# HAC T-Coil TEST REPORT

No. 23T04Z80421-32

**For**

**TCL Communication Ltd.**

**GSM/UMTS/LTE/NR Mobile phone**

**Model Name: T614D**

**with**

**Hardware Version: 06**

**Software Version: 3CSF**

**FCC ID: 2ACCJH179**

**HAC-2019 Compliance: PASS**

**Issued Date: 2023-12-29**

**Note:**

The test results in this test report relate only to the devices specified in this report. This report shall not be reproduced except in full without the written approval of CTTL.

**Test Laboratory:**

**CTTL, Telecommunication Technology Labs, CAICT**

No. 52, Huayuan North Road, Haidian District, Beijing, P. R. China 100191.

Tel:+86(0)10-62304633-2512, Fax:+86(0)10-62304633-2504

Email: cttl_terminals@caict.ac.cn, website: www.caict.ac.cn

# REPORT HISTORY

| Report Number | Revision | Issue Date | Description |
| --- | --- | --- | --- |
| 23T04Z80421-32 | Rev.0 | 2023-12-29 | Initial creation of test report |

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# 1 Test Laboratory

## 1.1 Introduction & Accreditation

**Telecommunication Technology Labs, CAICT** is an ISO/IEC 17025:2017 accredited test laboratory under American Association for Laboratory Accreditation (A2LA) with lab code 7049.01, and is also an FCC accredited test laboratory (CN1349), and ISED accredited test laboratory (CAB identifier:CN0066). The detail accreditation scope can be found on A2LA website.

## 1.2 Testing Location

| | |
|---|---|
| Company Name: | CTTL |
| Address: | No. 52, Huayuan North Road, Haidian District, Beijing, P. R. China 100191. |

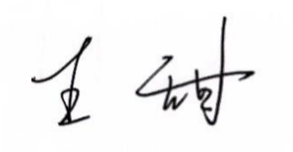
## 1.3 Testing Environment

| | |
|---|---|
| Temperature: | 18°C~25°C, |
| Relative humidity: | 30%~ 70% |
| Ground system resistance: | < 0.5 Ω |
| Ambient noise is checked and found very low and in compliance with requirement of standards. Reflection of surrounding objects is minimized and in compliance with requirement of standards | |

## 1.4 Project Data

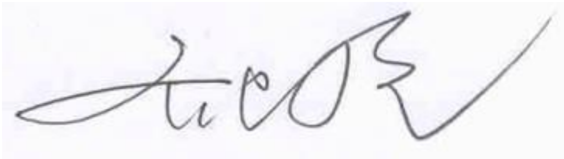
| | |
|---|---|
| Project Leader: | Qi Dianyuan |
| Test Engineer: | Wang Tian |
| Testing Start Date: | December 8, 2023 |
| Testing End Date: | December 28, 2023 |

## 1.5 Signature



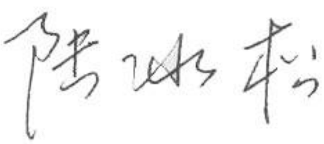
**Wang Tian**

**(Prepared this test report)**



**Qi Dianyuan**

**(Reviewed this test report)**



**Lu Bingsong**

**Deputy Director of the laboratory**

**(Approved this test report)**

# 2 Client Information

## 2.1 Applicant Information

| | |
|---|---|
| Company Name: | TCL Communication Ltd. |
| Address/Post: | 5/F, Building 22E, 22 Science Park East Avenue, Hong Kong Science Park, Shatin, NT, Hong Kong |
| Contact Person: | Annie Jiang |
| Contact Email: | nianxiang.jiang@tcl.com |
| Telephone: | +86 755 3661 1621 |
| Fax | +86 755 3661 2000-81722 |

## 2.2 Manufacturer Information

| | |
|---|---|
| Company Name: | TCL Communication Ltd. |
| Address/Post: | 5/F, Building 22E, 22 Science Park East Avenue, Hong Kong Science Park, Shatin, NT, Hong Kong |
| Contact Person: | Annie Jiang |
| Contact Email: | nianxiang.jiang@tcl.com |
| Telephone: | +86 755 3661 1621 |
| Fax | +86 755 3661 2000-81722 |

# 3 Equipment Under Test (EUT) and Ancillary Equipment (AE)

## 3.1 About EUT

| | |
|---|---|
| Description: | GSM/UMTS/LTE/NR Mobile phone |
| Model name: | T614D |
| Operating mode(s): | GSM850/900/18001900,<br>WCDMA B1/2/4/5/8<br>LTE Band 1/2/3/4/5/7/12/13/20/25/26/28/38/40/41/48/66/71<br>5G NR N2/5/25/41/48/66/71/77/78<br>BT, Wi-Fi 2.4G/5G,NFC |

## 3.2 Internal Identification of EUT used during the test

| EUT ID* | IMEI | HW Version | SW Version |
|---|---|---|---|
| EUT1 | 016499000012605/016499000012639 | 06 | 3CSF |
| EUT2 | 016499000012910/016499000012951 | 06 | 3CSF |

*EUT ID: is used to identify the test sample in the lab internally.

## 3.3 Internal Identification of AE used during the test

| AE ID* | Description | Model | SN | Manufacturer |
|---|---|---|---|---|
| AE1 | Battery | TLp049FA | / | TMB |
| AE2 | Battery | TLp049F7 | / | Veken |

*AE ID: is used to identify the test sample in the lab internally.

## 3.4 Air Interfaces / Bands Indicating Operating Modes

| Air-interface | Band(MHz) | Type | C63.19/tested | Simultaneous Transmissions | Name of Voice Service |
|---|---|---|---|---|---|
| GSM | 850 | VO | Yes | BT, WLAN | CMRS Voice |
| | 1900 | | | | |
| GPRS/EDGE | 850 | DT | Yes | | MEET |
| | 1900 | | | | |
| WCDMA (UMTS) | 850 | VO | Yes | BT, WLAN | CMRS Voice |
| | 1700 | | | | |
| | 1900 | | | | |
| | HSPA | DT | Yes | | MEET |
| LTE TDD | Band41/48 | V/D | Yes | BT, WLAN | VoLTE, MEET |
| LTE FDD | Band2/4/5/7/12/13/25/26/66/71 | V/D | Yes | BT, WLAN | VoLTE, MEET |
| NR | n2/n5/n25/n41/n48/n66/n71/n77/n78 | DT | Yes | BT, WLAN | VoNR, MEET |
| BT | 2450 | DT | NA | WWAN | NA |
| WLAN | 2450 | V/D | Yes | WWAN | VoWiFi, MEET |
| WLAN | 5G | V/D | Yes | WWAN | VoWiFi, MEET |

NA: Not Applicable VO: Voice Only V/D: CMRS and IP Voice Service over Digital Transport DT: Digital Transport

# 4 Reference Documents

The following document listed in this section is referred for testing.

| Reference | Title | Version |
|---|---|---|
| ANSI C63.19 | American National Standard Methods of Measurement of Compatibility Between Wireless Communications Devices and Hearing Aids | 2019 Edition |
| KDB285076 D01v06r04 | Equipment Authorization Guidance for Hearing Aid Compatibility | 2023 Edition |
| KDB285076 D02v04 | Guidance for performing T-Coil tests for air interfaces supporting voice over IP (e.g., LTE and WiFi) to support CMRS based telephone services | 2022 Edition |
| KDB285076 D03v01r06 | Hearing aid compatibility frequently asked questions | 2022 Edition |

# 5 OPERATIONAL CONDITIONS DURING TEST

## 5.1 HAC MEASUREMENT SET-UP

These measurements are performed using the DASY6/8 automated dosimetric assessment system. It is made by Schmid & Partner Engineering AG (SPEAG) in Zurich, Switzerland. It consists of high precision robotics system (Stäubli), robot controller, Intel Core2 computer, near-field probe, probe alignment sensor. The robot is a six-axis industrial robot performing precise movements. A cell controller system contains the power supply, robot controller, teach pendant (Joystick),and remote control, is used to drive the robot motors. The PC consists of the HP Intel Core21.86 GHz computer with Windows 10 system and HAC Measurement Software DASY6/8, A/D interface card, monitor, mouse, and keyboard. The Stäubli Robot is connected to the cell controller to allow software manipulation of the robot. A data acquisition electronic (DAE)circuit performs the signal amplification, signal multiplexing, AD-conversion, offset measurements, mechanical surface detection, collision detection, etc. is connected to the Electro-optical coupler (EOC). The EOC performs the conversion from the optical into digital electric signal of the DAE and transfers data to the PC plug-in card.

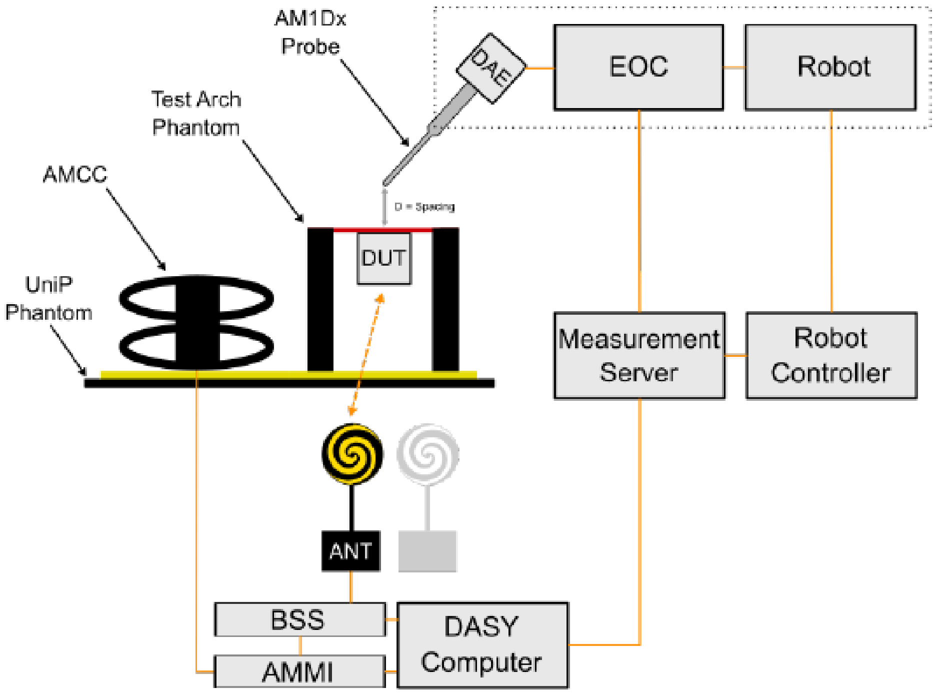



**Figure 5.1 HAC Test Measurement Set-up**

The DAE4 consists of a highly sensitive electrometer-grade preamplifier with auto-zeroing, a channel and gain-switching multiplexer, a fast 16 bit AD-converter and a command decoder and control logic unit. Transmission to the PC-card is accomplished through an optical downlink for data and status information and an optical uplink for commands and clock lines. The mechanical probe mounting device includes two different sensor systems for frontal and sidewise probe contacts. They are also used for mechanical surface detection and probe collision detection. The robot uses its own controller with a built in VME-bus computer.

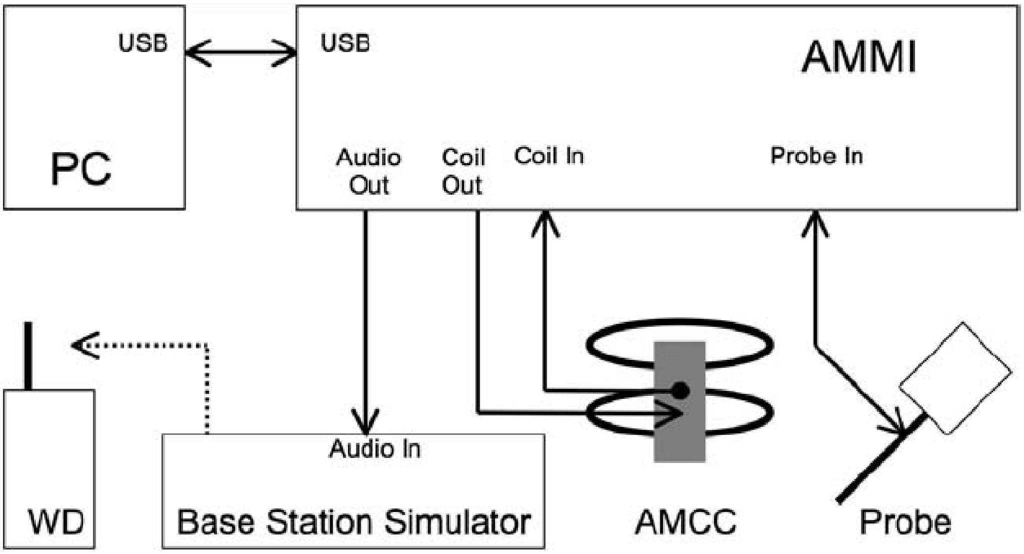



**Figure 5.2 T-Coil setup with HAC Test Arch and AMCC**

## 5.2 AM1D probe

The AM1D probe is an active probe with a single sensor. It is fully RF-shielded and has a rounded tip 6mm in diameter incorporating a pickup coil with its center offset 3mm from the tip and the sides. The symmetric signal preamplifier in the probe is fed via the shielded symmetric output cable from the AMMI with a 48V "phantom" voltage supply. The 7-pin connector on the back in the axis of the probe does not carry any signals. It is mounted to the DAE for the correct orientation of the sensor. If the probe axis is tilted 54.7 degree from the vertical, the sensor is approximately vertical when the signal connector is at the underside of the probe (cable hanging downwards).

Specification:

| | |
|---|---|
| **Frequency range** | 0.1~20kHz (RF sensitivity < -100dB, fully RF shielded) |
| **Sensitivity** | < -50dB A/m @ 1kHz |
| **Pre-amplifier** | 40dB, symmetric |
| **Dimensions** | Tip diameter/length: 6/290mm, sensor according to ANSI-C63.19 |

## 5.3 AMCC

The Audio Magnetic Calibration coil is a Helmholtz Coil designed for calibration of the AM1D probe. The two horizontal coils generate a homogeneous magnetic field in the z direction. The DC input resistance is adjusted by a series resistor to approximately 50Ohm, and a shunt resistor of 10Ohm permits monitoring the current with a scale of 1:10

Port description:

| **Signal** | **Connector** | **Resistance** |
|---|---|---|
| Coil In | BNC | Typically 50Ohm |
| Coil Monitor | BNO | 10Ohm±1% (100mV corresponding to 1 A/m) |

Specification:

| | |
|---|---|
| **Dimensions** | 370 x 370 x 196 mm, according to ANSI-C63.19 |

## 5.4 AMMI


**Figure 5.3 AMMI front panel**

The Audio Magnetic Measuring Instrument (AMMI) is a desktop 19-inch unit containing a sampling unit, a waveform generator for test and calibration signals, and a USB interface.

Specification:

| | |
|---|---|
| **Sampling rate** | 48 kHz / 24 bit |
| **Dynamic range** | 85 dB |
| **Test signal generation** | User selectable and predefined (vis PC) |
| **Calibration** | Auto-calibration / full system calibration using AMCC with monitor output |
| **Dimensions** | 482 x 65 x 270 mm |

## 5.5 Test Arch Phantom &Phone Positioner

The Test Arch phantom should be positioned horizontally on a stable surface. Reference markings on the Phantom allow the complete setup of all predefined phantom positions and measurement grids by manually teaching three points in the robot. It enables easy and well defined positioning of the phone and validation dipoles as well as simple teaching of the robot (Dimensions: 370 x 370 x 370 mm).

The Phone Positioner supports accurate and reliable positioning of any phone with effect on near field <±0.5 dB.

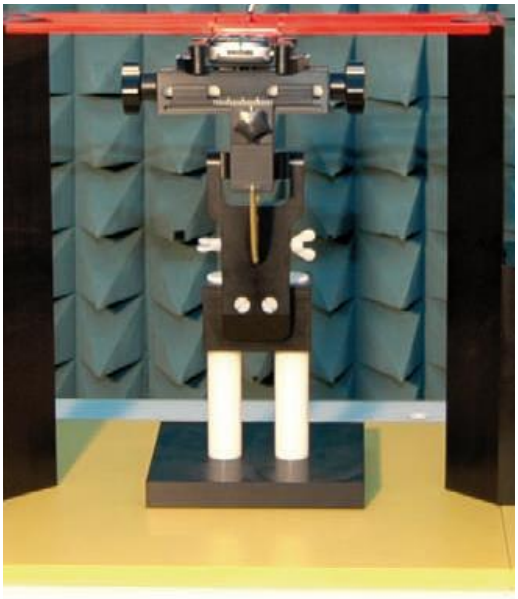


**Figure 5.4 HAC Phantom & Device Holder**

## 5.6 Robotic System Specifications

**Specifications**

**Positioner:** Stäubli Unimation Corp. Robot Model: RX160L

**Repeatability:** ±0.02 mm

**No. of Axis:** 6

**Data Acquisition Electronic (DAE) System**

**Cell Controller**

**Processor:**Intel Core2

**Clock Speed:** 1.86GHz

**Operating System:** Windows 10

**Data Converter**

**Features:**Signal Amplifier, multiplexer, A/D converter, and control logic

**Software:** DASY6/8 cD6 HAC

**Connecting Lines:**Optical downlink for data and status info.

Optical uplink for commands and clock

## 5.7 T-Coil measurement points and reference plane

The T-Coil measurement plane, reference plane and other measurement parameters shall be:

a) 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 WD handset, which, in normal handset use, rest against the ear.

b) The measurement plane is parallel to, and 10 mm in front of, the reference plane

c) The reference axis is normal to the reference plane and passes through the center of the acoustic output (or the center of the hole array); or may be centered on or near a secondary inductive source. The actual location of the reference axis and resultant measurement area shall be noted in the test report.

d) The measurement area shall be 50 mm by 50 mm. The measurement area for both desired ABM signal and undesired ABM field may be located where the transverse magnetic measurements are optimum with regard to the requirements. However, the measurement area should be in the vicinity of the acoustic output of the WD and shall be located in the same half of the phone as the WD receiver. In a WD handset with a centered receiver and a circularly symmetrical magnetic field, the measurement axis and the reference axis would coincide.

e) Measurements of desired ABM signal strength and undesired ABM field are made at 2.0 mm ±0.5 mm or 4 mm intervals in an X-Y measurement area pattern over the entire measurement area (676 measurement points total); either all measured, or measured plus interpolated.

f) Desired ABM signal frequency response is measured at a single location at or near the maximum desired ABM signal strength location.

g) The actual locations of the measurement points shall be noted in the test report.

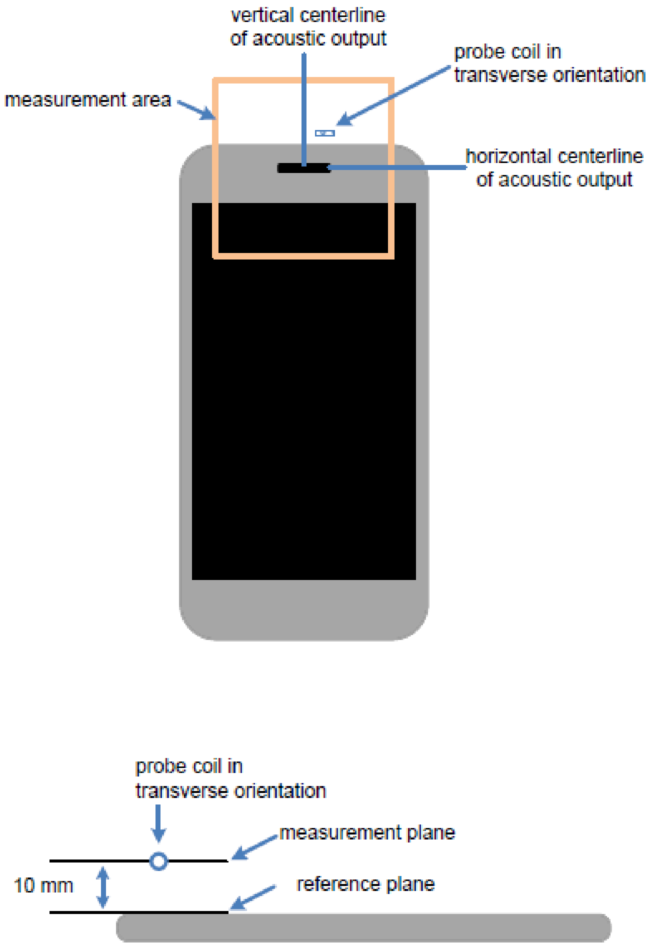



**Figure 5.5 Measurement and reference planes probe orientation for WD audio frequency magnetic field measurements**

# 6 T-Coil TEST PROCEDUERES

**The following steps summarize the basic test flow for determining desired ABM signal and undesired ABM field：**

a) A validation of the test setup and instrumentation shall be performed. This may be done using a TMFS or Helmholtz Coil. Measure the emissions and confirm that they are within tolerance of the expected values.

b) Confirm that equipment that requires calibration has been calibrated, and that the noise level meets the requirements given in C63.19-2019 section 6.3.2.

c) Position the WD in the test setup and connect the WD RF connector to a base station simulator.

d) The drive level to the WD is set such that the reference input level specified in Table 6-1 is input to the base station simulator (or manufacturer's test mode equivalent) in the 1 kHz, 1/3 octave band. This drive level shall be used for the T-Coil signal test (desired ABM signal) 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, shall be used for the reference audio signal. If interference is found at 1025 Hz an alternative nearby reference audio signal frequency may be used.35 The same drive level will be used for the desired ABM signal frequency response measurements at each 1/3 octave band center frequency. The WD volume control may be set at any level up to maximum, provided that a signal at any frequency at maximum modulation would not result in clipping or signal overload.

e) At each measurement location over the measurement area and in the transverse orientation, measure and record the desired 1 kHz T-Coil magnetic signal (desired ABM signal) as described in Step c).

f) At or near a location representing a maximum in the just-measured desired ABM signal, measure and record the desired T-Coil magnetic signals (desired ABM signal at fi) 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 c), and the reading taken for that band.36 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, 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).) Compare the frequency response found to the requirements of section 7.

g) At the same locations measured in Step d), measure and record the undesired broadband audio magnetic signal (undesired ABM field) with no audio signal applied (or digital zero applied, if appropriate) using the specified spectral weighting, the half-band integrator followed by the temporal weighting.

h) Calculate and record the location and number of the measurement points that satisfy both the minimum desired ABM signal level and the maximum undesired ABM field level specified. Compare this to the requirements section 7 and record the result.

i) Calculate and record the location and number of the measurement points that satisfy the maximum undesired ABM field level and distribution requirements specified in section 7.

**Table 6-1:T-Coil signal quality categories**

| Standard | Protocol | Input (dBm0) |
|---|---|---|
| TIA-2000 | CDMA | −18 |
| TIA/EIA-136 | TDMA (50 Hz) | −18 |
| J-STD-007 | GSM (217 Hz) | −16 |
| T1/T1P1/3GPP (See Note 1) | UMTS (WCDMA) | −16 |
| iDEN® | TDMA (22 Hz and 11 Hz) | −18 |
| VoIP a (See Note 2) | Voice over Internet Protocol | −16 |
| NOTE 1—For UMTS (Universal Mobile Telecommunications System), refer to 3GPP TS26.131 and TS26.132 (http://www.3gpp.org). NOTE 2—VoIP is used in this table as a general term specifying a group of voice services that use −16 dBm0 as their normal acoustic level. The group includes a variety of voice services, including Voice-over-LTE (VoLTE), Voice-over-IP-multimedia-subsystem (VoIMS), Voice-over-Wi-Fi (VoWiFi) and similar services. For 3G, LTE, and WLAN terminals used for Commercial Mobile Radio Service (CMRS) based telephony, refer to 3GPP TS26.131 and TS26.132. | | |

# 7 T-Coil PERFORMANCE REQUIREMENTS

In order to comply with the requirements for T-Coil use, a WD's tested operating modes shall simultaneously meet the requirements for minimum desired ABM signal level and maximum undesired ABM field contained in this part at the minimum specified number of scanned locations

## 7.1 T-Coil coupling qualifying field strengths

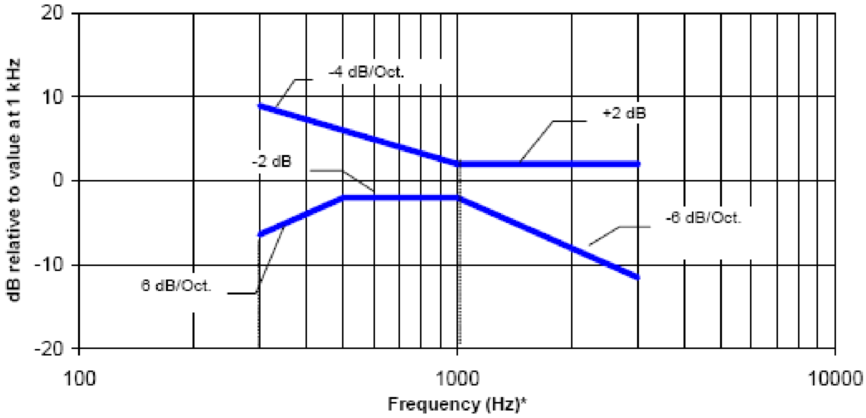
When measured as specified in ANSI C63.19, there are two groups of qualifying measurement points:

***Primary group***: A qualifying measurement point shall have its T-Coil signal, desired ABM signal, ≥−18 dB(A/m) at 1 kHz, in a 1/3 octave band filter. These measurements shall be made with the WD operating at a reference input level as specified in Table 6.1. Simultaneously, the qualifying measurement point shall have its weighted magnetic noise, undesired ABM field ≤−38 dB(A/m).

***Secondary group***: A qualifying measurement point shall have its weighted magnetic noise, undesired ABM field ≤−38 dB(A/m). This group inherently includes all the members of the primary group.

## 7.2 Frequency response

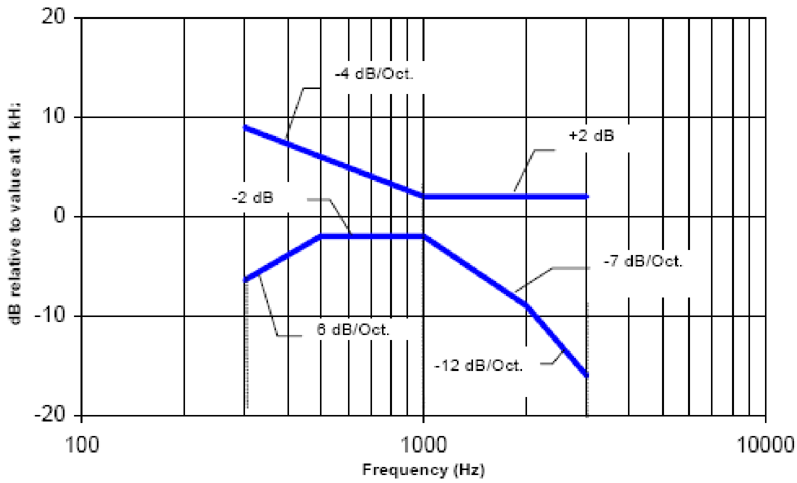
The frequency response of the axial component of the magnetic field, measured in 1/3 octave bands, shall follow the response curve specified in this sub-clause, over the frequency range 300 Hz to 3000 Hz. Figure 7.1 and Figure 7.2 provide the boundaries for the specified frequency. These response curves are for true field strength measurements of the T-Coil signal. Thus the 6 dB/octave probe response has been corrected from the raw readings.




NOTE—Frequency response is between 300 Hz and 3000 Hz.

**Figure 7.1—Magnetic field frequency response for WDs with a field ≤ –15 dB (A/m) at 1 kHz**




NOTE—Frequency response is between 300 Hz and 3000 Hz.

**Figure 7.2—Magnetic field frequency response for WDs with a fieldthat exceeds –15 dB(A/m) at 1 kHz**

## 7.3 Desired ABM signal, undesired ABM field qualification requirements

For a WD that is expected to operate primarily in radio access technologies that include 2G GSM for legacy support, the WD shall be qualified for telecoil compatibility one of two ways:

a) The WD shall be rated for telecoil use for all other voice operating modes, exclusive of 2G GSM, according to the section 7.3.1.

b) If the WD is to be rated for telecoil use in its 2G GSM operating modes, these modes shall be qualified according to the section 7.3.2.

### 7.3.1 Non-2G GSM operating modes

The goal of this requirement is to ensure an adequate area where desired ABM signal is sufficiently strong to be heard clearly and a larger area where undesired ABM field is sufficiently low as to avoid undue annoyance. Qualifying measurement points shall fulfill the requirements of 7.1; both the primary and secondary group requirements shall be met:

*The primary group shall include at least 75 measurement points.*

*The secondary group shall include at least 300 contiguous measurement points.*

Additionally, to avoid an oddly shaped area of low noise, the secondary group shall include at least one longitudinal column of at least 10 contiguous qualifying points and at least one transverse row containing at least 15 contiguous qualifying points.

### 7.3.2 2G GSM operating modes

If the 2G GSM operating mode(s) are selected for qualification, the qualifying measurement points shall fulfil the requirements of 6.6.2; both the primary and secondary group requirements shall be met:

*The primary group shall include at least 25 measurement points.*

*The secondary group shall include at least 125 contiguous measurement points.*

# 8 CMRS Voice DUT CONFIGURATION

## 8.1 GSM Codec Investigation

An investigation was performed to determine the audio codec configuration to be used for testing, the following tests results which the worst case codec would be remarked to be used for the testing for the DUT.

**GSM CMRS Codec Investigation**

| Codec Setting | NB FR | NB HR | EFR | WB FR | Orientation | Band | Channel |
|---|---|---|---|---|---|---|---|
| Secondary Group Point Count | 369 | 373 | 359 | 364 | Y(Transverse) | GSM1900 | 661 |
| Frequency Response | PASS | PASS | PASS | PASS | | | |
| Primary Group Contiguous Point Count | 117 | 129 | 142 | 138 | | | |

## 8.2 UMTS Codec Investigation

An investigation was performed to determine the audio codec configuration to be used for testing, the following tests results which the worst case codec would be remarked to be used for the testing for the DUT.

**WCDMA/UMTS CMRS Codec Investigation**

| Codec Setting | AMR 12.2kbps | AMR 7.95kbps | AMR 4.75kbps | Orientation | Band | Channel |
|---|---|---|---|---|---|---|
| Secondary Group Point Count | 676 | 659 | 674 | Y(Transverse) | WCDMA 1900 | 9400 |
| Frequency Response | PASS | PASS | PASS | | | |
| Primary Group Contiguous Point Count | 369 | 386 | 372 | | | |

# 9 VoLTE TEST SYSTEM SETUP AND DUT CONFIGURATION

## 9.1 Test System Setup for VoLTE over IMS T-coil Testing

The general test setup used for VoLTE over I Multimedia Subsystem (IMS) server.
MS is shown below. The callbox used when performing VoLTE over IMS T-coil measurements is a CMW500. The Data Application Unit (DAU) of the CMW500 was used to simulate the IP Multimedia Subsystem (IMS) server.

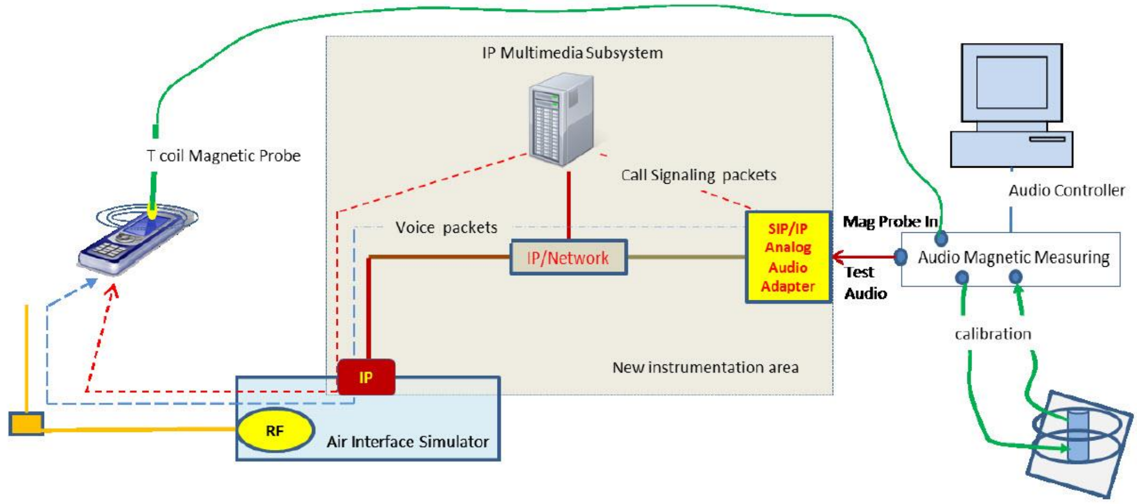



**Figure 9.1 Test Setup for VoLTE over IMS T-coil Measurements**

The following software/firmware was used to simulate the VoLTE server for testing:

| Firmware | License Keys | Software Name |
|---|---|---|
| for LTE | KS500 | LTE FDD R8 SIG BASIC |
| | KS550 | LTE TDD R8 SIG BASIC |
| | KA100 | IP APPL ENABLING IPv4 |
| | KA150 | IP APPL ENABLING IPv6 |
| for Audio | KAA20 | IP APPL IMS BASIC |
| | KM050 | DATA APPL MEAS |
| | KS104 | EVS SPEECH CODEC |

## 9.2 Codec Configuration

An investigation was performed to determine the audio codec configuration to be used for testing. WB AMR 23.85kbps setting was used for the audio codec on the CMW500 for VoLTE over IMS T-coil testing. See below table for comparisons between different codecs and codec data rates:

**AMR Codec Investigation – VoLTE over IMS**

| Codec Setting | WB AMR 23.85kbps | WB AMR 6.60kbps | NB AMR 12.2kbps | NB AMR 4.75kbps | Orientation | Band/BW | Channel |
|---|---|---|---|---|---|---|---|
| Secondary Group Point Count | 556 | 571 | 566 | 561 | Y(Transverse) | B2/20M | 18900 |
| Frequency Response | PASS | PASS | PASS | PASS | | | |
| Primary Group Contiguous Point Count | 227 | 228 | 276 | 270 | | | |

**EVS Codec Investigation – VoLTE over IMS**

| Codec Setting | EVS Primary SWB 13.2kbps | EVS Primary SWB 9.6kbps | EVS Primary WB 13.2kbps | EVS Primary WB 5.9kbps | EVS Primary NB 13.2kbps | EVS Primary NB 5.9kbps | Orientation | Band /BW | Channel |
|---|---|---|---|---|---|---|---|---|---|
| Secondary Group Point Count | 526 | 531 | 537 | 529 | 542 | 529 | Y(Transverse) | B2/20M | 18900 |
| Frequency Response | PASS | PASS | PASS | PASS | PASS | PASS | | | |
| Primary Group Contiguous Point Count | 279 | 286 | 286 | 283 | 312 | 296 | | | |

## 9.3 Radio Configuration

An investigation was performed to determine the modulation, the bandwidth configuration and RB configuration to be used for testing. 20MHz BW, QPSK, 1RB, 50RB offset was used for the testing as the worst-case configuration for the handset. See below table for comparisons between different radio configurations:

**VoLTE over IMS SNR by Radio Configuration**

| Band | Channel | Bandwidth [MHz] | Modulation | RB Size | RB Offset(%) | Primary Group Contiguous Point Count | Secondary Group Point Count |
|---|---|---|---|---|---|---|---|
| LTE B2 | 18900 | 20 | QPSK | 1 | 0 | 264 | 540 |
| LTE B2 | 18900 | 20 | QPSK | 1 | 50 | 227 | 556 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| LTE B2 | 18900 | 20 | QPSK | 1 | 99 | 276 | 546 |
| LTE B2 | 18900 | 20 | QPSK | 50 | 25 | 247 | 593 |
| LTE B2 | 18900 | 20 | QPSK | 100 | 0 | 257 | 543 |
| LTE B2 | 18900 | 20 | 16QAM | 1 | 50 | 250 | 563 |
| LTE B2 | 18900 | 20 | 64QAM | 1 | 50 | 247 | 510 |
| LTE B2 | 18900 | 10 | QPSK | 1 | 50 | 232 | 517 |
| LTE B2 | 18900 | 5 | QPSK | 1 | 50 | 276 | 543 |
| LTE B2 | 18900 | 1.4 | QPSK | 1 | 50 | 262 | 546 |

### 9.4 LTE TDD Uplink-Downlink Configuration Investigation

An investigation was performed to determine the worst-case Uplink-Downlink configuration for LTE TDD T-coil testing.

Per 3GPP TS 36.211, the total frame length for each TDD radio frame of length $T_f$=307200.$T_s$=10 ms, where $T_s$ is a number of time units equal to 1/(150002048) seconds. Additionally, each radio frame consists of 10 subframes, each of length 30720*$T_s$= 1ms, and subframes can be designated as uplink (U), downlink (D), or special subframe (S), depending on the Uplink-Downlink configuration as indicated in Table 4.2-2 of 3GPP TS 36.211. In the transmission duty factor calculation, the special subframe configuration with the shortest UpPTS duration within the special subframe is used and will be applied for measurement. From 3GPP TS 36.211 Table 4.2-1, the shortest UpPTS is 2192*$T_s$ which occurs in the normal cyclic prefix and special subframe configuration 4.

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

**Uplink-Downlink Configurations for Type 2 Frame Structures**

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

## a. Power Class 2 Uplink-Downlink Configuration Investigation

Power Class 2 was evaluated with the following radio configurations: channel 40620, 20MHz BW, QPSK, 1RB, 50RB Offset. For Power Class 2, configurations 1-5 are supported. The configuration which resulted in the worst SNNR was used for full testing. Uplink-Downlink configuration 2 was used as the worst-case configuration for LTE TDD T-coil testing. See table below for the SNR comparison between each Uplink-Downlink configuration:

**LTE TDD Power Class 2 SNR by UL-DL Configuration**

| Frequency [MHz] | Channel | Bandwidth [MHz] | Modulation | RB Size | RB Offset(%) | UL-DL Configuration | Primary Group Contiguous Point Count | Secondary Group Point Count |
|---|---|---|---|---|---|---|---|---|

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 2593 | 40620 | 20 | QPSK | 1 | 50 | 1 | 155 | 398 |
| 2593 | 40620 | 20 | QPSK | 1 | 50 | 3 | 159 | 390 |
| 2593 | 40620 | 20 | QPSK | 1 | 50 | 5 | 162 | 396 |

## b. Power Class 3 Uplink-Downlink Configuration Investigation

Power Class 3 was evaluated with the following radio configurations: channel 40620, 20MHz BW, QPSK, 1RB, 50RB Offset. For Power Class 3, all configurations (0-6) are supported. The configuration which resulted in the worst SNNR was used for full testing. Uplink-Downlink configuration 0 was used as the worst-case configuration for LTE TDD T-coil testing. See table below for the SNR comparison between each Uplink-Downlink configuration:

**LTE TDD Power Class 3 SNR by UL-DL Configuration**

| Frequency [MHz] | Channel | Bandwidth [MHz] | Modulation | RB Size | RB Offset(%) | UL-Configuration | Primary Group Contiguous Point Count | Secondary Group Point Count |
|---|---|---|---|---|---|---|---|---|
| 2593 | 40620 | 20 | QPSK | 1 | 50 | 0 | 197 | 479 |
| 2593 | 40620 | 20 | QPSK | 1 | 50 | 3 | 199 | 472 |
| 2593 | 40620 | 20 | QPSK | 1 | 50 | 6 | 207 | 480 |

## c. Conclusion

Per the investigations above, UL-DL Configuration 1 was used to evaluate LTE TDD Power Class 2 and UL-DL Configuration 0 was used to evaluate LTE TDD Power Class 3.

# 10 VoNR TEST SYSTEM SETUP AND DUT CONFIGURATION

## 10.1 Test System Setup for VoNR over IMS T-coil Testing

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

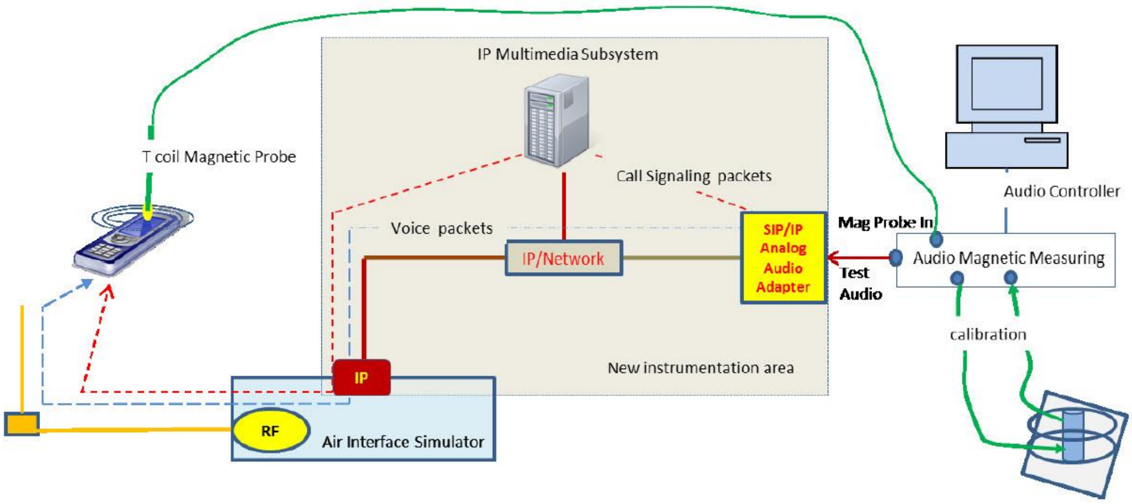



**Figure 10.1 Test Setup for VoNR over IMS T-coil Measurements**

The following software/firmware was used to simulate the VoNR server for testing:

| Firmware | License Keys | Software Name |
|---|---|---|
| for VoNR | KS600B | VONR processing option |

## 10.2 Codec Configuration

An investigation was performed to determine the audio codec configuration to be used for testing. EVS Primary WB 5.9kbps setting was used for the audio codec on the CMX500 for VoNR over IMS T-coil testing. See below table for comparisons between different codecs and codec data rates:

**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 |
|---|---|---|---|---|---|---|---|
| Secondary Group Point Count | 415 | 420 | 416 | 418 | Y(Transverse) | N66/20M | 349000 |
| Frequency Response | PASS | PASS | PASS | PASS | | | |
| Primary Group Contiguous Point Count | 145 | 140 | 169 | 170 | | | |

**EVS Codec Investigation – VoNR over IMS**

| Codec Setting | EVS Primary SWB 13.2kbps | EVS Primary SWB 9.6kbps | EVS Primary WB 13.2kbps | EVS Primary WB 5.9kbps | EVS Primary NB 13.2kbps | EVS Primary NB 5.9kbps | Orientation | Band /BW | Channel |
|---|---|---|---|---|---|---|---|---|---|
| Secondary Group Point Count | 404 | 405 | 392 | 401 | 406 | 408 | Y(Transverse) | N66/20M | 349000 |
| Frequency Response | PASS | PASS | PASS | PASS | PASS | PASS | | | |
| Primary Group Contiguous Point Count | 110 | 109 | 124 | 90 | 138 | 99 | | | |

## 10.3 Radio Configuration

An investigation was performed to determine the modulation, the bandwidth configuration and RB configuration to be used for testing. 20MHz BW, QPSK, 1RB, 50RB offset was used for the testing as the worst-case configuration for the handset. See below table for comparisons between different radio configurations:

**VoNR over IMS SNR by Radio Configuration**

| Band | Channel | Bandwidth [MHz] | Modulation | RB Size | RB Offset | Primary Group Contiguous Point Count | Secondary Group Point Count |
|---|---|---|---|---|---|---|---|
| N66 | 349000 | 20 | DFT-s-OFDM | 50 | 25 | 97 | 400 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | | QPSK | | | | |
| N66 | 349000 | 20 | DFT-s-OFDM QPSK | 1 | 104 | 90 | 401 |
| N66 | 349000 | 20 | DFT-s-OFDM QPSK | 1 | 1 | 113 | 420 |
| N66 | 349000 | 20 | DFT-s-OFDM QPSK | 2 | 0 | 103 | 401 |
| N66 | 349000 | 20 | DFT-s-OFDM QPSK | 2 | 104 | 104 | 380 |
| N66 | 349000 | 20 | DFT-s-OFDM QPSK | 100 | 0 | 114 | 389 |
| N66 | 349000 | 20 | DFT-s-OFDM 16QAM | 50 | 25 | 102 | 413 |
| N66 | 349000 | 20 | DFT-s-OFDM 64QAM | 50 | 25 | 97 | 383 |
| N66 | 349000 | 20 | DFT-s-OFDM 256QAM | 50 | 25 | 104 | 399 |
| N66 | 349000 | 20 | DFT-s-OFDM PI/2 BPSK | 50 | 25 | 111 | 412 |
| N66 | 349000 | 20 | CP-OFDM QPSK | 53 | 26 | 109 | 405 |

# 11 VoWIFI TEST SYSTEM SETUP AND DUT CONFIGURATION

## 11.1 Test System Setup for VoWiFI over IMS T-coil Testing

The general test setup used for VoWiFi over IMS, or CMRS WiFi Calling, is shown below. The callbox used when performing VoWiFi over IMS T-coil measurements is a CMW500. The Data Application Unit (DAU) of the CMW500 was used to simulate the IP Multimedia Subsystem (IMS) server.

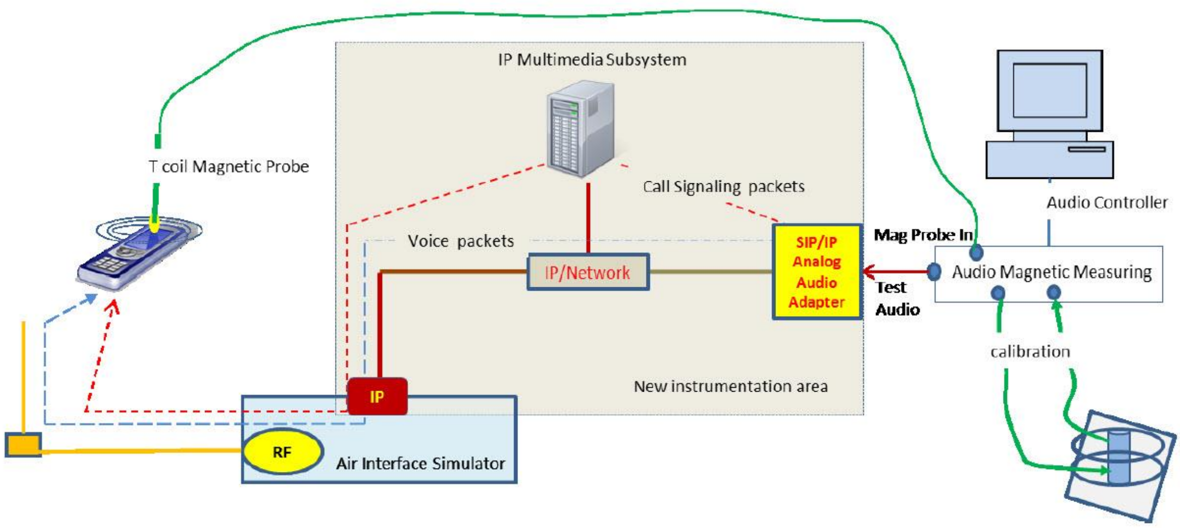



**Figure 11.1 Test Setup for VoWiFi over IMS T-coil Measurements**

The following software/firmware was used to simulate the VoWiFi server for testing:

| Firmware | License Keys | Software Name |
|---|---|---|
| for WLAN | KS650 | WLAN A/B/G SIG BASIC |
| | KS651 | WLAN N SIG BASIC |
| | KA100 | IP APPL ENABLING IPv4 |
| | KA150 | IP APPL ENABLING IPv6 |
| for Audio | KAA20 | IP APPL IMS BASIC |
| | KM050 | DATA APPL MEAS |
| | KS104 | EVS SPEECH CODEC |

## 11.2 Codec Configuration

An investigation was performed to determine the audio codec configuration to be used for testing. The EVS Primary WB 5.9kbps setting was used for the audio codec on the CMW500 for VoWiFi over IMS T-coil testing. See below table for comparisons between different codecs and codec data rates:

**AMR Codec Investigation – VoWiFi over IMS**

| Codec Setting | WB AMR 23.85kbps | WB AMR 6.60kbps | NB AMR 12.2kbps | NB AMR 4.75kbps | Orientation | Mode | Channel |
|---|---|---|---|---|---|---|---|
| Secondary Group Point Count | 396 | 390 | 395 | 394 | Y(Transverse) | 2.4GHz 802.11b | 6 |
| Frequency Response | PASS | PASS | PASS | PASS | | | |
| Primary Group Contiguous Point Count | 133 | 122 | 161 | 156 | | | |

**EVS Codec Investigation – VoWiFi over IMS**

| Codec Setting | EVS Primary SWB 13.2kbps | EVS Primary SWB 9.6kbps | EVS Primary WB 13.2kbps | EVS Primary WB 5.9kbps | EVS Primary NB 13.2kbps | EVS Primary NB 5.9kbps | Orientation | Mode | Channel |
|---|---|---|---|---|---|---|---|---|---|
| Secondary Group Point Count | 405 | 399 | 396 | 399 | 397 | 396 | Y(Transverse) | 2.4GHz 802.11b | 6 |
| Frequency Response | PASS | PASS | PASS | PASS | PASS | PASS | | | |
| Primary Group Contiguous Point Count | 131 | 116 | 135 | 104 | 163 | 134 | | | |

### 11.3 Radio Configuration

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

| Mode | Bandwidth [MHz] | Channel | Modulation | Data Rate [Mbps] | Secondary Group Point Count | Primary Group Contiguous Point Count |
|---|---|---|---|---|---|---|
| 802.11b | 20 | 6 | DSSS | 1 | 104 | 399 |
| 802.11b | 20 | 6 | CCK | 11 | 108 | 398 |
| 802.11g | 20 | 6 | BPSK | 6 | 99 | 414 |
| 802.11g | 20 | 6 | 64-QAM | 54 | 102 | 413 |
| 802.11n | 20 | 44 | BPSK | 6.5 | 210 | 574 |
| 802.11n | 20 | 44 | 256-QAM | 78 | 218 | 533 |
| 802.11n | 40 | 46 | BPSK | 13.5 | 203 | 591 |
| 802.11n | 40 | 46 | 256-QAM | 180 | 209 | 588 |
| 802.11ac | 80 | 42 | BPSK | 29.3 | 189 | 548 |
| 802.11ac | 80 | 42 | 256-QAM | 390 | 199 | 539 |
| 802.11ax | 160 | 50 | BPSK | 29.3 | 205 | 577 |
| 802.11ax | 160 | 50 | 256-QAM | 390 | 225 | 584 |

# 12 OTT VoIP TEST SYSTEM AND DUT CONFIGURATION

## 12.1 Test System Setup for OTT VoIP T-coil Testing

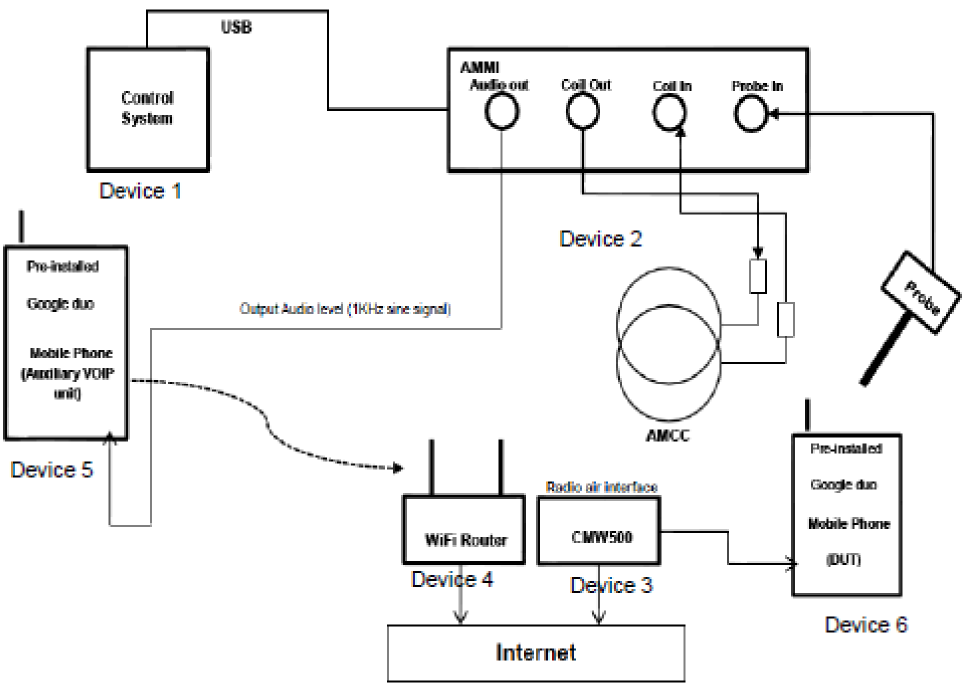
**OTT VoIP Application**

Google Duo is a pre-installed application on the DUT which allows for VoIP calls in a head-to-ear scenario. Duo uses the OPUS audio codec and supports a bitrate range of 6kbps to 75kbps. All air interfaces capable of a data connection were evaluated with Google Duo. When HAC testing we are using the Google Duo version is 26.0.179825522.alpha.DEV and the bitrate configuration can find at settings → Voice call parameters settings → Audio codec bitrate(6-75kbps).

**Test Procedure and Equipment Setup**

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

The AMMI is connected to the support device's Mic via Audio Data Line. The support device is connected to the Internet via Wi-Fi and the DUT is connected to the mobile base station via the technology under test. Using the DUT's OTT application, a VoIP call is established with the support device. The test signal is sent from the DASY PC to the AMMI, from the AMMI to the support device, and finally to the DUT. To exercise the license antenna, the DUT was simultaneously connected to an external AP and to a mobile base station.



**Codec Bit-rate Investigation**

For a voice service/air interface, investigate the variations of bit-rate configurations and document the parameters (ABM1, ABM2, frequency response) for that voice service. It is only necessary to document this for one channel/band, the following tests results which the worst case codec would be remarked to be used for the testing for the handset.

**Air Interface Investigation**

Using the worst-case bit-rate and Radio Configuration, a limited set of bands/channel/ bandwidths were then tested to confirm that there is no effect to the test compliance when changing the band/channel/bandwidth, it is necessary to report only a set band/channel/bandwidth for each orientation for a voice service/air interface. The summary of evaluation results is described in section 13.5

## 12.2 Codec Configuration

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

**Codec Investigation – OTT over EDGE**

| Codec Setting | 64kbps | 6kbps | Orientation | Channel |
|---|---|---|---|---|
| Secondary Group Point Count | 389 | 387 | Y(Transverse) | 661 |
| Frequency Response | Pass | Pass | | |
| Primary Group Contiguous Point Count | 95 | 90 | | |

**Codec Investigation – OTT over HSPA**

| Codec Setting | 64kbps | 6kbps | Orientation | Channel |
|---|---|---|---|---|
| Secondary Group Point Count | 567 | 574 | Y(Transverse) | 9800 |
| Frequency Response | Pass | Pass | | |
| Primary Group Contiguous Point Count | 251 | 245 | | |

**Codec Investigation – OTT over LTE**

| Codec Setting | 64kbps | 6kbps | Orientation | Band/BW | Channel |
|---|---|---|---|---|---|
| Secondary Group Point Count | 501 | 505 | Y(Transverse) | B25/20M | 26365 |
| Frequency Response | Pass | Pass | | | |
| Primary Group Contiguous Point Count | 187 | 182 | | | |

**Codec Investigation – OTT over NR**

| Codec Setting | 64kbps | 6kbps | Orientation | Band/BW | Channel |
|---|---|---|---|---|---|
| Secondary Group Point Count | 412 | 419 | Y(Transverse) | N66/20M | 349000 |
| Frequency Response | Pass | Pass | | | |
| Primary Group Contiguous Point Count | 130 | 126 | | | |

**Codec Investigation – OTT over WiFi**

| Codec Setting | 64kbps | 6kbps | Orientation | Band/BW | Channel |
|---|---|---|---|---|---|
| Secondary Group Point Count | 359 | 354 | Y(Transverse) | 2.4GHz 802.11b | 6 |
| Frequency Response | Pass | Pass | | | |
| Primary Group Contiguous Point Count | 87 | 83 | | | |

# 13 HAC T-Coil TEST DATA SUMMARY

## 13.1 Test Results for 2/3G

| Band | Ch. | Primary Group Contiguous Point Count | Secondary Group Point Count | Secondary Group Max Longitudinal | Secondary Group Max Transverse | Frequency Response |
|---|---|---|---|---|---|---|
| **GSM 850** | 190 | 81 | 333 | 21 | **26** | **PASS** |
| **PCS 1900** | 661 | 117 | 369 | 19 | **26** | **PASS** |
| **W850** | 4407 | 360 | 669 | 26 | **26** | **PASS** |
| **W1900** | 9800 | 369 | 676 | 26 | **26** | **PASS** |
| **W1700** | 1762 | 335 | 624 | 26 | **26** | **PASS** |

Note:

1. Bluetooth and WiFi function is turn off and microphone is muted.
2. The volume is adjusted to maximum level during T-Coil testing.

## 13.2 Test Results for VoLTE

| Band | Ch. | Bandwidth | Primary Group Contiguous Point Count | Secondary Group Point Count | Secondary Group Max Longitudinal | Secondary Group Max Transverse | Frequency Response |
|---|---|---|---|---|---|---|---|
| **LTE B2** | 18900 | 20M | 227 | 556 | 25 | **26** | **PASS** |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **LTE B5** | 20525 | 10M | 195 | 505 | 22 | **26** | **PASS** |
| **LTE B7** | 21100 | 20M | 267 | 570 | 26 | **26** | **PASS** |
| **LTE B12** | 23095 | 10M | 242 | 537 | 25 | **26** | **PASS** |
| **LTE B13** | 23230 | 10M | 222 | 510 | 24 | **26** | **PASS** |
| **LTE B25** | 26365 | 20M | 205 | 518 | 23 | **26** | **PASS** |
| **LTE B26** | 26865 | 10M | 267 | 566 | 26 | **26** | **PASS** |
| **LTE B66** | 132322 | 20M | 253 | 550 | 25 | **26** | **PASS** |
| **LTE B71** | 133322 | 20M | 250 | 542 | 25 | **26** | **PASS** |
| **LTE B41 （PC 2）** | 40620 | 20M | 155 | 398 | 20 | **26** | **PASS** |
| **LTE B41 （PC 3）** | 40620 | 20M | 197 | 479 | 24 | **26** | **PASS** |
| **LTE B48** | 55990 | 20M | 208 | 487 | 24 | **26** | **PASS** |

Note:

1. Bluetooth and WiFi function is turn off and microphone is muted.
2. The volume is adjusted to maximum level during T-Coil testing.

## 13.3 Test Results for VoNR

**Test results for 5G NR with SA mode**

| Band | Ch. | Bandwidth | Primary Group Contiguous Point Count | Secondary Group Point Count | Secondary Group Max Longitudinal | Secondary Group Max Transverse | Frequency Response |
|---|---|---|---|---|---|---|---|
| **N2** | 376000 | 20M | 93 | 408 | 20 | **26** | **PASS** |
| **N5** | 167300 | 20M | 119 | 460 | 21 | **26** | **PASS** |
| **N25** | 376500 | 20M | 105 | 411 | 20 | **26** | **PASS** |
| **N66** | 349000 | 20M | 90 | 401 | 20 | **26** | **PASS** |
| **N71** | 136100 | 20M | 122 | 448 | 21 | **26** | **PASS** |
| **N41** | 518598 | 20M | 82 | 407 | 20 | **26** | **PASS** |
| **N48** | 641666 | 20M | 125 | 465 | 22 | **26** | **PASS** |
| **N77** | 633334 | 20M | 87 | 402 | 20 | **26** | **PASS** |
| **N78** | 636666 | 20M | 109 | 434 | 22 | **26** | **PASS** |

Note:

1. Bluetooth and WiFi function is turn off and microphone is muted.
2. The volume is adjusted to maximum level during T-Coil testing.

Test results for 5G NR with NSA mode

| Band | Primary Group Contiguous Point Count | Secondary Group Point Count | Secondary Group Max Longitudinal | Secondary Group Max Transverse | Frequency Response |
|---|---|---|---|---|---|
| **B2-N5/66/71/41/77** | 86 | 332 | 16 | **26** | **PASS** |
| **B5-N2/66/77/78** | 129 | 410 | 18 | **26** | **PASS** |
| **B7-N66/77/78** | 133 | 416 | 20 | **26** | **PASS** |
| **B12-N2/66/77** | 132 | 425 | 20 | **26** | **PASS** |
| **B13-N2/66/77** | 110 | 360 | 17 | **26** | **PASS** |
| **B66-N2/5/71/41/77** | 110 | 443 | 20 | **26** | **PASS** |

## 13.4 Test Results for VoWiFi

| Mode | Ch. | Band width | Primary Group Contiguous Point Count | Secondary Group Point Count | Secondary Group Max Longitudinal | Secondary Group Max Transverse | Frequency Response |
|---|---|---|---|---|---|---|---|
| **802.11b** | 6 | 20M | 104 | 399 | 23 | **26** | **PASS** |
| **802.11g** | 6 | 20M | 99 | 414 | 21 | **26** | **PASS** |
| **802.11n** | 6 | 20M | 105 | 427 | 24 | **26** | **PASS** |
| **802.11n** | 6 | 40M | 110 | 432 | 23 | **26** | **PASS** |
| **802.11a** | 44 | 20M | 234 | 582 | 26 | **26** | **PASS** |
| **802.11n** | 46 | 40M | 203 | 591 | 26 | **26** | **PASS** |
| **802.11ac** | 42 | 80M | 189 | 548 | 23 | **23** | **PASS** |
| **802.11ax** | 50 | 160M | 205 | 577 | 26 | **26** | **PASS** |
| **802.11ac** | 58 | 80M | 204 | 592 | 26 | **26** | **PASS** |
| **802.11ac** | 122 | 80M | 197 | 582 | 26 | **26** | **PASS** |
| **802.11ac** | 155 | 80M | 192 | 575 | 26 | **26** | **PASS** |

Note:

1. Bluetooth function is turn off and microphone is muted.
2. The volume is adjusted to maximum level during T-Coil testing.

## 13.5 Test Results for OTT VoIP

**Test results for 2/3G**

| Band | Ch. | Primary Group Contiguous Point Count | Secondary Group Point Count | Secondary Group Max Longitudinal | Secondary Group Max Transverse | Frequency Response |
|---|---|---|---|---|---|---|
| **EDGE850** | 190 | 75 | 364 | 20 | **26** | **PASS** |
| **EDGE1900** | 661 | 90 | 387 | 19 | **26** | **PASS** |
| **W850** | 4407 | 236 | 568 | 26 | **26** | **PASS** |
| **W1900** | 9800 | 245 | 574 | 26 | **26** | **PASS** |
| **W1700** | 1637 | 226 | 558 | 26 | **26** | **PASS** |

Note: 1. Bluetooth and WiFi function is turn off and microphone is muted.

2. The volume is adjusted to maximum level during T-Coil testing.

**Test results for LTE**

| Band | Ch. | Bandwidth | Primary Group Contiguous Point Count | Secondary Group Point Count | Secondary Group Max Longitudinal | Secondary Group Max Transverse | Frequency Response |
|---|---|---|---|---|---|---|---|
| **LTE B2** | 18900 | 20M | 182 | 505 | 22 | **26** | **PASS** |
| **LTE B5** | 20525 | 10M | 141 | 490 | 21 | **26** | **PASS** |
| **LTE B7** | 21100 | 20M | 185 | 508 | 22 | **26** | **PASS** |
| **LTE B12** | 23095 | 10M | 186 | 500 | 22 | **26** | **PASS** |
| **LTE B13** | 23230 | 10M | 169 | 481 | 21 | **26** | **PASS** |
| **LTE B25** | 26365 | 20M | 188 | 509 | 22 | **26** | **PASS** |
| **LTE B26** | 26865 | 10M | 207 | 535 | 22 | **26** | **PASS** |
| **LTE B66** | 132322 | 20M | 189 | 517 | 22 | **26** | **PASS** |
| **LTE B71** | 133322 | 20M | 193 | 513 | 23 | **26** | **PASS** |
| **LTE B41（PC 2）** | 40620 | 20M | 121 | 403 | 20 | **26** | **PASS** |
| **LTE B41（PC 3）** | 40620 | 20M | 121 | 401 | 20 | **26** | **PASS** |
| **LTE B48** | 55990 | 20M | 158 | 480 | 22 | **26** | **PASS** |

Note:

1. Bluetooth and WiFi function is turn off and microphone is muted.
2. The volume is adjusted to maximum level during T-Coil testing.

**Test results for 5G NR with SA mode**

| Band | Ch. | Bandwidth | Primary Group Contiguous Point Count | Secondary Group Point Count | Secondary Group Max Longitudinal | Secondary Group Max Transverse | Frequency Response |
|---|---|---|---|---|---|---|---|
| **N2** | 376000 | 20M | 112 | 387 | 20 | **26** | **PASS** |
| **N5** | 167300 | 10M | 161 | 472 | 22 | **26** | **PASS** |
| **N25** | 376500 | 20M | 129 | 416 | 20 | **26** | **PASS** |
| **N66** | 349000 | 20M | 126 | 419 | 20 | **26** | **PASS** |
| **N71** | 136100 | 20M | 152 | 459 | 21 | **26** | **PASS** |
| **N41** | 518598 | 20M | 122 | 397 | 20 | **26** | **PASS** |
| **N48** | 641666 | 20M | 117 | 396 | 18 | **26** | **PASS** |
| **N77** | 633334 | 20M | 82 | 397 | 19 | **26** | **PASS** |
| **N78** | 636666 | 20M | 111 | 396 | 19 | **26** | **PASS** |

Note:

1. Bluetooth and WiFi function is turn off and microphone is muted.
2. The volume is adjusted to maximum level during T-Coil testing.

**Test results for 5G NR with NSA mode**

| Band | Primary Group Contiguous Point Count | Secondary Group Point Count | Secondary Group Max Longitudinal | Secondary Group Max Transverse | Frequency Response |
|---|---|---|---|---|---|
| **B2-N5/66/71/41/77** | 81 | 347 | 16 | **26** | **PASS** |
| **B5-N2/66/77/78** | 83 | 344 | 16 | **26** | **PASS** |
| **B7-N66/77/78** | 117 | 400 | 18 | **26** | **PASS** |
| **B12-N2/66/77** | 79 | 337 | 16 | **26** | **PASS** |
| **B13-N2/66/77** | 80 | 338 | 16 | **26** | **PASS** |
| **B66-N2/5/71/41/77** | 82 | 350 | 16 | **26** | **PASS** |

Note:

1. Bluetooth and WiFi function is turn off and microphone is muted.
2. The volume is adjusted to maximum level during T-Coil testing.

**Test results for WiFi**

| Mode | Ch. | Band width | Primary Group Contiguous Point Count | Secondary Group Point Count | Secondary Group Max Longitudinal | Secondary Group Max Transverse | Frequency Response |
|---|---|---|---|---|---|---|---|
| **802.11b** | 6 | 20M | 83 | 354 | 18 | **26** | **PASS** |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **802.11g** | 6 | 20M | 160 | 458 | 20 | **26** | **PASS** |
| **802.11n** | 6 | 20M | 153 | 449 | 20 | **26** | **PASS** |
| **802.11n** | 6 | 40M | 161 | 457 | 20 | **26** | **PASS** |
| **802.11a** | 44 | 20M | 200 | 522 | 22 | **26** | **PASS** |
| **802.11n** | 46 | 40M | 213 | 535 | 23 | **26** | **PASS** |
| **802.11ac** | 42 | 80M | 217 | 543 | 26 | **26** | **PASS** |
| **802.11ax** | 50 | 160M | 213 | 539 | 26 | **26** | **PASS** |
| **802.11a** | 60 | 20M | 207 | 530 | 26 | **26** | **PASS** |
| **802.11a** | 124 | 20M | 197 | 517 | 22 | **26** | **PASS** |
| **802.11a** | 157 | 20M | 202 | 516 | 26 | **26** | **PASS** |

Note:

1. Bluetooth function is turn off and microphone is muted.
2. The volume is adjusted to maximum level during T-Coil testing.

## 13.6 Total Measurement Conclusion

| Probe Position | Frequency Band(MHz) | Compliance |
|---|---|---|
| Transverse | GSM 850 | PASS |
| | GSM 1900 | PASS |
| | WCDMA850 | PASS |
| | WCDMA1900 | PASS |
| | WCDMA1700 | PASS |
| | LTE B2 | PASS |
| | LTE B5 | PASS |
| | LTE B7 | PASS |
| | LTE B12 | PASS |
| | LTE B13 | PASS |
| | LTE B25 | PASS |
| | LTE B26 | PASS |
| | LTE B66 | PASS |
| | LTE B71 | PASS |
| | LTE B41（PC 2） | PASS |
| | LTE B41（PC 3） | PASS |
| | N2 | PASS |
| | N5 | PASS |
| | N25 | PASS |
| | N66 | PASS |
| | N71 | PASS |
| | N41 | PASS |
| | N48 | PASS |
| | N77 | PASS |
| | N78 | PASS |
| | WiFi 2.4G | PASS |
| | WiFi 5G | PASS |

## 14 MEASUREMENT UNCERTAINTY

| Error Description | Unc. Value | Prob. Dist. | Div. | (ci) ABMd | (ci) ABMu | Std. Unc. ABMd | Std. Unc. ABMu |
|---|---|---|---|---|---|---|---|
| **Probe Sensitivity** | | | | | | | |
| Reference Level | ±3.0 % | N | 1 | 1 | 1 | ±3.0 % | ±3.0 % |
| AMCC Geometry | ±0.4 % | R | √3 | 1 | 1 | ±0.2 % | ±0.2 % |
| AMCC Current | ±1.0 % | R | √3 | 1 | 1 | ±0.6 % | ±0.6 % |
| Probe Positioning during Calibr. | ±0.1 % | R | √3 | 1 | 1 | ±0.1, % | ±0.1 % |
| Noise Contribution | ±0.7 % | R | √3 | 0.0143 | 1 | ±0.0 % | ±0.4 % |
| Frequency Slope | ±5.9 % | R | √3 | 0.1 | 1.0 | ±0.3 % | ±3.5 % |
| **Probe System** | | | | | | | |
| Repeatability / Drift | ±1.0 % | R | √3 | 1 | 1 | ±0.6 % | ±0.6 % |
| Linearity / Dynamic Range | ±0.6 % | R | √3 | 1 | 1 | ±0.4 % | ±0.4 % |
| Acoustic Noise | ±1.0 % | R | √3 | 0.1 | 1 | ±0.1 % | ±0.6 % |
| Probe Angle | ±1 % | R | √3 | 1 | 1 | ±0.6 % | ±0.6 % |
| Spectral Processing | ±0.9 % | R | √3 | 1 | 1 | ±0.5 % | ±0.5 % |
| Integration Time | ±0.6 % | N | 1 | 1 | 5 | ±0.6 % | ±3.0 % |
| Field Disturbation | ±0.2 % | R | √3 | 1 | 1 | ±0.1 % | ±0.1 % |
| **Test Signal** | | | | | | | |
| Ref. Signal Spectral Response | ±0.6 % | R | √3 | 0 | 1 | ±0.0 % | ±0.4 % |
| **Positioning** | | | | | | | |
| Probe Positioning | ±1.9 % | R | √3 | 1 | 1 | ±1.1 % | ±1.1 % |
| Phantom Thickness | ±0.9 % | R | √3 | 1 | 1 | ±0.5 % | ±0.5 % |
| DUT Positioning | ±1.9 % | R | √3 | 1 | 1 | ±1.1 % | ±1.1 % |
| **External Contributions** | | | | | | | |
| RF Interference | ±0.0 % | R | √3 | 1 | 0.3 | ±0.0 % | ±0.0 % |
| Test Signal Variation | ±2.0 % | R | √3 | 1 | 1 | ±1.2 % | ±1.2 % |
| **Combined Uncertainty** | | | | | | | |
| Combined Std. Uncertainty (ABM Field) | | | | | | ±3.9 % | ±6.0 % |
| **Expanded Std. Uncertainty** | | | | | | ±7.8 % | ±11.9 % |

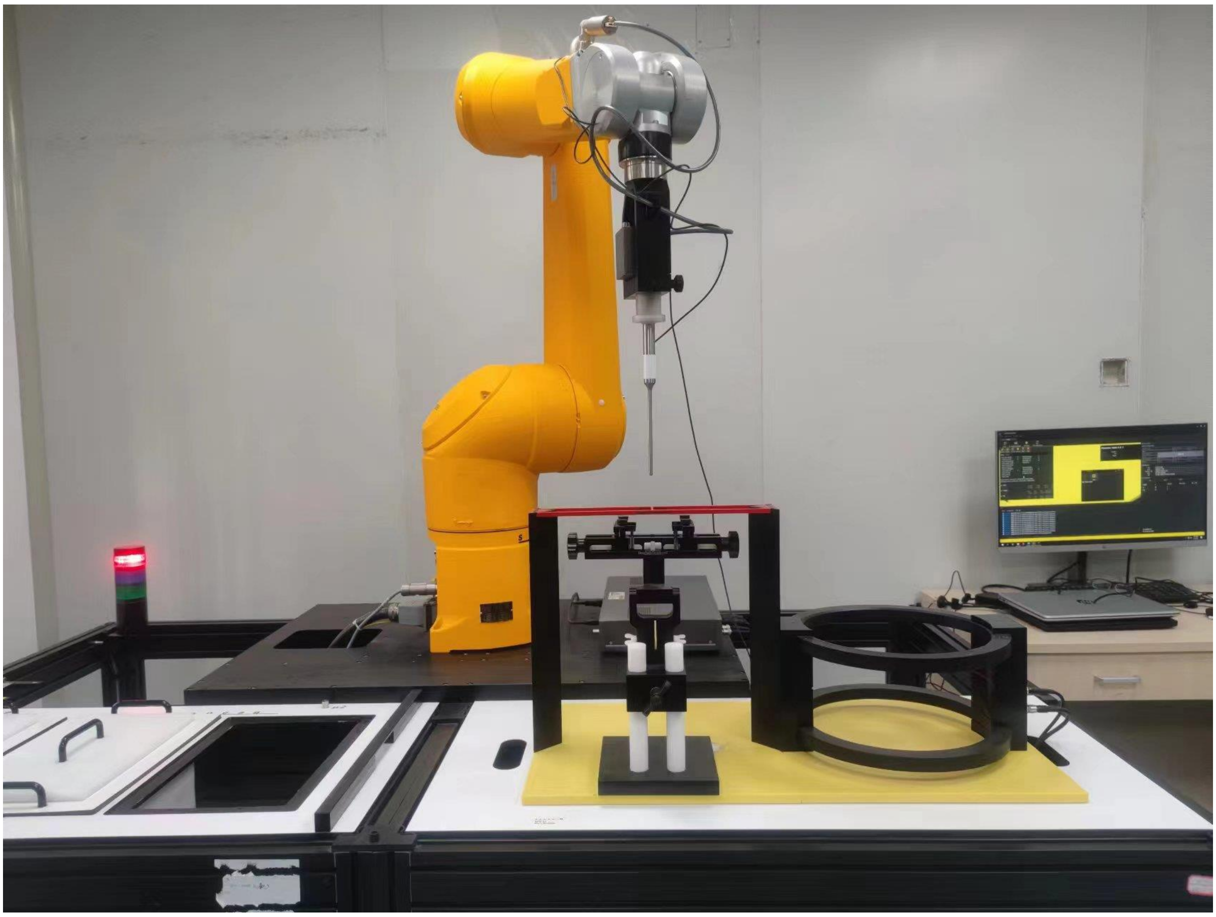
# 15 MAIN TEST INSTRUMENTS

**List of Main Instruments**

| No. | Name | Type | Serial Number | Calibration Date | Valid Period |
|---|---|---|---|---|---|
| 01 | Audio Magnetic 1D Field Probe | AM1DV2 | 1064 | July 14, 2023 | One year |
| 02 | Audio Magnetic Calibration Coil | AMCC | 1064 | NCR | NCR |
| 03 | Audio Measuring Instrument | AMMI | 1044 | NCR | NCR |
| 04 | HAC Test Arch | N/A | 1014 | NCR | NCR |
| 05 | DAE | SPEAG DAE4 | 771 | February 8, 2023 | One year |
| 06 | Software | DASY5 V5.0 Build 119.9 | N/A | NCR | NCR |
| 07 | Software | SEMCAD V13.2 Build 87 | N/A | NCR | NCR |
| 08 | Universal Radio Communication Tester | CMW 500 | 166370 | July 4, 2023 | One year |

***END OF REPORT BODY***

# ANNEX A TEST LAYOUT



**Picture A1: HAC T-Coil System Layout**

# ANNEX B TEST PLOTS

**T-Coil GSM850 Transverse**

# T-Coil Coupling Mode Test Report

## Results

| Primary Group Contiguous Point Count | Secondary Group Point Count | Secondary Group Max Longitudinal | Secondary Group Max Transverse |
|---|---|---|---|
| 81 | 333 | 21 | 26 |

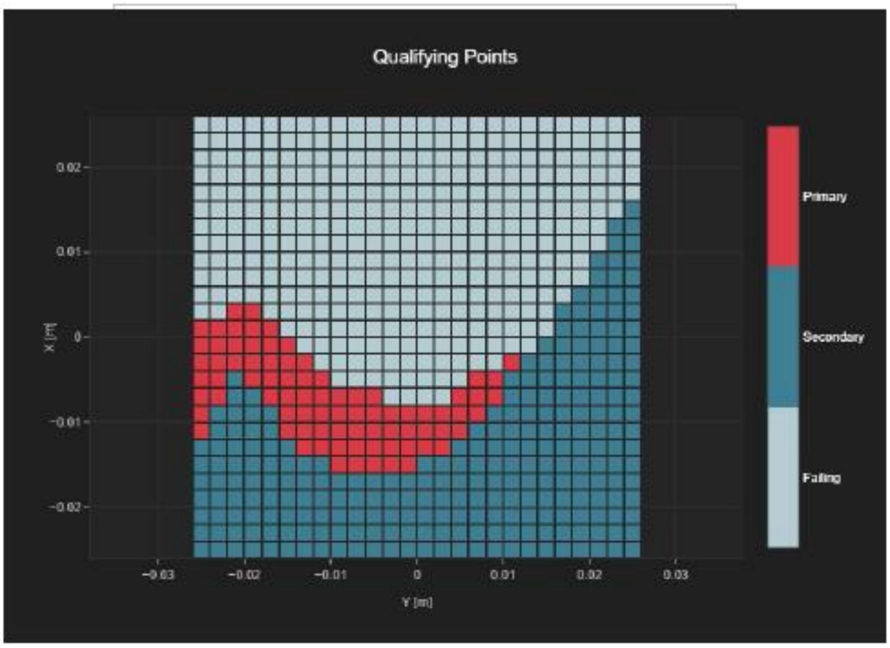



**Fig B.1 T-Coil GSM850**

**T-Coil N41 Transverse**

# T-Coil Coupling Mode Test Report

## Results

| Primary Group Contiguous Point Count | Secondary Group Point Count | Secondary Group Max Longitudinal | Secondary Group Max Transverse |
|---|---|---|---|
| 82 | 407 | 20 | 26 |

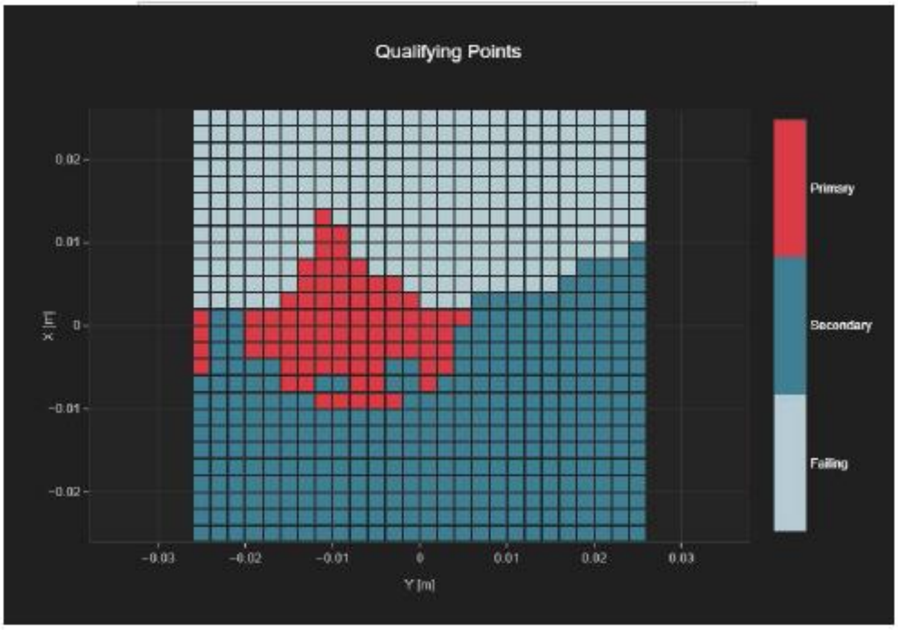



**Fig B.2 T-Coil N41**

**T-Coil GSM850 Transverse - OTT VoIP**

# T-Coil Coupling Mode Test Report

## Results

| Primary Group Contiguous Point Count | Secondary Group Point Count | Secondary Group Max Longitudinal | Secondary Group Max Transverse |
|---|---|---|---|
| 75 | 364 | 20 | 26 |


**Fig B.3 T-Coil GSM850-OTT**

**T-Coil B12-N77 Transverse - OTT VoIP**

# T-Coil Coupling Mode Test Report

## Results

| Primary Group Contiguous Point Count | Secondary Group Point Count | Secondary Group Max Longitudinal | Secondary Group Max Transverse |
|---|---|---|---|
| 79 | 337 | 16 | 26 |

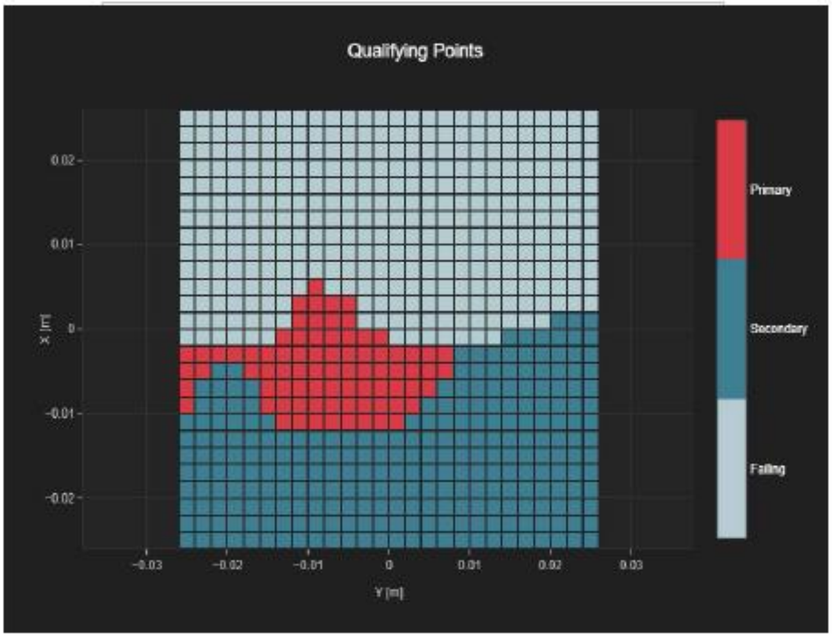



**Fig B.4 T-Coil B12-N77-OTT**

## ANNEX C FREQUENCY REPONSE CURVES

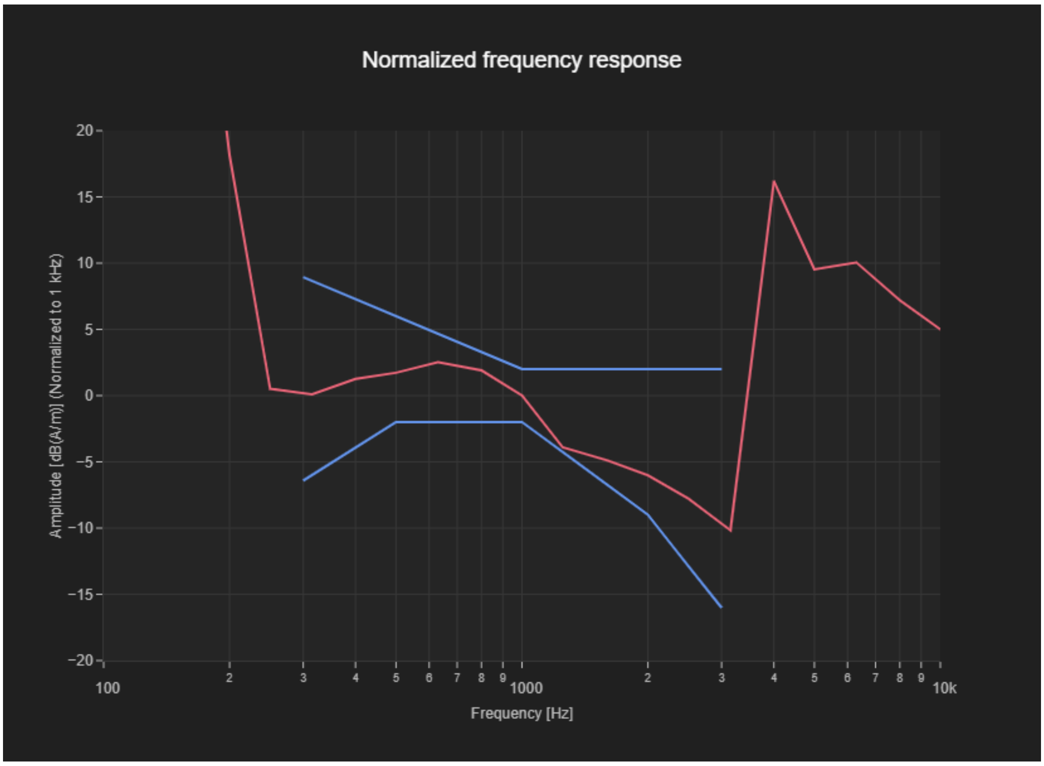



**Figure C.1 Frequency Response of GSM850**

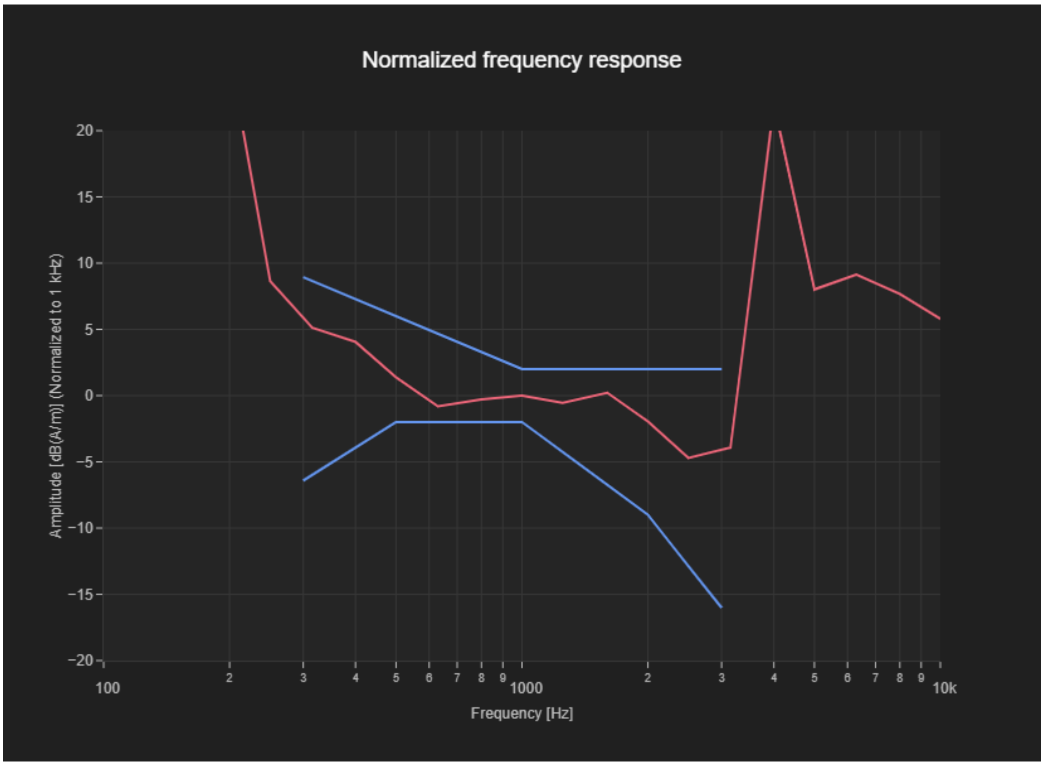



**Figure C.2 Frequency Response of N41**

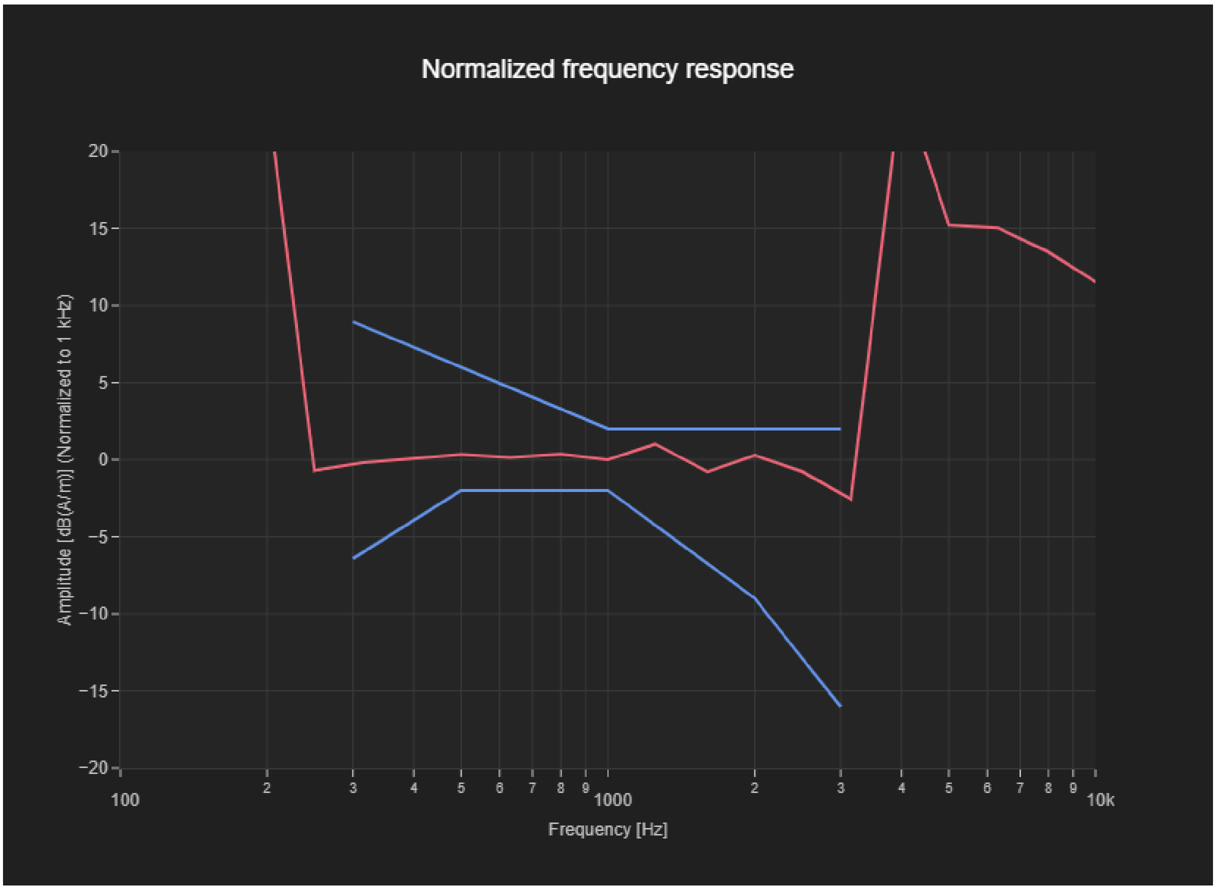



**Figure C.3 Frequency Response of** GSM850-0TT

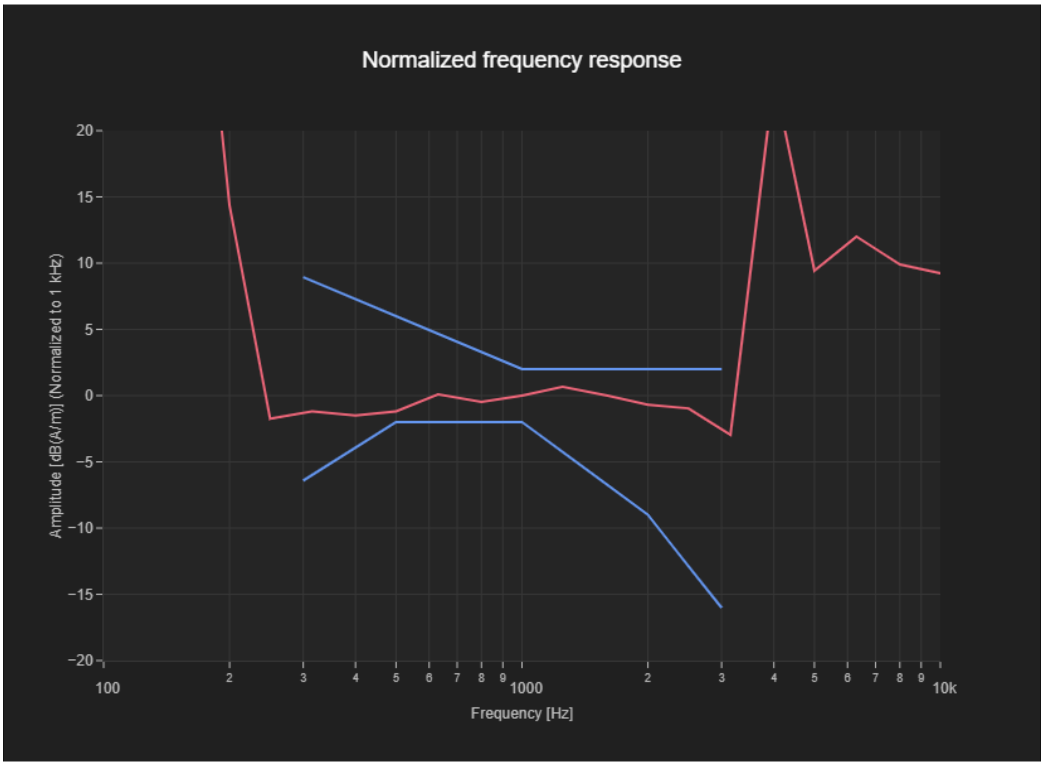



**Figure C.4 Frequency Response of** B12−N77-0TT

# ANNEX D PROBE CALIBRATION CERTIFICATE

**Calibration Laboratory of**
Schmid & Partner
Engineering AG
**Zeughausstrasse 43, 8004 Zurich, Switzerland**

**S** Schweizerischer Kalibrierdienst
**C** Service suisse d'étalonnage
**S** Servizio svizzero di taratura
Swiss Calibration Service

Accredited by the Swiss Accreditation Service (SAS)
**The Swiss Accreditation Service is one of the signatories to the EA Multilateral Agreement for the recognition of calibration certificates**

**Accreditation No.: SCS 0108**

**Client** **CTTL Beijing**

**Certificate No. AM1DV2-1064_Jul23**

## CALIBRATION CERTIFICATE

| | |
|---|---|
| Object | AM1DV2 - SN: 1064 |
| Calibration procedure(s) | QA CAL-24.v4<br>Calibration procedure for AM1D magnetic field probes and TMFS in the audio range |
| Calibration date: | July 14, 2023 |

This calibration certificate documents the traceability to national standards, which realize the physical units of measurements (SI).
The measurements and the uncertainties with confidence probability are given on the following pages and are part of the certificate.

All calibrations have been conducted in the closed laboratory facility: environment temperature (22 ± 3)°C and humidity < 70%.

Calibration Equipment used (M&TE critical for calibration)

| Primary Standards | ID # | Cal Date (Certificate No.) | Scheduled Calibration |
|---|---|---|---|
| Keithley Multimeter Type 2001 | SN: 0810278 | 29-Aug-22 (No. 34389) | Aug-23 |
| Reference Probe AM1DV2 | SN: 1008 | 20-Dec-22 (No. AM1DV2-1008_Dec22) | Dec-23 |
| DAE4 | SN: 781 | 03-Jan-23 (No. DAE4-781_Jan23) | Jan-24 |

| Secondary Standards | ID # | Check Date (in house) | Scheduled Check |
|---|---|---|---|
| AMCC | SN: 1050 | 01-Oct-13 (in house check Oct-20) | Oct-23 |
| AMMI Audio Measuring Instrument | SN: 1062 | 26-Sep-12 (in house check Oct-20) | Oct-23 |

| | Name | Function | Signature |
|---|---|---|---|
| Calibrated by: | Leif Klysner | Laboratory Technician | [signature] |
| Approved by: | Sven Kühn | Technical Manager | [signature] |

Issued: July 17, 2023





## References


[1] ANSI-C63.19-2007
American National Standard for Methods of Measurement of Compatibility between Wireless Communications Devices and Hearing Aids.

[2] ANSI-C63.19-2019 (ANSI-C63.19-2011)
American National Standard, Methods of Measurement of Compatibility between Wireless Communications Devices and Hearing Aids.

[3] DASY System Handbook


## Description of the AM1D probe

The AM1D Audio Magnetic Field Probe is a fully shielded magnetic field probe for the frequency range from 100 Hz to 20 kHz. The pickup coil is compliant with the dimensional requirements of [1+2]. The probe includes a symmetric low noise amplifier for the signal available at the shielded 3 pin connector at the side. Power is supplied via the same connector (phantom power supply) and monitored via the LED near the connector. The 7 pin connector at the end of the probe does not carry any signals, but determines the angle of the sensor when mounted on the DAE. The probe supports mechanical detection of the surface.
The single sensor in the probe is arranged in a tilt angle allowing measurement of 3 orthogonal field components when rotating the probe by 120° around its axis. It is aligned with the perpendicular component of the field, if the probe axis is tilted nominally 35.3° above the measurement plane, using the connector rotation and sensor angle stated below.
The probe is fully RF shielded when operated with the matching signal cable (shielded) and allows measurement of audio magnetic fields in the close vicinity of RF emitting wireless devices according to [1+2] without additional shielding.

## Handling of the item

The probe is manufactured from stainless steel. In order to maintain the performance and calibration of the probe, it must not be opened. The probe is designed for operation in air and shall not be exposed to humidity or liquids. For proper operation of the surface detection and emergency stop functions in a DASY system, the probe must be operated with the special probe cup provided (larger diameter).

## Methods Applied and Interpretation of Parameters

- *Coordinate System:* The AM1D probe is mounted in the DASY system for operation with a HAC Test Arch phantom with AMCC Helmholtz calibration coil according to [3], with the tip pointing to "southwest" orientation.
- *Functional Test:* The functional test preceding calibration includes test of Noise level RF immunity (1kHz AM modulated signal). The shield of the probe cable must be well connected. Frequency response verification from 100 Hz to 10 kHz.
- *Connector Rotation:* The connector at the end of the probe does not carry any signals and is used for fixation to the DAE only. The probe is operated in the center of the AMCC Helmholtz coil using a 1 kHz magnetic field signal. Its angle is determined from the two minima at nominally +120° and –120° rotation, so the sensor in the tip of the probe is aligned to the vertical plane in z-direction, corresponding to the field maximum in the AMCC Helmholtz calibration coil.
- *Sensor Angle:* The sensor tilting in the vertical plane from the ideal vertical direction is determined from the two minima at nominally +120° and –120°. DASY system uses this angle to align the sensor for radial measurements to the x and y axis in the horizontal plane.
- *Sensitivity:* With the probe sensor aligned to the z-field in the AMCC, the output of the probe is compared to the magnetic field in the AMCC at 1 kHz. The field in the AMCC Helmholtz coil is given by the geometry and the current through the coil, which is monitored on the precision shunt resistor of the coil.



**AM1D probe identification and configuration data**

| | |
|---|---|
| Item | **AM1DV2** Audio Magnetic 1D Field Probe |
| Type No | SP AM1 001 AF |
| Serial No | **1064** |

| | |
|---|---|
| Overall length | 296 mm |
| Tip diameter | 6.0 mm (at the tip) |
| Sensor offset | 3.0 mm (centre of sensor from tip) |
| Internal Amplifier | 40 dB |

| | |
|---|---|
| Manufacturer / Origin | Schmid & Partner Engineering AG, Zurich, Switzerland |

**Calibration data**

| | | | |
|---|---|---|---|
| Connector rotation angle | (in DASY system) | **102.9** ° | +/- 3.6 ° (k=2) |
| Sensor angle | (in DASY system) | **0.45** ° | +/- 0.5 ° (k=2) |
| Sensitivity at 1 kHz | (in DASY system) | **0.0657 V/(A/m)** | +/- 2.2 % (k=2) |

The reported uncertainty of measurement is stated as the standard uncertainty of measurement multiplied by the coverage factor k=2, which for a normal distribution corresponds to a coverage probability of approximately 95%.

# ANNEX E DAE CALIBRATION CERTIFICATE

In Collaboration with
s p e a g
CALIBRATION LABORATORY

中国认可
国际互认
校准
CALIBRATION
CNAS L0570

Add: No.52 HuaYuanBei Road, Haidian District, Beijing, 100191, China
Tel: +86-10-62304633-2117
E-mail: emf@caict.ac.cn http://www.caict.ac.cn

Client : CTTL

Certificate No: Z23-60065

## CALIBRATION CERTIFICATE

| | |
|---|---|
| Object | DAE4 - SN: 771 |
| Calibration Procedure(s) | FF-Z11-002-01<br>Calibration Procedure for the Data Acquisition Electronics (DAEx) |
| Calibration date: | February 08, 2023 |

This calibration Certificate documents the traceability to national standards, which realize the physical units of measurements(SI). The measurements and the uncertainties with confidence probability are given on the following pages and are part of the certificate.

All calibrations have been conducted in the closed laboratory facility: environment temperature(22±3)℃ and humidity<70%.

Calibration Equipment used (M&TE critical for calibration)

| Primary Standards | ID # | Cal Date(Calibrated by, Certificate No.) | Scheduled Calibration |
|---|---|---|---|
| Process Calibrator 753 | 1971018 | 14-Jun-22 (CTTL, No.J22X04180) | Jun-23 |

| | Name | Function | Signature |
|---|---|---|---|
| Calibrated by: | Yu Zongying | SAR Test Engineer | |
| Reviewed by: | Lin Hao | SAR Test Engineer | |
| Approved by: | Qi Dianyuan | SAR Project Leader | |

Issued: February 14, 2023

In Collaboration with
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CALIBRATION LABORATORY

Add: No.52 HuaYuanBei Road, Haidian District, Beijing, 100191, China
Tel: +86-10-62304633-2117
E-mail: emf@caict.ac.cn http://www.caict.ac.cn

**Glossary:**

| | |
|---|---|
| DAE | data acquisition electronics |
| Connector angle | information used in DASY system to align probe sensor X to the robot coordinate system. |

**Methods Applied and Interpretation of Parameters:**

- *DC Voltage Measurement*: Calibration Factor assessed for use in DASY system by comparison with a calibrated instrument traceable to national standards. The figure given corresponds to the full scale range of the voltmeter in the respective range.
- *Connector angle*: The angle of the connector is assessed measuring the angle mechanically by a tool inserted. Uncertainty is not required.
- The report provide only calibration results for DAE, it does not contain other performance test results.



 

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CALIBRATION LABORATORY

Add: No.52 HuaYuanBei Road, Haidian District, Beijing, 100191, China
Tel: +86-10-62304633-2117
E-mail: emf@caict.ac.cn http://www.caict.ac.cn

## DC Voltage Measurement

A/D - Converter Resolution nominal

High Range: 1LSB = 6.1μV , full range = -100…+300 mV

Low Range: 1LSB = 61nV , full range = -1…….+3mV

DASY measurement parameters: Auto Zero Time: 3 sec; Measuring time: 3 sec

| Calibration Factors | X | Y | Z |
|---|---|---|---|
| **High Range** | 403.771 ± 0.15% (k=2) | 403.972 ± 0.15% (k=2) | 404.298 ± 0.15% (k=2) |
| **Low Range** | 3.97108 ± 0.7% (k=2) | 3.97174 ± 0.7% (k=2) | 3.96471 ± 0.7% (k=2) |

## Connector Angle

| | |
|---|---|
| **Connector Angle** to be used in DASY system | 288.5º ± 1 º |



 

**The photos of HAC test are presented in the additional document:**

Appendix to test report No. 23T04Z80421-31/32

The photos of HAC test