

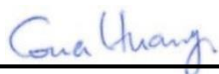
# HEARING AID COMPATIBILITY T-COIL TEST REPORT

FCC ID : HD5-CT50LFN  
Equipment : Mobile Computer  
Brand Name : Honeywell  
Model Name : CT50LFN  
T-Rating : T3  
Applicant : Honeywell International Inc.  
9680 Old Bailes Road, Fort Mill, South Carolina 29707 United States  
Standard : FCC 47 CFR §20.19  
ANSI C63.19-2011

The product was received on Sep. 20, 2018 and testing was started from Sep. 26, 2018 and completed on Sep. 26, 2018. We, SPORTON INTERNATIONAL INC., would like to declare that the tested sample has been evaluated in accordance with the test procedures and has been in compliance with the applicable technical standards.

The report must not be used by the client to claim product certification, approval, or endorsement by TAF or any agency of government.

The test results in this variant report apply exclusively to the tested model / sample. Without written approval of SPORTON INTERNATIONAL INC. EMC & Wireless Communications Laboratory, the test report shall not be reproduced except in full.



Approved by: Cona Huang / Deputy Manager

**SPORTON INTERNATIONAL INC. EMC & Wireless Communications Laboratory**  
No. 52, Huaya 1st Rd., Guishan Dist., Taoyuan City, Taiwan (R.O.C.)



## **Table of Contents**

|                                                         |           |
|---------------------------------------------------------|-----------|
| <b>1. Attestation of Test Results .....</b>             | <b>4</b>  |
| <b>2. General Information .....</b>                     | <b>5</b>  |
| <b>3. Testing Location.....</b>                         | <b>6</b>  |
| <b>4. Applied Standards .....</b>                       | <b>6</b>  |
| <b>5. Air Interface and Operating Mode.....</b>         | <b>7</b>  |
| <b>6. Measurement standards for T-Coil .....</b>        | <b>8</b>  |
| 6.1 Frequency Response .....                            | 8         |
| 6.2 T-Coil Signal Quality Categories.....               | 8         |
| <b>7. T-Coil Test Procedure .....</b>                   | <b>9</b>  |
| 7.1 Test Flow Chart.....                                | 10        |
| 7.2 Test Setup Diagram .....                            | 11        |
| 7.3 Description of EUT Test Position .....              | 13        |
| <b>8. Test Equipment List.....</b>                      | <b>14</b> |
| <b>9. T-Coil testing for OTT VoIP Application .....</b> | <b>15</b> |
| <b>10. Uncertainty Assessment .....</b>                 | <b>20</b> |
| <b>11. References.....</b>                              | <b>21</b> |

**Appendix A. Plots of T-Coil Measurement**

**Appendix B. DASY Calibration Certificate**

**Appendix C. Test Setup Photos**



## History of this test report

| Report No. | Version | Description             | Issued Date   |
|------------|---------|-------------------------|---------------|
| HA891357B  | Rev. 01 | Initial issue of report | Oct. 02, 2018 |
|            |         |                         |               |
|            |         |                         |               |

**1. Attestation of Test Results**

| Air Interface | Band MHz   | T-Rating | Frequency Response | Magnetic Intensity |
|---------------|------------|----------|--------------------|--------------------|
| OTT over EDGE | EDGE850    | T3       | Pass               | Pass               |
|               | EDGE1900   | T4       | Pass               | Pass               |
| OTT over UMTS | Band 2     | T4       | Pass               | Pass               |
|               | Band 5     | T4       | Pass               | Pass               |
| OTT over CDMA | BC0        | T4       | Pass               | Pass               |
|               | BC1        | T4       | Pass               | Pass               |
| OTT over LTE  | Band 2     | T4       | Pass               | Pass               |
|               | Band 4     | T4       | Pass               | Pass               |
|               | Band 5     | T4       | Pass               | Pass               |
|               | Band 17    | T4       | Pass               | Pass               |
| OTT over WiFi | 2450       | T4       | Pass               | Pass               |
|               | 5200       | T4       | Pass               | Pass               |
|               | 5300       | T4       | Pass               | Pass               |
|               | 5500       | T4       | Pass               | Pass               |
|               | 5800       | T4       | Pass               | Pass               |
| Date Tested   | 2018/09/26 |          |                    |                    |

The device is compliance with HAC limits specified in guidelines FCC 47CFR §20.19 and ANSI Standard ANSI C63.19.

**Reviewed by: Jason Wang**

**Report Producer: Daisy Peng**



## 2. General Information

| Product Feature & Specification |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
|---------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Applicant Name                  | Honeywell International Inc.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
| Equipment Name                  | Mobile Computer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
| Brand Name                      | Honeywell                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| Model Name                      | CT50LFN                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
| FCC ID                          | HD5-CT50LFN                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
| HW Version                      | MVT                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
| SW Version                      | 3.4.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| Date Tested                     | 2018/09/26                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
| Frequency Band                  | GSM850: 824.2 MHz ~ 848.8 MHz<br>GSM1900: 1850.2 MHz ~ 1909.8 MHz<br>WCDMA Band II: 1852.4 MHz ~ 1907.6 MHz<br>WCDMA Band V: 826.4 MHz ~ 846.6 MHz<br>CDMA2000 BC0: 824.7 MHz ~ 848.31 MHz<br>CDMA 2000 BC1: 1851.25 MHz ~ 1908.75 MHz<br>LTE Band 2: 1850.7 MHz ~ 1909.3 MHz<br>LTE Band 4: 1710.7 MHz ~ 1754.3 MHz<br>LTE Band 5: 824.7 MHz ~ 848.3 MHz<br>LTE Band 17: 706.5 MHz ~ 713.5 MHz<br>WLAN 2.4GHz Band: 2412 MHz ~ 2462 MHz<br>WLAN 5.2GHz Band: 5180 MHz ~ 5240 MHz<br>WLAN 5.3GHz Band: 5260 MHz ~ 5320 MHz<br>WLAN 5.5GHz Band: 5500 MHz ~ 5700 MHz<br>WLAN 5.8GHz Band: 5745 MHz ~ 5825 MHz<br>Bluetooth: 2402 MHz ~ 2480 MHz |
| Mode                            | GSM/GPRS/EGPRS<br>RMC/AMR 12.2Kbps<br>HSDPA<br>HSUPA<br>DC-HSDPA<br>CDMA2000 : 1xRTT/1xEv-Do(Rev.0)/1xEv-Do(Rev.A)<br>LTE: QPSK, 16QAM<br>802.11a/b/g/n/ac HT20/HT40/VHT20/VHT40/VHT80<br>Bluetooth EDR/LE                                                                                                                                                                                                                                                                                                                                                                                                                                     |



### **3. Testing Location**

Sporton Lab is accredited to ISO 17025 by Taiwan Accreditation Foundation (TAF code: 1190) and the FCC designation No. TW1190 under the FCC 2.948(e) by Mutual Recognition Agreement (MRA) in FCC test.

| Testing Laboratory |                                                                                                                     |
|--------------------|---------------------------------------------------------------------------------------------------------------------|
| Test Site          | SPORTON INTERNATIONAL INC.                                                                                          |
| Test Site Location | No. 52, Huaya 1st Rd., Guishan Dist., Taoyuan City, Taiwan (R.O.C.)<br>TEL: +886-3-327-3456<br>FAX: +886-3-328-4978 |
| Test Site No.      | Sporton Site No.:<br><b>SAR04-HY</b>                                                                                |

### **4. Applied Standards**

- FCC CFR47 Part 20.19
- ANSI C63.19 2011-version
- FCC KDB 285076 D01 HAC Guidance v05
- FCC KDB 285076 D02 T Coil testing v03
- FCC KDB 285076 D03 HAC FAQ v01

## 5. Air Interface and Operating Mode

| Air Interface | Band MHz  | Type | C63.19 Tested | Simultaneous Transmitter | Name of Voice Service                                       | Power Reduction |
|---------------|-----------|------|---------------|--------------------------|-------------------------------------------------------------|-----------------|
| GSM           | EDGE850   | VD   | Yes           | WLAN, BT                 | SIP calling <sup>(1,2)</sup>                                | No              |
|               | EDGE1900  |      |               |                          | / Google Duo <sup>(1)</sup>                                 |                 |
| UMTS          | 850 HSPA  | VD   | Yes           | WLAN, BT                 | SIP calling <sup>(1,2)</sup>                                | No              |
|               | 1900 HSPA |      |               | WLAN, BT                 | / Google Duo <sup>(1)</sup>                                 | No              |
| CDMA          | 850 EVDO  | VD   | Yes           | WLAN, BT                 | SIP calling <sup>(1,2)</sup>                                | No              |
|               | 1900 EVDO |      |               | WLAN, BT                 | / Google Duo <sup>(1)</sup>                                 | No              |
| LTE (FDD)     | Band 2    | VD   | Yes           | WLAN, BT                 | SIP calling <sup>(1,2)</sup><br>/ Google Duo <sup>(1)</sup> | No              |
|               | Band 4    |      |               | WLAN, BT                 |                                                             | No              |
|               | Band 5    |      |               | WLAN, BT                 |                                                             | No              |
|               | Band 17   |      |               | WLAN, BT                 |                                                             | No              |
| Wi-Fi         | 2450      | VD   | Yes           | GSM,WCDMA,CDMA,LTE       | SIP calling <sup>(1,2)</sup><br>/ Google Duo <sup>(1)</sup> | No              |
|               | 5200      |      |               |                          |                                                             | No              |
|               | 5300      |      |               |                          |                                                             | No              |
|               | 5500      |      |               |                          |                                                             | No              |
|               | 5800      |      |               |                          |                                                             | No              |
| BT            | 2450      | DT   | No            | GSM,WCDMA,CDMA,LTE       | NA                                                          | No              |

**Type Transport:**

VO= Voice only

DT= Digital Transport only (no voice)

VD= CMRS and IP Voice Service over Digital Transport

**Remark:**

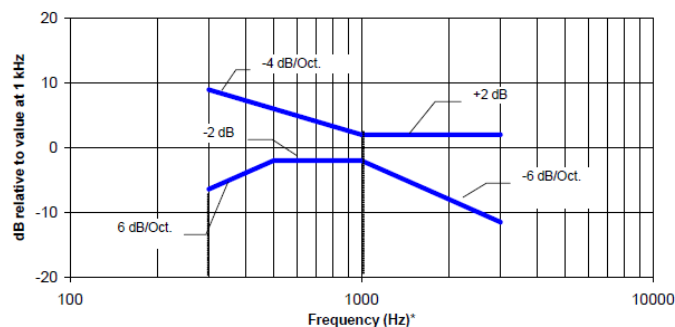
- For protocols not listed in Table 7.1 of ANSI C63.19-2011 or the ANSI C63.19-2011 VoLTE interpretation, the average speech level of -20 dBm0 should be used.
- The SIP calling is android internal auxiliary functions under the dialing program.

## 6. Measurement standards for T-Coil

### 6.1 Frequency Response

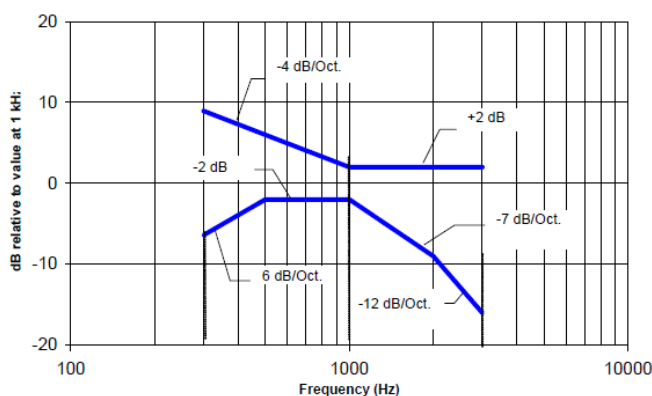
The frequency response of the perpendicular component of the magnetic field, measured in 1/3 octave bands, shall follow the response curve specified in this sub-clause, over the frequency range 300 Hz to 3000 Hz.

Figure 1.1 and Figure 1.2 provide the boundaries as a function of frequency. These response curves are for true field-strength measurements of the T-Coil signal. Thus, the 6 dB/octave probe response has been corrected from the raw readings.



NOTE—The frequency response is between 300 Hz and 3000 Hz.

Fig. 1.1 Magnetic field frequency response for WDs with field strength  $\leq -15$  dB at 1 kHz



NOTE—The frequency response is between 300 Hz and 3000 Hz.

Fig. 1.2 Magnetic field frequency response for WDs with a field that exceeds  $-15$  dB(A/m) at 1 kHz

### 6.2 T-Coil Signal Quality Categories

This section provides the signal quality requirement for the intended T-Coil signal from a WD. Only the RF immunity of the hearing aid is measured in T-Coil mode. It is assumed that a hearing aid can have no immunity to an interference signal in the audio band, which is the intended reception band for this mode. A device is assessed beginning by determining the category of the RF environment in the area of the T-Coil source.

The RF measurements made for the T-Coil evaluation are used to assign the category T1 through T4. The limitation is given in Table 1. This establishes the RF environment presented by the WD to a hearing aid.

| Category    | Telephone parameters WD signal quality<br>((signal + noise) to noise ratio in dB) |
|-------------|-----------------------------------------------------------------------------------|
| Category T1 | 0 to 10 dB                                                                        |
| Category T2 | 10 to 20 dB                                                                       |
| Category T3 | 20 to 30 dB                                                                       |
| Category T4 | > 30 dB                                                                           |

Table 1 T-Coil Signal Quality Categories



## **7. T-Coil Test Procedure**

Referenced to ANSI C63.19-2011, Section 7.4,

This section describes the procedures used to measure the ABM (T-Coil) performance of the WD. In addition to measuring the absolute signal levels, the A-weighted magnitude of the unintended signal shall also be determined. To assure that the required signal quality is measured, the measurement of the intended signal and the measurement of the unintended signal must be made at the same location for each measurement position. In addition, the RF field strength at each measurement location must be at or below that required for the assigned category.

Measurements shall not include undesired properties from the WD's RF field; therefore, use of a coaxial connection to a base station simulator or non-radiating load, there might still be RF leakage from the WD, which can interfere with the desired measurement. Pre-measurement checks should be made to avoid this possibility. All measurements shall be performed with the WD operating on battery power with an appropriate normal speech audio signal input level given in ANSI C63.19-2011 Table 7.1. If the device display can be turned off during a phone call, then that may be done during the measurement as well,

Measurement shall be performed at two locations specified in ANSI C63.19-2011 A.3, with the correct probe orientation for a particular location, in a multistage sequence by first measuring the field intensity of the desired T-Coil signal the same location as the desired ABM or T-Coil signal (ABM1), and the ratio of desired to undesired magnetic components (ABM2) must be measured at the same location as the desired ABM or T-Coil signal (ABM1), and the ratio of desired to undesired ABM signals must be calculated. For the perpendicular field location, only the ABM1 frequency response shall be determined in a third measurement stage.

The following steps summarize the basic test flow for determining ABM1 and ABM2. These steps assume that a sine wave or narrowband 1/3 octave signal can be used for the measurement of ABM1.

- a. A validation of the test setup and instrumentation may be performed using a TMFS or Helmholtz coil Measure the emissions and confirm that they are within the specified tolerance.
- b. Position the WD in the test setup and connect the WD RF connector to a base station simulator or a non-radiating load. Confirm that equipment that requires calibration has been calibrated, and that the noise level meets the requirements given in ANSI C63.19-2011 clause 7.3.1.
- c. The drive level to the WD is set such that the reference input level specified in ANSI C63.19-2011 Table 7.1 is input to the base station simulator (or manufacturer's test mode equivalent) in 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 ANSI C63.19-2011 clause 7.4.2, shall be used for the reference audio signal. If interference is found at 1025 Hz an alternative nearby reference audio signal frequency may be used. The same drive level shall be used for the ABM1 frequency response measurements at each 1/3 octave band center frequency. The WD volume control may be set at any level up to maximum, provided that a signal at any frequency at maximum modulation would not result in clipping or signal overload.
- d. Determine the magnetic measurement locations for the WD device (A.3), if not already specified by the manufacturer, as described in ANSI C63.19-2011 clause 7.4.4.1.1 and 7.4.4.2.
- e. At each measurement location, measure and record the desired T-Coil magnetic signals (ABM1 at  $f_i$ ) as described in ANSI C63.19-2011 clause 7.4.4.2 in each individual ISO 266-1975 R10 standard 1/3 octave band. The desired audio band input frequency ( $f_i$ ) shall be centered in each 1/3 octave band maintaining the same drive level as determined in item c) and the reading taken for that band.
- f. 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 probe output, as specified in D.9, may be used, as long as the appropriate calibration curve is applied to the measured result, so as to yield an accurate measurement of the field magnitude. (The resulting measurement shall be an accurate measurement in dB A/m.)
- g. All Measurements of the desired signal shall be shown to be of the desired signal and not of an undesired signal. This may be shown by turning the desired signal ON and OFF with the probe measuring the same location. If the scanning method is used the scans shall show that all measurement points selected for the ABM1 measurement meet the ambient and test system noise criteria in ANSI C63.19-2011 clause 7.3.1.
- h. At the measurement location for each orientation, measure and record the undesired broadband audio magnetic signal (ABM2) as specified in ANSI C63.19-2011 clause 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).
- i. Obtain the data from the postprocessor, SEMCAD, and determine the category that properly classifies the signal quality based on ANSI C63.19-2011 Table 8.5.

## 7.1 Test Flow Chart

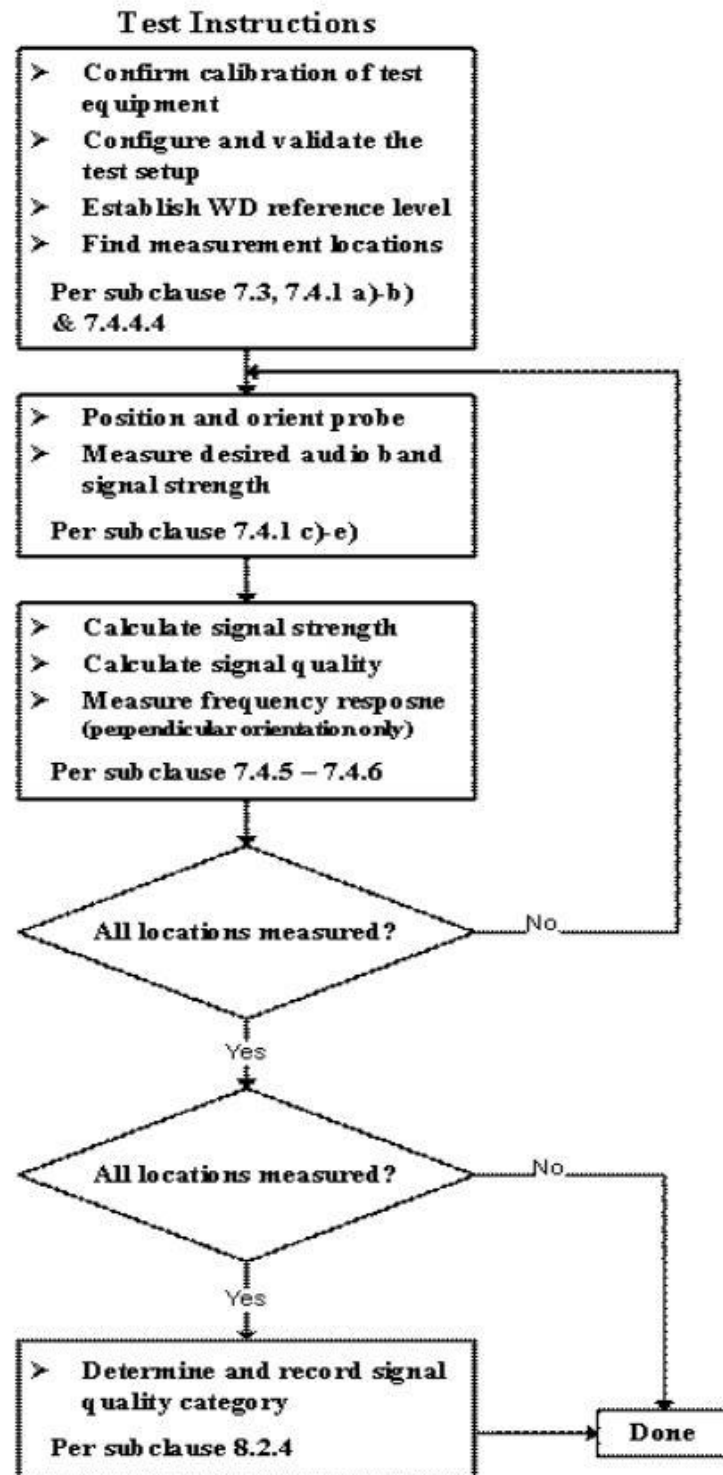
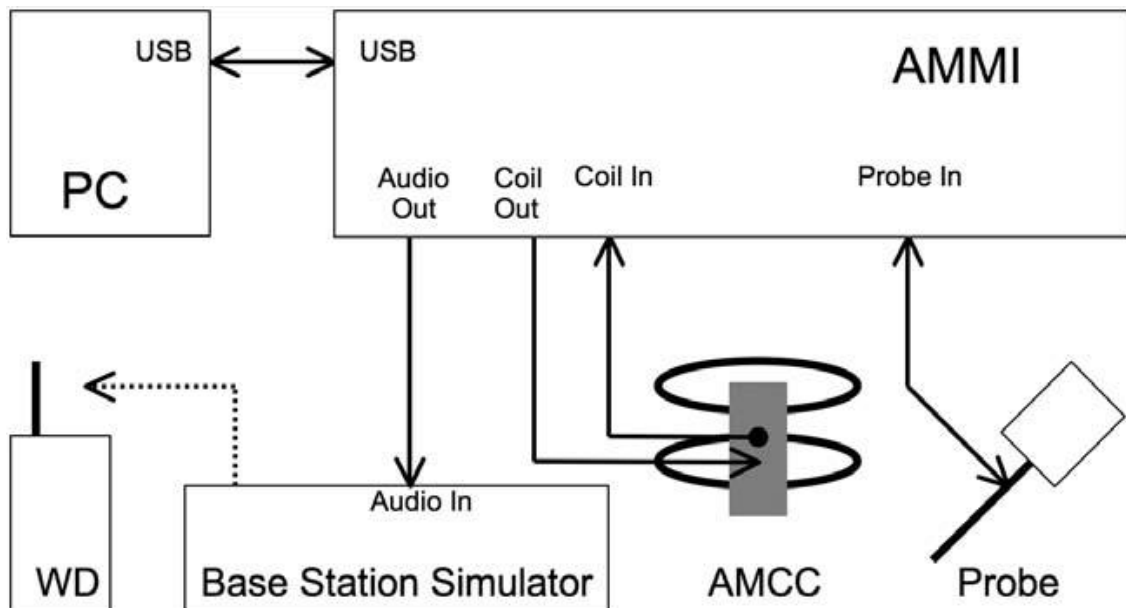


Fig. 2 T-Coil Signal Test flowchart

## **7.2 Test Setup Diagram**



### **General Note:**

1. Define the all applicable input audio level as below according to C63 and KDB 285076 D02v03:  
- OTT VoIP input Level: -20dBm0
2. The test setup used for Google DUO VoIP call is via the data application unit on CMW500 connection to the Internet, also connection to the other auxiliary VoIP unit which is used to configure the audio codec and bit rate and also monitor the audio input level of -20dBm0.
3. The test setup used for SIP calling VoIP application is via the data application unit on CMW500 connection to the Internet, also connection to the other auxiliary VoIP unit which is used to configure the audio codec and determined the audio input level of -20dBm0



## HAC T-COIL TEST REPORT

Report No. : HA891357B

1. The Required gain factor for the specific signal shall typically be multiplied by this factor to achieve approx. the same level as for the 1kHz sine signal
2. The below calculation formula is an example and showing how to determine the input level for the device.

The predefined signal types have the following differences / factors compared to the 1kHz sine signal:

| Signal<br>[file name]         | Duration<br>[s] | Peak-to-<br>RMS [dB] | RMS<br>[dB] | Required gain<br>factor *) | Gain<br>setting |
|-------------------------------|-----------------|----------------------|-------------|----------------------------|-----------------|
| 1kHz sine                     | ---             | 3.0                  | 0.0         | 1.00                       |                 |
| 48k_1.025kHz_10s.wav          | 10              | 3.0                  | 0.0         | 1.00                       |                 |
| 48k_1kHz_3.15kHz_10s.wav      | 10              | 6.0                  | -3.0        | 1.42                       |                 |
| 48k_315Hz_1kHz_10s.wav        | 10              | 6.0                  | -2.9        | 1.40                       |                 |
| 48k_csek_8k_441_white_10s.wav | 10              | 13.8                 | -10.5       | 3.34                       |                 |
| 48k_multisine_50-5000_10s.wav | 10              | 11.1                 | -7.9        | 2.49                       |                 |
| 48k_voice_1kHz_1s.wav         | 1               | 16.2                 | -12.7       | 4.33                       |                 |
| 48k_voice_300-3000_2s.wav     | 2               | 21.6                 | -18.6       | 8.48                       |                 |

(\*) The gain for the specific signal shall typically be multiplied by this factor to achieve approx. the same level as for the 1kHz sine signal.

Insert the gain applicable for your setup in the last column of the table.

Calculation formula:

- Audio Level at -16dBm0 = ((-16dBm0) – (3.14dBm0)) + X dBv
- Calculated Gain at -16dBm0 = 10(( audio level at -16dBm0 – Y dBm0) / 20) \* 10
- Gating setting at -16dBm0 = required gain factor \* calculated gain

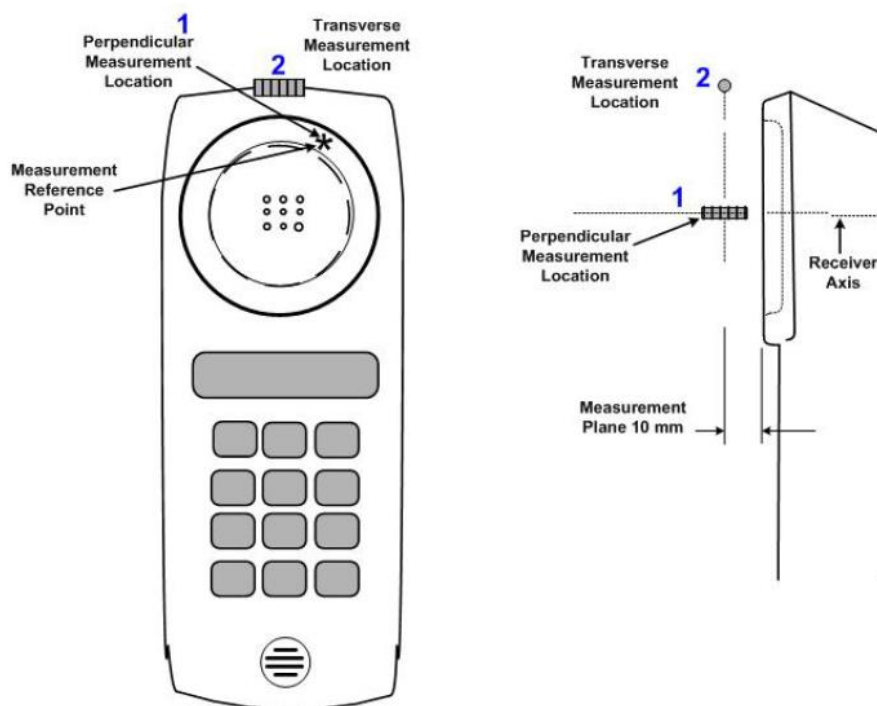
| Gain Value | 20* log(gain) | AMCC Coil In | Level  |
|------------|---------------|--------------|--------|
| (linear)   | dB            | (dBv RMS)    | dBm0   |
|            |               | -2.47        | 3.14   |
| 10         | 20            | -19.85       | -14.24 |
| 8.17       | 18.24         | -21.61       | -16    |

| Signal Type            | Duration<br>(s) | Peak to RMS<br>(dB) | RMS<br>(dB) | Required Gain<br>Factor | Calculated<br>Gain Setting |
|------------------------|-----------------|---------------------|-------------|-------------------------|----------------------------|
| 1kHz sine              | -               | 3                   | 0           | 1                       | 8.17                       |
| 48k_voice_1kHz         | 1               | 16.2                | -12.7       | 4.33                    | 35.36                      |
| 48k_voice_300Hz ~ 3kHz | 2               | 21.6                | -18.6       | 8.48                    | 69.25                      |

### **7.3 Description of EUT Test Position**

Fig.3 illustrate the references and reference plane that shall be used in a typical EUT emissions measurement. The principle of this section is applied to EUT with similar geometry. Please refer to Appendix C for the setup photographs.

- ◆ The area is 5 cm by 5 cm.
- ◆ The area is centered on the audio frequency output transducer of the EUT.
- ◆ The area is in a reference plane, which is defined as 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 EUT handset, which, in normal handset use, rest against the ear.
- ◆ The measurement plane is parallel to, and 10 mm in front of, the reference plane.



**Fig.3 A typical EUT reference and plane for T-Coil measurements**

**8. Test Equipment List**

| Manufacturer | Name of Equipment               | Type/Model | Serial Number | Calibration   |               |
|--------------|---------------------------------|------------|---------------|---------------|---------------|
|              |                                 |            |               | Last Cal.     | Due Date      |
| SPEAG        | Audio Magnetic 1D Field Probe   | AM1DV3     | 3130          | Nov. 21, 2017 | Nov. 20, 2018 |
| SPEAG        | Data Acquisition Electronics    | DAE4       | 910           | Jun. 21, 2018 | Jun. 20, 2019 |
| SPEAG        | Audio Magnetic Calibration Coil | AMCC       | 1049          | NCR           | NCR           |
| SPEAG        | Audio Measuring Instrument      | AMMI       | 1041          | NCR           | NCR           |
| TESTO        | Hygro meter                     | 608-H1     | 34913631      | Aug. 27, 2018 | Aug. 26, 2019 |
| SPEAG        | Test Arch Phantom               | N/A        | N/A           | NCR           | NCR           |
| SPEAG        | Phone Positioner                | N/A        | N/A           | NCR           | NCR           |
| R&S          | Base Station                    | CMW500     | 115793        | May. 24, 2018 | May. 23, 2019 |

**Note:**

1. NCR: "No-Calibration Required"

## 9. T-Coil testing for OTT VoIP Application

### General Notes:

1. According to the ANSI C63.19 2011 section 7.3.2, test middle channel of each frequency band for HAC testing for each orientation to determine worst HAC T-Coil rating.
2. The google Duo VoIP application are pre-installed on this device. According to KDB 285076 D02, all air interfaces via a data connection with VoIP application need to be considered HAC testing.
3. The Google Duo only support OPUS audio codec and support 6Kbps to 75Kbps bitrate.
4. The test setup used for OTT VoIP call is the DUT connect to the CMW500 and via the data application unit on CMW500 connection to the Internet, the Auxiliary EUT is connected to the WiFi access point, the channel/Modulation/Frequency bands/data rate is configured on the CMW500 for the DUT unit. For the Auxiliary VoIP unit which is used to configure the audio codec rate and determine the audio input level of -20dBm0 based on the KDB 285076 D02v03 requirement.
5. Codec Investigation: For a voice service/air interface, investigate the variations of codec configurations (WB, NB bit rate) and document the parameters (ABM1, ABM2, S+N/N, 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.
6. Air Interface Investigation:
  - a. Use the worst-case codec test and document a limited set of bands/channel/bandwidths. Observe the effect of changing the band and bandwidth to ensure that there are no unexpected variations. Using the knowledge of the observed variations, it is necessary to report only a set band/channel/bandwidth for each orientation for a voice service/air interface.
  - b. Select LTE FDD one frequency band to do measurement at the worst SNR position was additionally performed with varying the BWs/Modulations/RB size to verify the variation to find out worst configuration , the observed variation is very little to be within 1 dB which is much less than the margin from the rating threshold.
  - c. Select WLAN 2.4GHz and WLAN 5GHz one frequency band to do measurement at the worst SNR position was additionally performed with varying the BWs/Modulations/data rate to verify the variation to find out worst configuration , the observed variation is very little to be within 1 dB which is much less than the margin from the rating threshold.

### <Codec Investigation>

#### EDGE

| Google Duo          |            |             |             | SIP Calling        |              |                     |                |                | Orientation | Band / Channel |
|---------------------|------------|-------------|-------------|--------------------|--------------|---------------------|----------------|----------------|-------------|----------------|
| Codec               | Opus 6kbps | Opus 40kbps | Opus 75kbps | AMR NB 12.2 Kbit/s | GSM 13Kbit/s | GSM_EFR 12.2 Kbit/s | PCMA 64 Kbit/s | PCMU 64 Kbit/s |             |                |
| ABM 1 (dBA/m)       | -3.43      | -4.28       | -4.63       | -9.66              | -10.32       | -9.69               | -9.29          | -8.54          | Axial       | GSM850 / 189   |
| ABM 2 (dBA/m)       | -45.53     | -44         | -43.53      | -46.38             | -48.2        | -48.36              | -45.4          | -45.08         |             |                |
| Signal Quality (dB) | 42.1       | 39.72       | 38.9        | 36.72              | 37.88        | 38.67               | 36.11          | 36.54          |             |                |
| Freq. Response      | PASS       | PASS        | PASS        | PASS               | PASS         | PASS                | PASS           | PASS           |             |                |

Remark: According to codec investigation, the worst codec bitrate is PCMU 64Kbps

**HSPA**

| Google Duo          |            |             |             | SIP Calling        |              |                     |                |                | Orientation | Band / Channel |
|---------------------|------------|-------------|-------------|--------------------|--------------|---------------------|----------------|----------------|-------------|----------------|
| Codec               | Opus 6kbps | Opus 40kbps | Opus 75kbps | AMR NB 12.2 Kbit/s | GSM 13Kbit/s | GSM_EFR 12.2 Kbit/s | PCMA 64 Kbit/s | PCMU 64 Kbit/s |             |                |
| ABM 1 (dBA/m)       | -2.88      | -2.53       | -2.72       | -10.64             | -10.04       | -10                 | -10.13         | -10.74         |             |                |
| ABM 2 (dBA/m)       | -44.67     | -42.05      | -42.08      | -50.03             | -48.97       | -46.9               | -45.46         | -47.01         |             |                |
| Signal Quality (dB) | 41.79      | 39.52       | 39.36       | 39.39              | 38.93        | 36.9                | 35.33          | 36.27          |             |                |
| Freq. Response      | PASS       | PASS        | PASS        | PASS               | PASS         | PASS                | PASS           | PASS           |             |                |

Remark: According to codec investigation, the worst codec bitrate is PCMU 64Kbps

**EVDO**

| Google Duo          |            |             |             | SIP Calling        |              |                     |                |                | Orientation | Band / Channel |
|---------------------|------------|-------------|-------------|--------------------|--------------|---------------------|----------------|----------------|-------------|----------------|
| Codec               | Opus 6kbps | Opus 40kbps | Opus 75kbps | AMR NB 12.2 Kbit/s | GSM 13Kbit/s | GSM_EFR 12.2 Kbit/s | PCMA 64 Kbit/s | PCMU 64 Kbit/s |             |                |
| ABM 1 (dBA/m)       | -0.51      | -0.28       | -2.82       | -5.79              | -5.75        | -5.63               | -7.7           | -5.64          |             |                |
| ABM 2 (dBA/m)       | -39.56     | -39.52      | -41.68      | -42.59             | -42.81       | -42.79              | -44.37         | -43.01         |             |                |
| Signal Quality (dB) | 39.05      | 39.24       | 38.86       | 36.8               | 37.06        | 37.16               | 36.67          | 37.37          |             |                |
| Freq. Response      | PASS       | PASS        | PASS        | PASS               | PASS         | PASS                | PASS           | PASS           |             |                |

Remark: According to codec investigation, the worst codec bitrate is PCMU 64Kbps

**LTE FDD**

| Google Duo          |            |             |             | SIP Calling        |              |                     |                |                | Orientation | Band / Channel |
|---------------------|------------|-------------|-------------|--------------------|--------------|---------------------|----------------|----------------|-------------|----------------|
| Codec               | Opus 6kbps | Opus 40kbps | Opus 75kbps | AMR NB 12.2 Kbit/s | GSM 13Kbit/s | GSM_EFR 12.2 Kbit/s | PCMA 64 Kbit/s | PCMU 64 Kbit/s |             |                |
| ABM 1 (dBA/m)       | -1.14      | -2.35       | -1.08       | -7.92              | -7.93        | -8.73               | -10.47         | -8.73          |             |                |
| ABM 2 (dBA/m)       | -42.25     | -42.52      | -38.9       | -44.38             | -44.72       | -45.42              | -46.53         | -45.35         |             |                |
| Signal Quality (dB) | 41.11      | 40.17       | 37.82       | 36.46              | 36.79        | 36.69               | 36.06          | 36.62          |             |                |
| Freq. Response      | PASS       | PASS        | PASS        | PASS               | PASS         | PASS                | PASS           | PASS           |             |                |

Remark: According to codec investigation, the worst codec bitrate is PCMU 64Kbps

**WLAN**

| VoIP Codec(Google Duo) |            |             |             | VoIP Codec(SIP Calling) |              |                     |                |                | Orientation | Band / Channel |
|------------------------|------------|-------------|-------------|-------------------------|--------------|---------------------|----------------|----------------|-------------|----------------|
| Codec                  | Opus 6kbps | Opus 40kbps | Opus 75kbps | AMR NB 12.2 Kbit/s      | GSM 13Kbit/s | GSM_EFR 12.2 Kbit/s | PCMA 64 Kbit/s | PCMU 64 Kbit/s |             |                |
| ABM 1 (dBA/m)          | 1.94       | 1.04        | 0.93        | -7.86                   | -7.83        | -7.81               | -8.89          | -7.8           |             |                |
| ABM 2 (dBA/m)          | -41.78     | -41.62      | -37.3       | -43.49                  | -43.44       | -43.55              | -44.42         | -43.43         |             |                |
| Signal Quality (dB)    | 43.72      | 42.66       | 38.23       | 35.63                   | 35.61        | 35.74               | 35.53          | 35.63          |             |                |
| Freq. Response         | PASS       | PASS        | PASS        | PASS                    | PASS         | PASS                | PASS           | PASS           |             |                |

Remark: According to codec investigation, the worst codec bitrate is PCMU 64Kbps

**<Air Interface Investigation>**

| Air Interface |        | BW (MHz) | Modulation / Mode | RB Size | RB offset | Channel | Probe Position | ABM1 dB (A/m) | ABM2 dB (A/m) | Signal Quality dB |
|---------------|--------|----------|-------------------|---------|-----------|---------|----------------|---------------|---------------|-------------------|
| FDD           | LTE B2 | 20       | QPSK              | 1       | 0         | 18900   | Axial (Z)      | -10.47        | -46.53        | 36.06             |
|               | LTE B2 | 20       | QPSK              | 50      | 0         | 18900   | Axial (Z)      | -10.32        | -46.45        | 36.13             |
|               | LTE B2 | 20       | QPSK              | 100     | 0         | 18900   | Axial (Z)      | -10.38        | -46.61        | 36.23             |
|               | LTE B2 | 20       | 16QAM             | 1       | 0         | 18900   | Axial (Z)      | -10.43        | -46.61        | 36.18             |
|               | LTE B2 | 15       | QPSK              | 1       | 0         | 18900   | Axial (Z)      | -10.42        | -46.52        | 36.10             |
|               | LTE B2 | 10       | QPSK              | 1       | 0         | 18900   | Axial (Z)      | -10.45        | -46.56        | 36.11             |
|               | LTE B2 | 5        | QPSK              | 1       | 0         | 18900   | Axial (Z)      | -10.26        | -46.41        | 36.15             |
|               | LTE B2 | 3        | QPSK              | 1       | 0         | 18900   | Axial (Z)      | -10.49        | -46.70        | 36.21             |
|               | LTE B2 | 1.4      | QPSK              | 1       | 0         | 18900   | Axial (Z)      | -10.43        | -46.65        | 36.22             |

| Frequency Bands | Air Interface  | BW (MHz) | Modulation / Mode | Channel | Probe Position | ABM1 dB (A/m) | ABM2 dB (A/m) | Signal Quality dB |
|-----------------|----------------|----------|-------------------|---------|----------------|---------------|---------------|-------------------|
| WLAN 2.4GHz     | 802.11b        | 20       | 1M                | 6       | Axial (Z)      | -7.83         | -43.33        | 35.50             |
|                 | 802.11b        | 20       | 11M               | 6       | Axial (Z)      | -7.87         | -43.55        | 35.68             |
|                 | 802.11g        | 20       | 6M                | 6       | Axial (Z)      | -7.82         | -43.42        | 35.60             |
|                 | 802.11g        | 20       | 54M               | 6       | Axial (Z)      | -7.81         | -43.43        | 35.62             |
|                 | 802.11n-HT20   | 20       | MCS0              | 6       | Axial (Z)      | -7.83         | -43.66        | 35.83             |
|                 | 802.11n-HT20   | 20       | MCS7              | 6       | Axial (Z)      | -7.82         | -43.77        | 35.95             |
| WLAN 5GHz       | 802.11a        | 20       | 6M                | 40      | Axial (Z)      | -8.76         | -43.81        | 35.05             |
|                 | 802.11a        | 20       | 54M               | 40      | Axial (Z)      | -8.77         | -44.05        | 35.28             |
|                 | 802.11an-HT20  | 20       | MCS0              | 40      | Axial (Z)      | -8.76         | -43.99        | 35.23             |
|                 | 802.11an-HT20  | 20       | MCS7              | 40      | Axial (Z)      | -8.76         | -44.02        | 35.26             |
|                 | 802.11an-HT40  | 40       | MCS0              | 38      | Axial (Z)      | -8.77         | -43.94        | 35.17             |
|                 | 802.11an-HT40  | 40       | MCS7              | 38      | Axial (Z)      | -8.77         | -43.99        | 35.22             |
|                 | 802.11ac-VHT20 | 20       | MCS0              | 40      | Axial (Z)      | -8.77         | -44.12        | 35.35             |
|                 | 802.11ac-VHT20 | 20       | MCS8              | 40      | Axial (Z)      | -8.77         | -43.83        | 35.06             |
|                 | 802.11ac-VHT40 | 40       | MCS0              | 38      | Axial (Z)      | -8.77         | -44.10        | 35.33             |
|                 | 802.11ac-VHT40 | 40       | MCS8              | 38      | Axial (Z)      | -8.77         | -43.95        | 35.18             |
|                 | 802.11ac-VHT80 | 80       | MCS0              | 50      | Axial (Z)      | -8.78         | -43.84        | 35.06             |
|                 | 802.11ac-VHT80 | 80       | MCS8              | 50      | Axial (Z)      | -8.78         | -44.01        | 35.23             |

| Plot No. | Air Interface | Modulation / Mode | Channel | Probe Position  | ABM1 dB (A/m) | ABM2 dB (A/m) | Signal Quality dB | T Rating | Ambient Noise dB (A/m) | Freq. Response Variation dB | Frequency Response |
|----------|---------------|-------------------|---------|-----------------|---------------|---------------|-------------------|----------|------------------------|-----------------------------|--------------------|
| 01       | GSM850        | EDGE 2 Tx slots   | 189     | Axial (Z)       | -9.29         | -45.40        | 36.11             | T4       | -50.80                 | 1.29                        | PASS               |
|          |               |                   |         | Transversal (Y) | -17.27        | -47.08        | 29.81             | T3       | -50.26                 |                             |                    |
| 02       | GSM1900       | EDGE 2 Tx slots   | 661     | Axial (Z)       | -9.10         | -45.54        | 36.44             | T4       | -50.33                 | 1.27                        | PASS               |
|          |               |                   |         | Transversal (Y) | -17.12        | -49.67        | 32.55             | T4       | -50.21                 |                             |                    |
| 03       | WCDMA II      | HSPA              | 9400    | Axial (Z)       | -10.13        | -45.46        | 35.33             | T4       | -50.35                 | 1.3                         | PASS               |
|          |               |                   |         | Transversal (Y) | -17.58        | -48.38        | 30.80             | T4       | -50.25                 |                             |                    |
| 04       | WCDMA V       | HSPA              | 4182    | Axial (Z)       | -10.49        | -45.70        | 35.21             | T4       | -50.34                 | 1.28                        | PASS               |
|          |               |                   |         | Transversal (Y) | -17.03        | -50.12        | 33.09             | T4       | -50.22                 |                             |                    |
| 05       | CDMA BC0      | RTAP 153.6Kbps    | 384     | Axial (Z)       | -7.70         | -44.37        | 36.67             | T4       | -50.33                 | 1.3                         | PASS               |
|          |               |                   |         | Transversal (Y) | -16.47        | -50.06        | 33.59             | T4       | -50.22                 |                             |                    |
| 06       | CDMA BC1      | RTAP 153.6Kbps    | 600     | Axial (Z)       | -8.25         | -44.87        | 36.62             | T4       | -50.31                 | 1.29                        | PASS               |
|          |               |                   |         | Transversal (Y) | -16.93        | -49.99        | 33.06             | T4       | -50.19                 |                             |                    |
| 07       | LTE Band 2    | 20M_QPSK_1_0      | 18900   | Axial (Z)       | -10.47        | -46.53        | 36.06             | T4       | -50.37                 | 1.31                        | PASS               |
|          |               |                   |         | Transversal (Y) | -16.35        | -47.60        | 31.25             | T4       | -50.17                 |                             |                    |
| 08       | LTE Band 4    | 20M_QPSK_1_0      | 20175   | Axial (Z)       | -8.07         | -44.29        | 36.22             | T4       | -50.34                 | 1.33                        | PASS               |
|          |               |                   |         | Transversal (Y) | -16.82        | -47.91        | 31.09             | T4       | -50.24                 |                             |                    |
| 09       | LTE Band 5    | 10M_QPSK_1_0      | 20525   | Axial (Z)       | -8.08         | -44.54        | 36.46             | T4       | -50.36                 | 1.3                         | PASS               |
|          |               |                   |         | Transversal (Y) | -16.26        | -46.95        | 30.69             | T4       | -50.21                 |                             |                    |
| 10       | LTE Band 17   | 10M_QPSK_1_0      | 23790   | Axial (Z)       | -8.10         | -44.39        | 36.29             | T4       | -50.35                 | 1.26                        | PASS               |
|          |               |                   |         | Transversal (Y) | -16.37        | -48.03        | 31.66             | T4       | -50.20                 |                             |                    |
| 11       | WLAN2.4GHz    | 802.11b 1Mbps     | 6       | Axial (Z)       | -8.89         | -44.42        | 35.53             | T4       | -50.36                 | 1.28                        | PASS               |
|          |               |                   |         | Transversal (Y) | -17.01        | -49.26        | 32.25             | T4       | -50.21                 |                             |                    |
| 12       | WLAN5GHz      | 802.11a 6Mbps     | 40      | Axial (Z)       | -9.27         | -44.96        | 35.69             | T4       | -50.37                 | 1.28                        | PASS               |
|          |               |                   |         | Transversal (Y) | -16.98        | -48.26        | 31.28             | T4       | -50.22                 |                             |                    |
| 13       | WLAN5GHz      | 802.11a 6Mbps     | 60      | Axial (Z)       | -10.07        | -45.55        | 35.48             | T4       | -50.32                 | 1.28                        | PASS               |
|          |               |                   |         | Transversal (Y) | -17.14        | -47.95        | 30.81             | T4       | -50.18                 |                             |                    |
| 14       | WLAN5GHz      | 802.11a 6Mbps     | 124     | Axial (Z)       | -9.25         | -45.18        | 35.93             | T4       | -50.34                 | 1.28                        | PASS               |
|          |               |                   |         | Transversal (Y) | -16.40        | -48.48        | 32.08             | T4       | -50.23                 |                             |                    |
| 15       | WLAN5GHz      | 802.11a 6Mbps     | 157     | Axial (Z)       | -9.08         | -45.01        | 35.93             | T4       | -50.36                 | 1.27                        | PASS               |
|          |               |                   |         | Transversal (Y) | -16.30        | -48.09        | 31.79             | T4       | -50.25                 |                             |                    |

**Remark:**

1. Phone Condition: Mute on; Backlight off; Max Volume
2. The detail frequency response results please refer to appendix A.
3. Test Engineer : Nick Yu and Steven Chang

## 10. Uncertainty Assessment

The evaluation of uncertainty by the statistical analysis of a series of observations is termed a Type A evaluation of uncertainty. The evaluation of uncertainty by means other than the statistical analysis of a series of observation is termed a Type B evaluation of uncertainty. Each component of uncertainty, however evaluated, is represented by an estimated standard deviation, termed standard uncertainty, which is determined by the positive square root of the estimated variance. The combined standard uncertainty of the measurement result represents the estimated standard deviation of the result. It is obtained by combining the individual standard uncertainties of both Type A and Type B evaluation using the usual "root-sum-squares" (RSS) methods of combining standard deviations by taking the positive square root of the estimated variances. Expanded uncertainty is a measure of uncertainty that defines an interval about the measurement result within which the measured value is confidently believed to lie. It is obtained by multiplying the combined standard uncertainty by a coverage factor. For purpose of this document, a coverage factor two is used, which corresponds to confidence interval of about 95 %. The DASY uncertainty Budget is showed in Table 8.2.

| Error Description                  | Uncertainty Value (±%) | Probability Distribution | Divisor | Ci (ABM1) | Ci (ABM2) | Standard Uncertainty (ABM1) | Standard Uncertainty (ABM2) |
|------------------------------------|------------------------|--------------------------|---------|-----------|-----------|-----------------------------|-----------------------------|
| <b>Probe Sensitivity</b>           |                        |                          |         |           |           |                             |                             |
| Reference Level                    | 3.0                    | Normal                   | 1       | 1         | 1         | ± 3.0 %                     | ± 3.0 %                     |
| AMCC Geometry                      | 0.4                    | Rectangular              | √3      | 1         | 1         | ± 0.2 %                     | ± 0.2 %                     |
| AMCC Current                       | 1.0                    | Rectangular              | √3      | 1         | 1         | ± 0.6 %                     | ± 0.6 %                     |
| Probe Positioning During Calibrate | 0.1                    | Rectangular              | √3      | 1         | 1         | ± 0.1 %                     | ± 0.1 %                     |
| Noise Contribution                 | 0.7                    | Rectangular              | √3      | 0.0143    | 1         | ± 0.0 %                     | ± 0.4 %                     |
| Frequency Slope                    | 5.9                    | Rectangular              | √3      | 0.1       | 1         | ± 0.3 %                     | ± 3.5 %                     |
| <b>Probe System</b>                |                        |                          |         |           |           |                             |                             |
| Repeatability / Drift              | 1.0                    | Rectangular              | √3      | 1         | 1         | ± 0.6 %                     | ± 0.6 %                     |
| Linearity / Dynamic Range          | 0.6                    | Rectangular              | √3      | 1         | 1         | ± 0.4 %                     | ± 0.4 %                     |
| Acoustic Noise                     | 1.0                    | Rectangular              | √3      | 0.1       | 1         | ± 0.1 %                     | ± 0.6 %                     |
| Probe Angle                        | 2.3                    | Rectangular              | √3      | 1         | 1         | ± 1.4 %                     | ± 1.4 %                     |
| Spectral Processing                | 0.9                    | Rectangular              | √3      | 1         | 1         | ± 0.5 %                     | ± 0.5 %                     |
| Integration Time                   | 0.6                    | Normal                   | 1       | 1         | 5         | ± 0.6 %                     | ± 3.0 %                     |
| Field Disturbation                 | 0.2                    | Rectangular              | √3      | 1         | 1         | ± 0.1 %                     | ± 0.1 %                     |
| <b>Test Signal</b>                 |                        |                          |         |           |           |                             |                             |
| Reference Signal Spectral Response | 0.6                    | Rectangular              | √3      | 0         | 1         | ± 0.0 %                     | ± 0.4 %                     |
| <b>Positioning</b>                 |                        |                          |         |           |           |                             |                             |
| Probe Positioning                  | 1.9                    | Rectangular              | √3      | 1         | 1         | ± 1.1 %                     | ± 1.1 %                     |
| Phantom Thickness                  | 0.9                    | Rectangular              | √3      | 1         | 1         | ± 0.5 %                     | ± 0.5 %                     |
| EUT Positioning                    | 1.9                    | Rectangular              | √3      | 1         | 1         | ± 1.1 %                     | ± 1.1 %                     |
| <b>External Contributions</b>      |                        |                          |         |           |           |                             |                             |
| RF Interference                    | 0.0                    | Rectangular              | √3      | 1         | 0.3       | ± 0.0 %                     | ± 0.0 %                     |
| Test Signal Variation              | 2.0                    | Rectangular              | √3      | 1         | 1         | ± 1.2 %                     | ± 1.2 %                     |
| Combined Standard Uncertainty      |                        |                          |         |           |           | ± 4.1 %                     | ± 6.1 %                     |
| Coverage Factor for 95 %           |                        |                          |         |           |           | K = 2                       |                             |
| Expanded Uncertainty               |                        |                          |         |           |           | ± 8.1 %                     | ± 12.3 %                    |

**Table 8.2 Uncertainty Budget of audio band magnetic measurement**



## **11. References**

- [1] ANSI C63.19-2011, "American National Standard for Methods of Measurement of Compatibility between Wireless Communications Devices and Hearing Aids", 27 May 2011.
- [2] FCC KDB 285076 D01v05, "Equipment Authorization Guidance for Hearing Aid Compatibility", Sep 2017
- [3] FCC KDB 285076 D02v03, "Guidance for performing T-Coil tests for air interfaces supporting voice over IP (e.g., LTE and WiFi) to support CMRS based telephone services", Sep 2017
- [4] FCC KDB 285076 D03v01, "Hearing aid compatibility frequently asked questions", Sep 2017
- [5] SPEAG DASY System Handbook