.44	-41.18	32.74	1.07	Pass	-51.87	T4
								Radial (Y)	-11.21	-42.94	31.73			-46.41	T4
29	FR1 n25	EVS NB 5.9kbps	376500	20	DFT-S QPSK	100	0	Axial (Z)	-5.67	-39.18	33.51	1.01	Pass	-51.87	T4
								Radial (Y)	-12.21	-43.18	30.97			-46.41	T4
30	FR1 n30	EVS NB 5.9kbps	462000	10	DFT-S QPSK	50	0	Axial (Z)	-5.62	-39.91	34.29	0.66	Pass	-51.87	T4
								Radial (Y)	-12.64	-44.78	32.14			-46.41	T4
31	FR1 n66	EVS NB 5.9kbps	349000	20	DFT-S QPSK	100	0	Axial (Z)	-7.82	-41.18	33.36	1.11	Pass	-51.87	T4
								Radial (Y)	-13.02	-43.53	30.51			-46.41	T4
32	FR1 n71	EVS NB 5.9kbps	136100	20	DFT-S QPSK	100	0	Axial (Z)	-5.68	-39.71	34.03	1.35	Pass	-51.87	T4
								Radial (Y)	-12.14	-43.75	31.61			-46.41	T4
33	FR1 n38	EVS NB 5.9kbps	519000	40	DFT-S QPSK	100	0	Axial (Z)	-1.6	-33.59	31.99	1.62	Pass	-51.87	T4
								Radial (Y)	-11.99	-41.79	29.8			-46.41	T3
34	FR1 n41	EVS NB 5.9kbps	518598	100	DFT-S QPSK	270	0	Axial (Z)	-6.33	-38.57	32.24	1.4	Pass	-46.41	T4
								Radial (Y)	-11.07	-41.03	29.96			-46.41	T3
35	FR1 n48	EVS NB 5.9kbps	640444	40	DFT-S QPSK	100	0	Axial (Z)	-3.23	-33.41	30.18	1.8	Pass	-51.87	T4
								Radial (Y)	-12.58	-42.56	29.98			-46.41	T3
36	FR1 n77	EVS NB 5.9kbps	645619	100	DFT-S QPSK	270	0	Axial (Z)	-5.37	-36.32	30.95	1.56	Pass	-51.87	T4
								Radial (Y)	-15.4	-44.4	29			-46.41	T3
37	FR1 n78	EVS NB 5.9kbps	645619	100	DFT-S QPSK	270	0	Axial (Z)	-6.9	-37.84	30.94	1	Pass	-51.87	T4
								Radial (Y)	-14.62	-42.78	28.16			-46.41	T3

6.5. Test Result for VoWiFi

Codec Investigation

Band	Codec	Channel	Modulation	Data Rate	Orientation	ABM1 (dB A/m)	ABM2 (dB A/m)	SNR (dB)	Frequency Response Margin (dB)	Frequency Response
WLAN 2.4GHz	AMR NB 4.75kbps	6	802.11b	1 Mbps	Axial (Z)	-8.33	-39.97	31.64	2	Pass
WLAN 2.4GHz	AMR NB 12.2kbps	6	802.11b	1 Mbps	Axial (Z)	-8.75	-40.9	32.15	1.52	Pass
WLAN 2.4GHz	AMR WB 6.6kbps	6	802.11b	1 Mbps	Axial (Z)	-9.98	-42.1	32.12	2	Pass
WLAN 2.4GHz	AMR WB 23.85kbps	6	802.11b	1 Mbps	Axial (Z)	-6.25	-39.5	33.25	1.9	Pass
WLAN 2.4GHz	EVS NB 5.9kbps	6	802.11b	1 Mbps	Axial (Z)	-5.79	-37.13	31.34	1.59	Pass
WLAN 2.4GHz	EVS NB 24.4kbps	6	802.11b	1 Mbps	Axial (Z)	-8.46	-41.65	33.19	1.71	Pass
WLAN 2.4GHz	EVS WB 5.9kbps	6	802.11b	1 Mbps	Axial (Z)	-7.75	-40.82	33.07	2	Pass
WLAN 2.4GHz	EVS WB 24.4kbps	6	802.11b	1 Mbps	Axial (Z)	-7.5	-41.48	33.98	1.93	Pass
WLAN 2.4GHz	EVS SWB 9.6kbps	6	802.11b	1 Mbps	Axial (Z)	-6.68	-39.06	32.38	1.79	Pass
WLAN 2.4GHz	EVS SWB 24.4kbps	6	802.11b	1 Mbps	Axial (Z)	-4.17	-36.66	32.49	1.89	Pass
WLAN 2.4GHz	EVS NB-WB 5.9kbps	6	802.11b	1 Mbps	Axial (Z)	-7.93	-39.32	31.39	1.82	Pass
WLAN 2.4GHz	EVS NB-WB 24.4kbps	6	802.11b	1 Mbps	Axial (Z)	-5.15	-37.02	31.87	2	Pass
WLAN 2.4GHz	EVS NB-SWB 9.6kbps	6	802.11b	1 Mbps	Axial (Z)	-6.4	-37.94	31.54	2	Pass
WLAN 2.4GHz	EVS NB-SWB 24.4kbps	6	802.11b	1 Mbps	Axial (Z)	-5.72	-38.06	32.34	1.99	Pass

Radio Configuration Investigation

Band	Codec	Channel	Modulation	Data Rate	Orientation	ABM1 (dB A/m)	ABM2 (dB A/m)	SNR (dB)	Frequency Response Margin (dB)	Frequency Response
WLAN 2.4GHz	EVS NB 5.9kbps	6	802.11b	1Mbps	Axial (Z)	-5.79	-37.13	31.34	1.59	Pass
WLAN 2.4GHz	EVS NB 5.9kbps	6	802.11b	11Mbps	Axial (Z)	-7.71	-39.22	31.51	2	Pass
WLAN 2.4GHz	EVS NB 5.9kbps	6	802.11g	6Mbps	Axial (Z)	-7.73	-39.71	31.98	2	Pass
WLAN 2.4GHz	EVS NB 5.9kbps	6	802.11g	54Mbps	Axial (Z)	-7.97	-40.31	32.34	1.67	Pass
WLAN 2.4GHz	EVS NB 5.9kbps	6	802.11n HT20	MCS0	Axial (Z)	-5.78	-38.34	32.56	1.29	Pass
WLAN 2.4GHz	EVS NB 5.9kbps	6	802.11n HT20	MCS7	Axial (Z)	-5.27	-37.88	32.61	1.94	Pass
WLAN 2.4GHz	EVS NB 5.9kbps	6	802.11n HT40	MCS0	Axial (Z)	-9.95	-42.38	32.43	2	Pass
WLAN 2.4GHz	EVS NB 5.9kbps	6	802.11n HT40	MCS7	Axial (Z)	-6.02	-37.91	31.89	1.39	Pass
WLAN 2.4GHz	EVS NB 5.9kbps	6	802.11ac VHT20	MCS0	Axial (Z)	-5.37	-37.08	31.71	1.92	Pass
WLAN 2.4GHz	EVS NB 5.9kbps	6	802.11ac VHT20	MCS8	Axial (Z)	-7.4	-38.85	31.45	1.41	Pass
WLAN 2.4GHz	EVS NB 5.9kbps	6	802.11ac VHT40	MCS0	Axial (Z)	-4.69	-37.25	32.56	2	Pass
WLAN 2.4GHz	EVS NB 5.9kbps	6	802.11ac VHT40	MCS8	Axial (Z)	-7.27	-39.73	32.46	2	Pass
WLAN 5.2GHz	EVS NB 5.9kbps	40	802.11a	6Mbps	Axial (Z)	-8.4	-38.52	30.12	1.68	Pass
WLAN 5.2GHz	EVS NB 5.9kbps	40	802.11a	54Mbps	Axial (Z)	-7.05	-37.18	30.13	1.62	Pass
WLAN 5.2GHz	EVS NB 5.9kbps	40	802.11n HT20	MCS0	Axial (Z)	-8.24	-38.27	30.03	2	Pass
WLAN 5.2GHz	EVS NB 5.9kbps	40	802.11n HT20	MCS7	Axial (Z)	-10.16	-41.18	31.02	0.68	Pass
WLAN 5.2GHz	EVS NB 5.9kbps	38	802.11n HT40	MCS0	Axial (Z)	-6.06	-38.3	32.24	2	Pass
WLAN 5.2GHz	EVS NB 5.9kbps	38	802.11n HT40	MCS7	Axial (Z)	-8.42	-41.34	32.92	1.96	Pass
WLAN 5.2GHz	EVS NB 5.9kbps	40	802.11ac VHT20	MCS0	Axial (Z)	-7.18	-41.12	33.94	1.09	Pass
WLAN 5.2GHz	EVS NB 5.9kbps	40	802.11ac VHT20	MCS8	Axial (Z)	-6.1	-39.88	33.78	1.71	Pass
WLAN 5.2GHz	EVS NB 5.9kbps	38	802.11ac VHT40	MCS0	Axial (Z)	-15.54	-49.73	34.19	1.53	Pass
WLAN 5.2GHz	EVS NB 5.9kbps	38	802.11ac VHT40	MCS8	Axial (Z)	-8.85	-40.94	32.09	1.93	Pass
WLAN 5.2GHz	EVS NB 5.9kbps	42	802.11ac VHT80	MCS0	Axial (Z)	-5.61	-38.38	32.77	1.93	Pass
WLAN 5.2GHz	EVS NB 5.9kbps	42	802.11ac VHT80	MCS9	Axial (Z)	-5.36	-37.71	32.35	1.85	Pass
WLAN 5.2GHz	EVS NB 5.9kbps	50	802.11ac VHT160	MCS0	Axial (Z)	-6.94	-39.97	33.03	0.87	Pass
WLAN 5.2GHz	EVS NB 5.9kbps	50	802.11ac VHT160	MCS9	Axial (Z)	-7.24	-40.32	33.08	1.33	Pass
WLAN 5.2GHz	EVS NB 5.9kbps	50	802.11ax HE160	MCS0	Axial (Z)	-6.25	-40.01	33.76	0.67	Pass
WLAN 5.2GHz	EVS NB 5.9kbps	50	802.11ax HE160	MCS11	Axial (Z)	-6.76	-40.35	33.59	1.4	Pass

Air Interface Investigation

Plot No.	Band	Codec	Channel	Modulation	Data Rate	Orientation	ABM1 (dB A/m)	ABM2 (dB A/m)	SNR (dB)	Frequency Response Margin (dB)	Frequency Response	Ambient Noise (dB A/m)	T-Rating
38	WLAN 2.4GHz	EVS NB 5.9kbps	6	802.11b	1Mbps	Axial (Z)	-5.79	-37.13	31.34	1.59	Pass	-52.05	T4
						Radial (Y)	-8.89	-43.86	34.97			-47.34	T4
39	WLAN 5.2GHz	EVS NB 5.9kbps	40	802.11n HT20	MCS0	Axial (Z)	-8.24	-38.27	30.03	2	Pass	-52.05	T4
						Radial (Y)	-10.28	-44.89	34.61			-47.34	T4
40	WLAN 5.3GHz	EVS NB 5.9kbps	60	802.11n HT20	MCS0	Axial (Z)	-7.03	-39.59	32.56	1.28	Pass	-52.05	T4
						Radial (Y)	-8.85	-44.97	36.12			-47.34	T4
41	WLAN 5.6GHz	EVS NB 5.9kbps	116	802.11n HT20	MCS0	Axial (Z)	-6.46	-39.33	32.87	1.52	Pass	-52.05	T4
						Radial (Y)	-10.53	-45.36	34.83			-47.34	T4
42	WLAN 5.8GHz	EVS NB 5.9kbps	157	802.11n HT20	MCS0	Axial (Z)	-7.24	-40.35	33.11	1.3	Pass	-52.05	T4
						Radial (Y)	-10.93	-45.64	34.71			-47.34	T4

7. Test Equipment

Equipment	Manufacturer	Model No.	Serial No.	Cal. Date	Cal. Interval
T-Coil Audio Magnetic 1D Field Probe	SPEAG	AM1DV3	3156	Aug 21, 2023	1 year
Data Acquisition Electronics	SPEAG	DAE4	779	Aug 07, 2023	1 year
Wireless Communication Test Set	R&S	CMW500	170768	Nov. 30, 2022	1 year
Wireless Communication Test Set	R&S	CMX500	102194	Jun. 01, 2023	1 year

Note: CBT (Calibrated Before Testing). Prior to testing, the measurement paths containing a cable, attenuator, coupler, or filter were connected to a calibrated source to determine the losses of the measurement path. The power meter offset was then adjusted to compensate for the measurement system losses. This level offset is stored within the power meter before measurements are made. This calibration verification procedure applies to output power measurements. The calibrated reading is then taken directly from the power meter after compensation of the losses for all final power measurements.

Test Engineer：Mars Chang, Raymond Wu

8. Measurement Uncertainty

The measurement uncertainties were not taken into account and are published for informational purposes only. The test results show that the equipment tested is capable of demonstrating compliance with the requirements as documented in this report.

Decision Rule:

■ Uncertainty is not included.

☐ Uncertainty is included.

Uncertainty Budget for HAC T-Coil

Source of Uncertainty	Uncertainty (± %)	Probability Distribution	Div.	ci (ABM1)	ci (ABM2)	Standard Uncertainty (± %, ABM1)	Standard Uncertainty (± %, ABM2)
Probe Sensitivity							
Reference Level	3.0	N	1	1	1	3.0	3.0
AMCC Geometry	0.4	R	$\sqrt{3}$	1	1	0.2	0.2
AMCC Current	1.0	R	$\sqrt{3}$	1	1	0.6	0.6
Probe Positioning During Calibration	0.07	R	$\sqrt{3}$	1	1	0.04	0.04
Noise Contribution	0.02	R	$\sqrt{3}$	0.0143	1	0.00	0.01
Frequency Slope	5.9	R	$\sqrt{3}$	0.1	1	0.3	3.4
Probe System							
Repeatability / Drift	1.0	R	$\sqrt{3}$	1	1	0.6	0.6
Linearity / Dynamic Range	0.6	R	$\sqrt{3}$	1	1	0.3	0.3
Acoustic Noise	1.0	R	$\sqrt{3}$	0.1	1	0.1	0.6
Probe Angle	2.3	R	$\sqrt{3}$	1	1	1.3	1.3
Spectral Processing	0.9	R	$\sqrt{3}$	1	1	0.5	0.5
Integration Time	0.6	N	1	1	5	0.6	3.0
Field Disturbation	0.2	R	$\sqrt{3}$	1	1	0.1	0.1
Test Signal							
Reference Signal Spectral Response	0.6	R	$\sqrt{3}$	0	1	0.0	0.3
Positioning							
Probe Positioning	1.9	R	$\sqrt{3}$	1	1	1.1	1.1
Phantom Thickness	0.9	R	$\sqrt{3}$	1	1	0.5	0.5
DUT Positioning	1.9	R	$\sqrt{3}$	1	1	1.1	1.1
External Contribution							
RF Interference	0.0	R	$\sqrt{3}$	1	0.3	0.0	0.0
Test Signal Variation	2.0	R	$\sqrt{3}$	1	1	1.2	1.2
Combined Standard Uncertainty					**RSS**	4.0	6.1
Expanded uncertainty (95 % conf. interval)						**8.0**	**12.2**

************************************** End of Report **************************************