# Hearing Aid Compatibility (HAC) T-Coil Test Report

| | |
|---|---|
| APPLICANT | : ZTE CORPORATION |
| EQUIPMENT | : WCDMA/LTE multi-mode Digital Mobile Phone |
| BRAND NAME | : ZTE |
| MODEL NAME | : Z980L |
| FCC ID | : SRQ-Z980L |
| STANDARD | : FCC 47 CFR §20.19<br>ANSI C63.19-2011 |
| HAC RATING | : T4 |

**The product sample completely tested on Aug. 06, 2014. We, SPORTON INTERNATIONAL (KUNSHAN) INC., would like to declare that the tested sample has been evaluated in accordance with the procedures and shown the compliance with the applicable technical standards.**

**The test results in this report apply exclusively to the tested model / sample. Without written approval of SPORTON INTERNATIONAL (KUNSHAN) INC., the test report shall not be reproduced except in full.**

**Reviewed by: Eric Huang / Deputy Manager**

**Approved by: Jones Tsai / Manager**

Testing Laboratory 2627

***SPORTON INTERNATIONAL (KUNSHAN) INC.***
***No. 3-2, PingXiang Road, Kunshan, Jiangsu Province, P.R.C.***

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# Revision History

| REPORT NO. | VERSION | DESCRIPTION | ISSUED DATE |
|---|---|---|---|
| HA472902B | Rev. 01 | Initial issue of report | Sep. 01, 2014 |
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# 1. Statement of Compliance

The Hearing Aid Compliance (HAC) maximum results found during testing for the **ZTE Z980L** are as follows:

| Band | Test Item | Criterion | Test Results | T Rating |
|---|---|---|---|---|
| GSM850 | Field Intensity (dB A/m) | ≥ –18 | -3.33 | T4 |
| | Frequency Response | pass | pass | |
| | Signal Quality (dB) | T3 ≥ 20 | 30.91 | |
| GSM1900 | Field Intensity (dB A/m) | ≥ –18 | -3.48 | T4 |
| | Frequency Response | pass | pass | |
| | Signal Quality (dB) | T3 ≥ 20 | 33.13 | |
| WCDMA Band V | Field Intensity (dB A/m) | ≥ –18 | -0.71 | T4 |
| | Frequency Response | pass | pass | |
| | Signal Quality (dB) | T3 ≥ 20 | 39.83 | |
| WCDMA Band IV | Field Intensity (dB A/m) | ≥ –18 | -1.83 | T4 |
| | Frequency Response | pass | pass | |
| | Signal Quality (dB) | T3 ≥ 20 | 41.17 | |
| WCDMA Band II | Field Intensity (dB A/m) | ≥ –18 | -0.12 | T4 |
| | Frequency Response | pass | pass | |
| | Signal Quality (dB) | T3 ≥ 20 | 40.18 | |

They are in compliance with HAC limits specified in guidelines FCC 47CFR §20.19 and ANSI Standard ANSI C63.19.

**HAC rating = T4 (ANSI C63.19-2011)**

## 2. Administration Data

| Testing Laboratory | |
|---|---|
| **Test Site** | SPORTON INTERNATIONAL (KUNSHAN) INC. |
| **Test Site Location** | No. 3-2, PingXiang Road, Kunshan, Jiangsu Province, P.R.C.<br>TEL: +86-0512-5790-0158<br>FAX: +86-0512-5790-0958 |
| **Test Site No.** | **Sporton Site No. :**<br>SAR01-KS |
| **Applicant** | |
| **Company Name** | ZTE CORPORATION |
| **Address** | ZTE Plaza, Keji Road South, Hi-Tech Industrial Park, Nanshan District, Shenzhen, Guangdong, 518057, P.R.China |
| **Manufacturer** | |
| **Company Name** | ZTE CORPORATION |
| **Address** | ZTE Plaza, Keji Road South, Hi-Tech Industrial Park, Nanshan District, Shenzhen, Guangdong, 518057, P.R.China |
| **Application Details** | |
| **Date of Start during the Test** | Aug. 06, 2014 |
| **Date of End during the Test** | Aug. 06, 2014 |

# 3. General Information

## 3.1 Description of Equipment Under Test (EUT)

| Product Feature & Specification | |
|---|---|
| EUT Type | WCDMA/LTE multi-mode Digital Mobile Phone |
| Brand Name | ZTE |
| Model Name | Z980L |
| FCC ID | SRQ-Z980L |
| IMEI Code | 004401783147362 |
| Tx Frequency | GSM850: 824.2 MHz ~ 848.8 MHz<br>GSM1900: 1850.2 MHz ~ 1909.8 MHz<br>WCDMA Band V: 826.4 MHz ~ 846.6 MHz<br>WCDMA Band IV: 1712.4 MHz ~ 1752.6 MHz<br>WCDMA Band II: 1852.4 MHz ~ 1907.6 MHz<br>LTE Band 17: 706.5 MHz ~ 713.5 MHz<br>LTE Band 5: 824.7 MHz ~ 848.3 MHz<br>LTE Band 4: 1710.7 MHz ~ 1754.3 MHz<br>LTE Band 2: 1850.7 MHz ~ 1909.3 MHz<br>WLAN 2.4GHz Band: 2412 MHz ~ 2462 MHz<br>Bluetooth: 2402 MHz ~ 2480 MHz |
| Antenna Type | WWAN PIFA Antenna<br>WLAN PIFA Antenna<br>Bluetooth: PIFA Antenna |
| HW Version | wvmA |
| SW Version | Z980LV1.0.0B01 |
| Mode | • GSM/GPRS/EGPRS<br>• WCDMA<br>• HSDPA<br>• HSUPA<br>• HSPA+ (Downlink Only)<br>• LTE: QPSK, 16QAM<br>• 802.11b/g/n HT20<br>• Bluetooth v3.0+EDR，Bluetooth v4.0 LE |
| EUT Stage | Identical Prototype |

## 3.2 Air Interface and Operating Mode

| Air Interface | Band MHz | Type | C63.19 Tested | Simultaneous Transmitter | OTT | Power Reduction |
|---|---|---|---|---|---|---|
| GSM | 850 | VO | Yes | WLAN, BT | NA | No |
| | 1900 | | | WLAN, BT | NA | No |
| | GPRS/EDGE | DT | No | WLAN, BT | Yes | No |
| WCDMA | 850 | VO | Yes | WLAN, BT | NA | No |
| | 1900 | | | WLAN, BT | NA | No |
| | 1700 | | | WLAN, BT | NA | No |
| | HSPA | DT | No | WLAN, BT | Yes | No |
| LTE | Band 2 | DT | No | WLAN, BT | Yes | No |
| | Band 4 | | | WLAN, BT | | No |
| | Band 5 | | | WLAN, BT | | No |
| | Band 17 | | | WLAN, BT | | No |
| WLAN | 2450 | DT | No | GSM, WCDMA,LTE | Yes | No |
| BT | 2450 | DT | No | GSM, WCDMA,LTE | NA | No |

VO=CMRS Voice Service
DT=Digital Transport
VD=CMRS IP Voice Service and Digital Transport
(*)No Associated T-Coil measurement has been made in accordance with 285076 D02 T-Coil testing for CMRS IP

## 3.3 Applied Standards

- FCC CFR47 Part 20.19
- ANSI C63.19 2011-version
- FCC KDB 285076 D01 HAC Guidance v04
- FCC KDB 285076 D02 T Coil testing for CMRS IP v01r01

# 4. HAC T-Coil

FCC wireless hearing aid compatibility rules ensure that consumers with hearing loss are able to access wireless communications services through a wide selection of handsets without experiencing disabling radio frequency (RF) interference or other technical obstacles.
To define and measure the hearing aid compatibility of handsets, in CFR47 part 20.19 ANSI C63.19 is referenced. A handset is considered hearing aid-compatible for acoustic coupling if it meets a rating of at least M3 under ANSI C63.19, and A handset is considered hearing aid compatible for inductive coupling if it meets a rating of at least T3.

For inductive coupling, the wireless communication devices should be measured as below.
1) Magnetic signal strength in the audio band
2) Magnetic signal frequency response through the audio band
3) Magnetic signal to noise

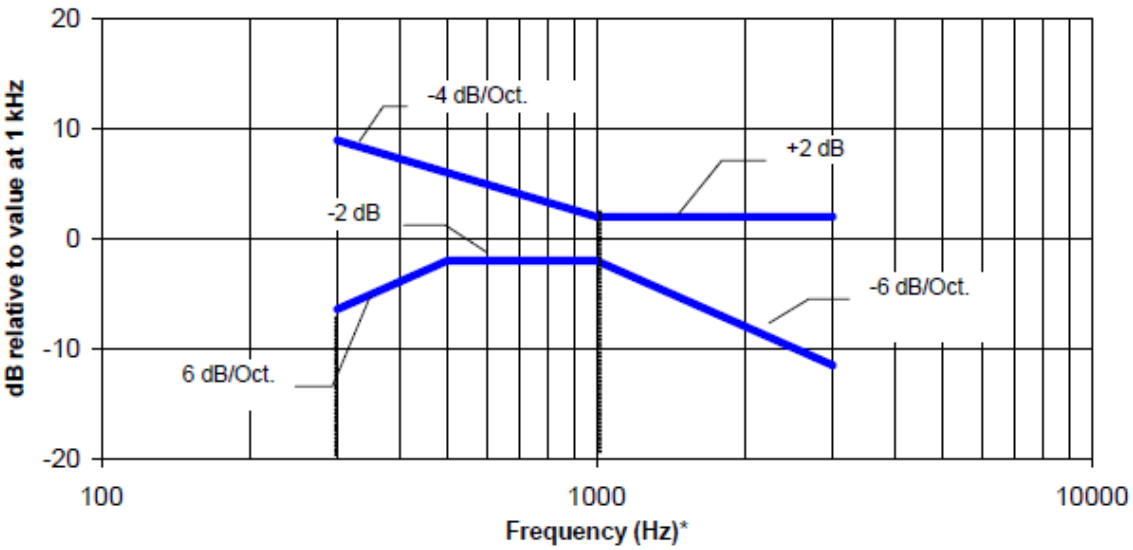
## 4.1 T-Coil Coupling Field Intensity

When measured as specified in this standard, the T-Coil signal shall be ≥ –18 dB (A/m) at 1 kHz, in a 1/3 octave band filter for all orientations.

## 4.2 T-Coil Frequency Response

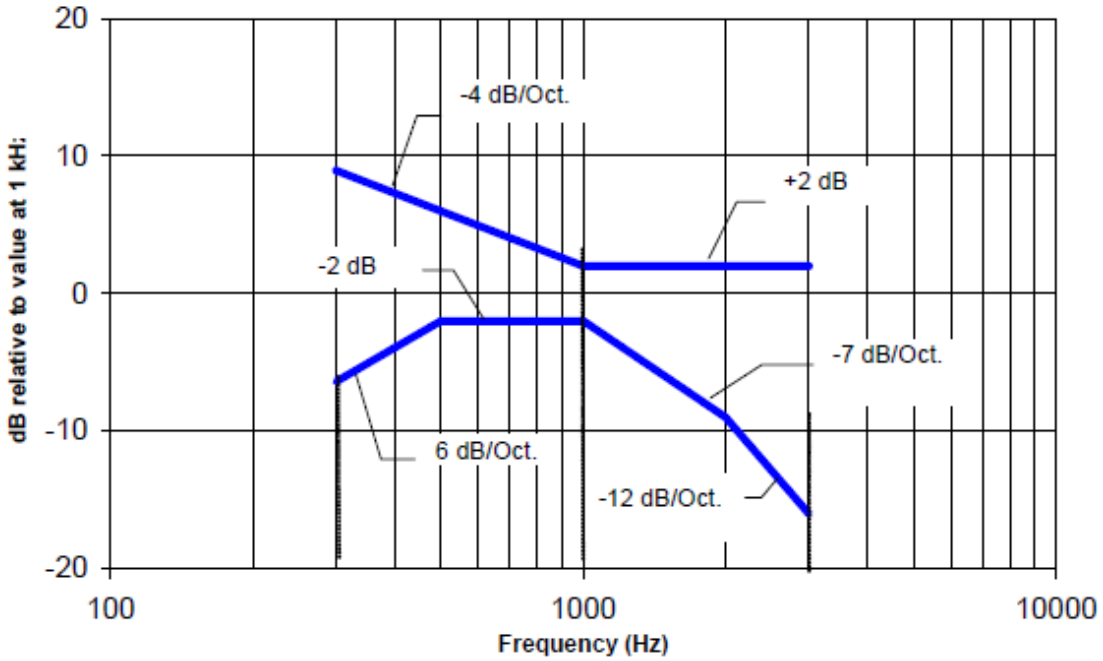
The frequency response of the perpendicular component of the magnetic field, measured in 1/3 octave bands, shall follow the response curve specified in this sub-clause, over the frequency range 300 Hz to 3000 Hz.

Figure 4.1 and Figure 4.2 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. 4.1 Magnetic field frequency response for WDs with field strength≤-15dB at 1 KHz**




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

**Fig. 4.2 Magnetic field frequency response for WDs with a field that exceeds –15 dB(A/m) at 1 kHz**

## 4.3 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 4.3. This establishes the RF environment presented by the WD to a hearing aid.

| Category | Telephone parameters WD signal quality ((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 4.3 T-Coil Signal Quality Categories**

# 5. Measurement System Specification

## 5.1 System Configuration

**Fig. 5.1 T-Coil setup with HAC Test Arch and AMCC**

## 5.2 Test Arch Phantom

| | |
|---|---|
| **Construction :** | 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 |

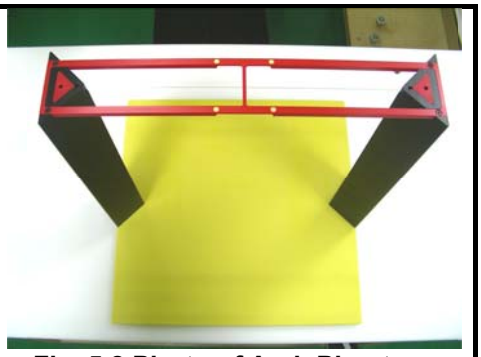


**Fig. 5.2 Photo of Arch Phantom**

## 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 10 Ohm permits monitoring the current with a scale of 1:10.

| Port description | | |
|---|---|---|
| **Signal** | **Connector** | **Resistance** |
| Coil In | BNC | typically 50 Ohm |
| 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 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 ~ 20 kHz (RF sensitivity <-100dB, fully RF shielded ) |
| **Sensitivity** | <-50dB A/m @ 1 kHz |
| **Pre-amplifier** | 40 dB, symmetric |
| **Dimensions** | Tip diameter/ length: 6/ 290 mm, sensor according to ANSI-C63.19 |

## 5.5 AMMI

**Fig. 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 |

## 5.6 System Hardware

| DAE |
|---|
| The data acquisition electronics (DAE) 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. |
| **Robot** |
| The SPEAG DASY system uses the high precision robots (DASY5: TX90XL) type from Stäubli SA (France). For the 6-axis controller system, the robot controller version (DASY5: CS8c) from Stäubli is used. |

## 5.7 Cabling of System

The principal cabling of the T-Coil setup is shown in Fig. 5.4. All cables provided with the basic setup have a length of approximately 5 m.

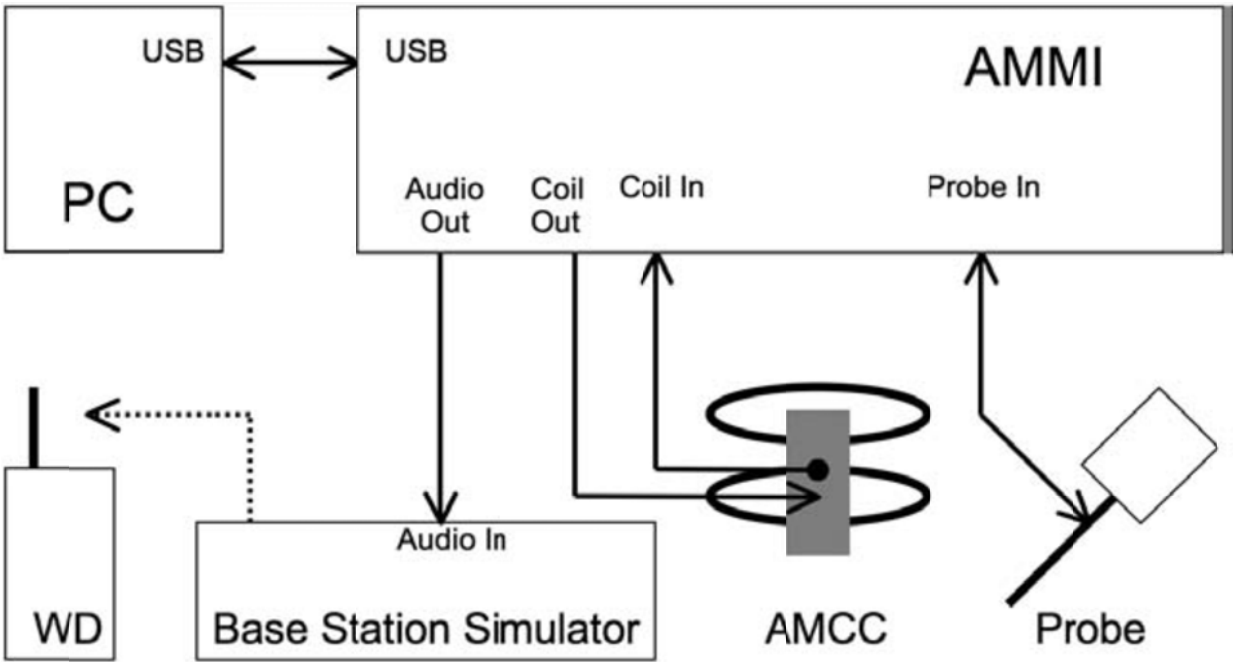



**Fig. 5.4 T-Coil setup cabling**

## 5.8 Test Equipment List

| Manufacturer | Name of Equipment | Type/Model | Serial Number | Calibration | |
|---|---|---|---|---|---|
| | | | | Last Cal. | Due Date |
| SPEAG | Active Audio Magnetic Field Probe | AM1DV3 | 3093 | May 20, 2014 | May 19, 2015 |
| SPEAG | Data Acquisition Electronics | DAE4 | 1210 | May 19, 2014 | May 18, 2015 |
| SPEAG | Test Arch Phantom | Par phantom | 1105 | NCR | NCR |
| SPEAG | Phone Positioner | N/A | N/A | NCR | NCR |
| R&S | Universal Radio Communication Tester | CMU200 | 116456 | Sep. 28, 2013 | Sep. 27, 2014 |
| SPEAG | Audio Magnetic Measuring Instrument | AMMI | 1128 | NA | NA |
| SPEAG | Helmholtz calibration coil | AMCC | NA | NA | NA |

**Table 5.1 Test Equipment List**

## 5.9 Probe Calibration in AMCC

The probe sensitivity at 1 kHz is 0.06556 V/(A/m) (-23.66 dBV/(A/m)) was calibrated by AMCC coil for verification of setup performance.

The evaluated probe sensitivity was able to be compared to the calibration of the AM1D probe. The frequency response and sensitivity was shown in Fig. 5.5. The probe signal is represented after application of an ideal integrator. The green curve represents the current though the AMCC, the blue curve the integrated probe signal. The DIFFERENCE between the two curves is equivalent to the frequency response of the probe system and shows the characteristics. The probe/system complies with the frequency response and linearity requirements in C63.19 according to the SPEAG's calibrated report as shown in Annex B (AM1D probe: SPAM100AF) (1)The frequency response has been tested within +/- 0.5 dB of ideal differentiator from 100 Hz to 10 kHz. (2)The linearity has also been tested within 0.1dB from 5 dB below limitation to 16 dB above noise level. The AMCC coil is qualified according to certificate report, SDHACPO02A as shown in Annex B.

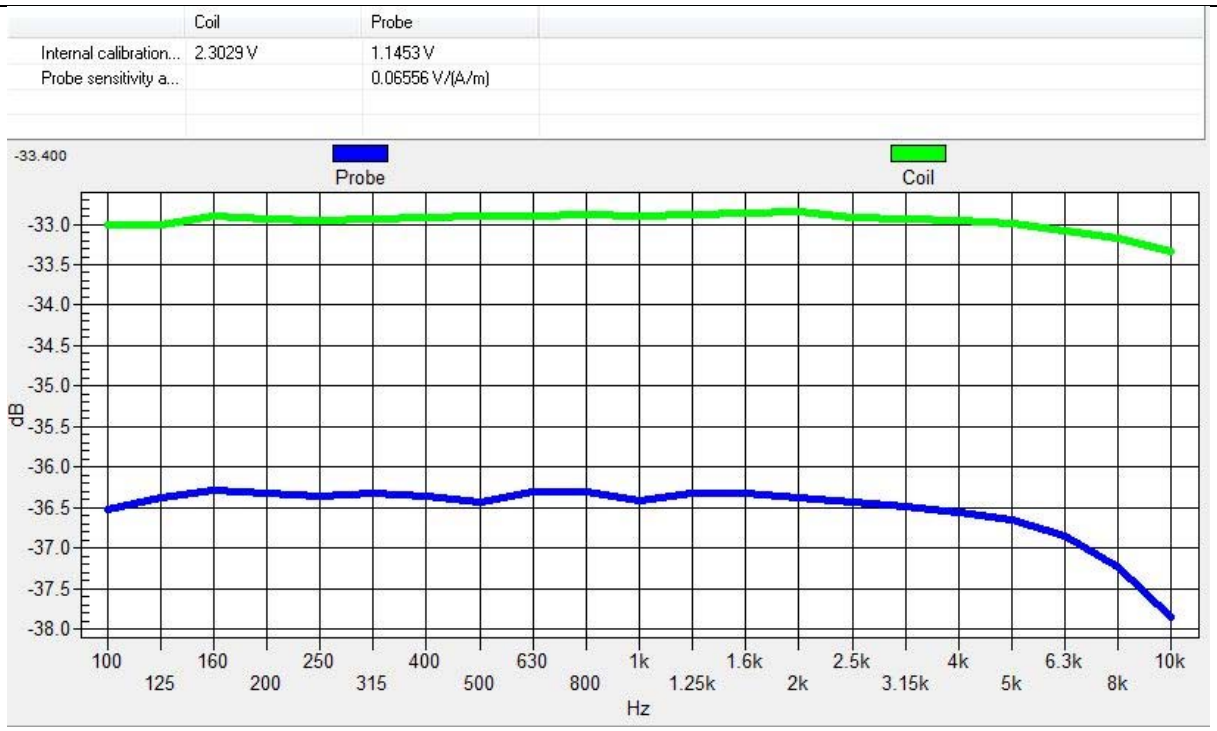



**Fig. 5.5 The frequency response and sensitivity of AM1D probe**

## 5.10 Reference Input of Audio Signal Spectrum

With the reference job "use as reference" in the beginning of a procedure, measure the spectrum of the current when applied to the AMCC, i.e. the input magnetic field spectrum, as shown below Fig. 5.6 and Fig. 5.7. For this, the delay of the window shall be set to a multiple of the signal period and at least 2s. From the measurement on the device, using the same signal, the postprocessor deducts the input spectrum, so the result represents the net EUT response.

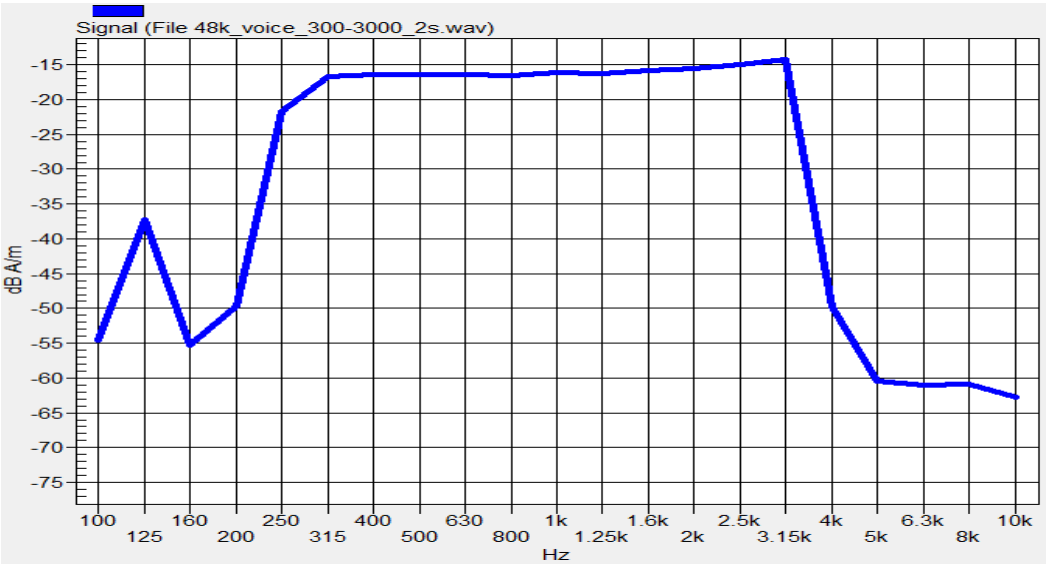



**Fig. 5.6 Audio signal spectrum of the broadband signal (48kHz_voice_300Hz~3 kHz)**

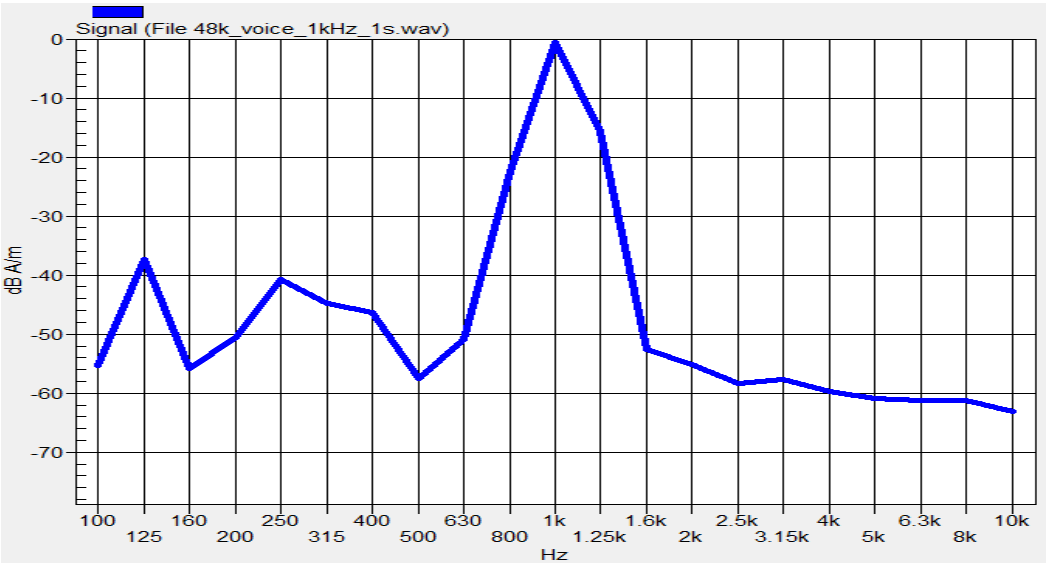



**Fig. 5.7 Audio signal spectrum of the narrowband signal (48kHz_voice_1kHz)**

## 5.11 Establish Reference Level

According to ANSI C63.19:2011 section 7.4.2.1, the normal speech input level for HAC T-coil tests shall be set to -16 dBm0 for GSM and UMTS (WCDMA), and to -18 dBm0 for CDMA. This technical note shows a possibility to evaluate and set the correct level with the HAC T-Coil setup with a Rohde&Schwarz communication tester CMU200 with audio option B52 and B85.

Establish a call from the CMU200 to a wireless device. Select CMU200 Network Bitstream ”Decoder Cal” to have a 1 kHz signal with a level of 3.14 dBm0 at the speech output. Run the measurement job and read the voltage level at the multi-meter display “Coil signal”. Read the RMS voltage corresponding to 3.14 dBm0 and note it.

Determine the 1 kHz input level to generate the desired signal level of -16 dBm0. Select CMU200 Network Bitstream “Codec Cal” to loop the input via the codec to the output. Run the measurement job (AMMI 1 kHz signal with gain 10 inserted) and read the voltage level at the multimeter display “Coil signal”. With Gain 10 setting, the measurement signal difference to the desired signal level of -16 dBm0.

Calculations:

*3.14 dBm0 = -2.44 dBV → -16 dBm0 = -21.58 dBV*
*Gain 10 = -20.7 dBV*
*-21.58 - (-20.7) = -0.88 dB*
*10* [10 ^ ((-0.88) / 20)] = 10 x 0.904 = 9.04*
*Required Gain Factor = 10^(-RMS(dB)/20)*
*Gain Setting = Required Gain Factor * 9.04*

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

| Signal Type | Duration (s) | Peak to RMS (dB) | RMS (dB) | Required Gain Factor (*) | Gain Setting |
|---|---|---|---|---|---|
| 48k_voice_1kHz | 1 | 16.2 | -12.7 | 4.33 | 39.13 |
| 48k_voice_300Hz ~ 3kHz | 2 | 21.6 | -18.6 | 8.48 | 76.63 |

Remark:
(*) 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

# 6. T-Coil Test Procedure

## 6.1 Test Process and Flow Chart

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 ise 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 fi) 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 (fi) 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.

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.)

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.

f) 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).

g) 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.

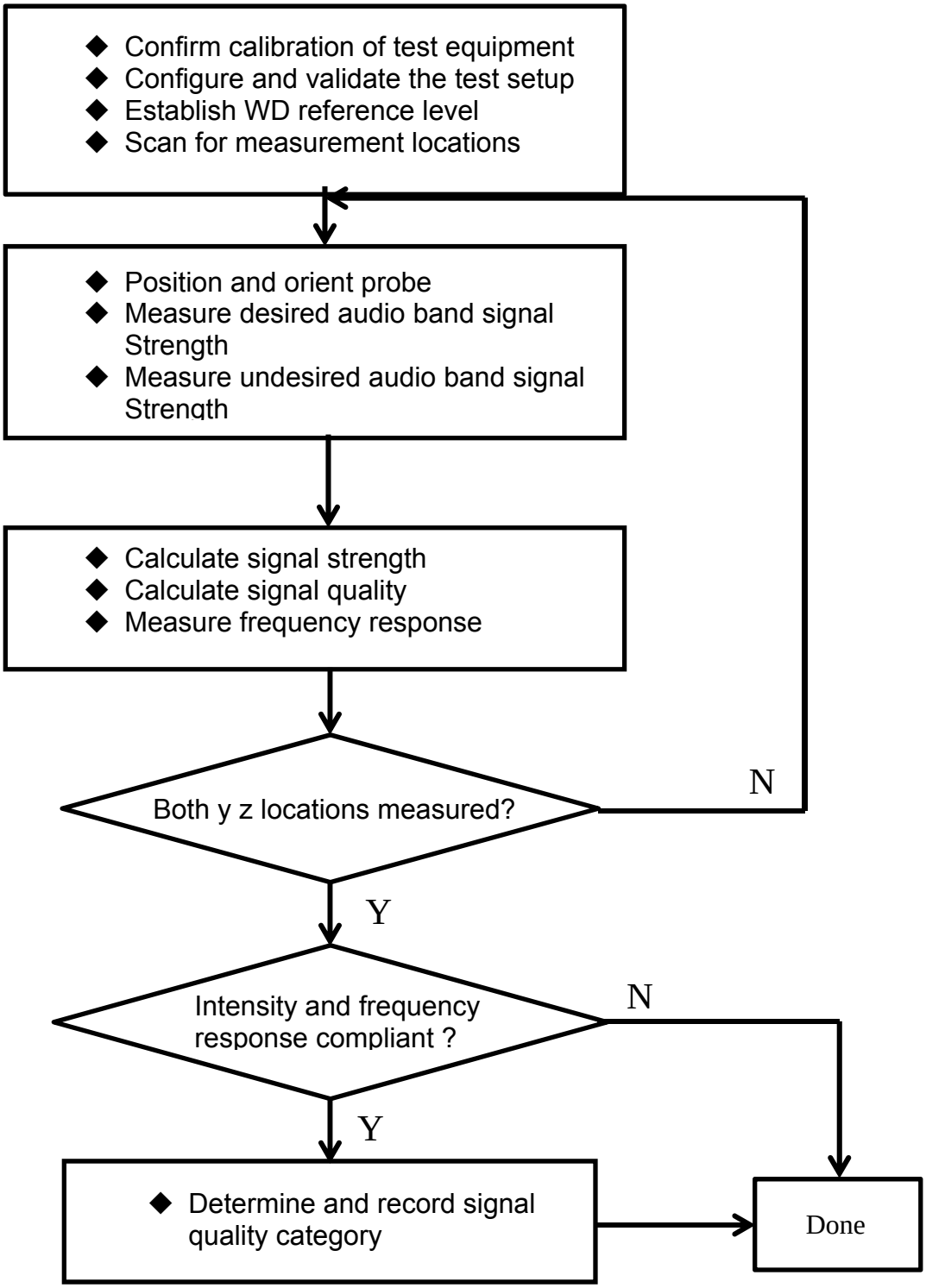



**Fig. 6.1 Test Flow Chart**

## 6.2 Description of EUT Test Position

Fig.6.2 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.

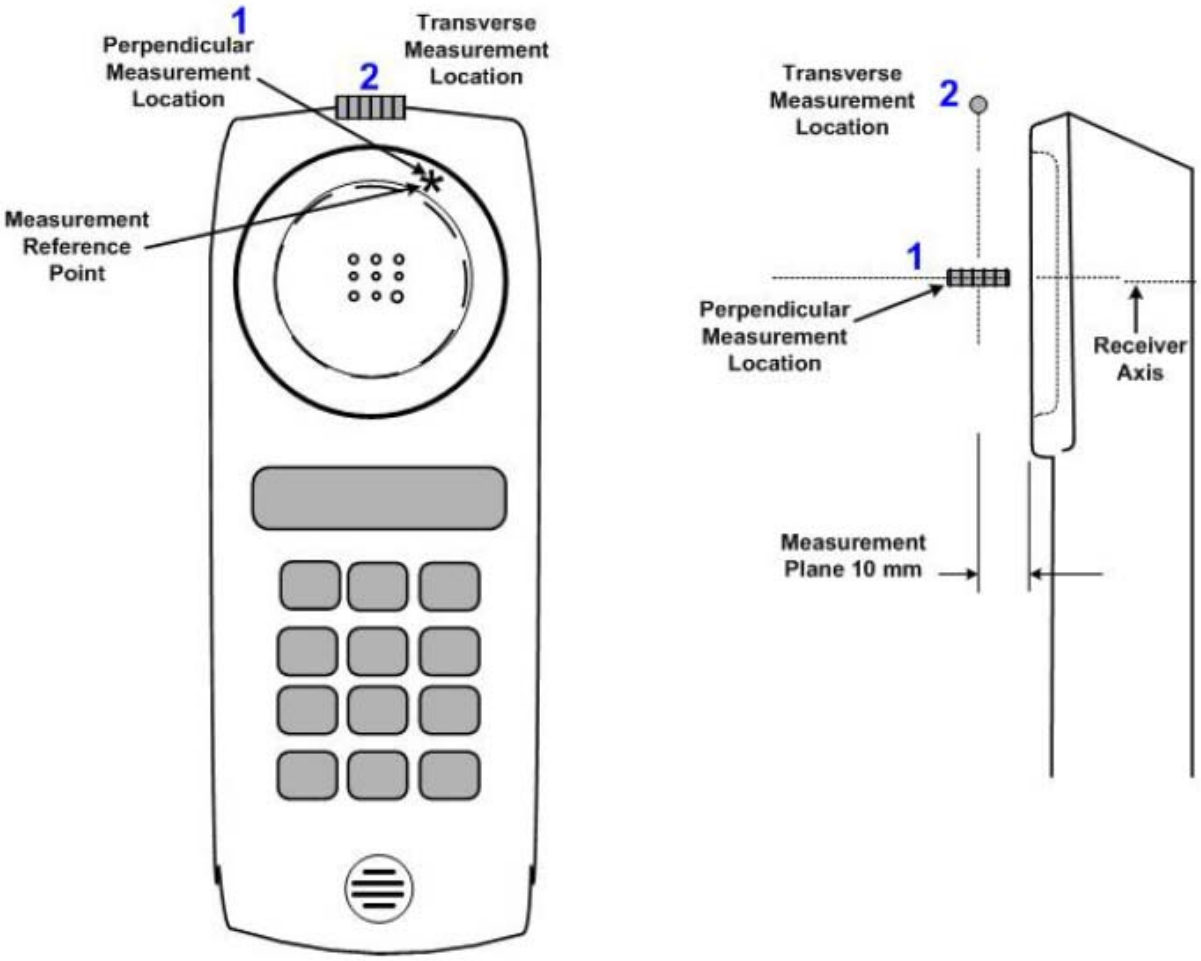



**Fig 6.2 A typical EUT reference and plane for T-Coil measurements**

# 7. HAC T-Coil Test Results

## 7.1 Magnitude Result

| Category | Telephone parameters WD signal quality ((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 |

The Table 7.1 shows testing result in position coordinates which are defined as deviation from earpiece center in millimeters. Signal strength measurement scans are presented in appendix A.

| Plot No. | Air Interface | Operating Mode | Channel | Probe Position | ABM1 (dB A/m) | ABM2 (dB A/m) | SNR (dB) | T Rating |
|---|---|---|---|---|---|---|---|---|
| 1 | GSM850 | Voice (speech codec /handset low) | 189 | Axial (Z) | 5.02 | -30.98 | 36.00 | T4 |
| | | | | **Transversal (Y)** | **-3.33** | **-34.24** | **30.91** | **T4** |
| 2 | GSM1900 | Voice (speech codec /handset low) | 661 | Axial (Z) | 4.64 | -32.51 | 37.15 | T4 |
| | | | | **Transversal (Y)** | **-3.48** | **-34.61** | **31.13** | **T4** |
| 3 | WCDMA Band V | Voice (speech codec low) | 4182 | Axial (Z) | 5.60 | -39.93 | 45.53 | T4 |
| | | | | **Transversal (Y)** | **-0.71** | **-40.54** | **39.83** | **T4** |
| 4 | WCDMA Band IV | Voice (speech codec low) | 1413 | Axial (Z) | 5.57 | -39.16 | 44.73 | T4 |
| | | | | **Transversal (Y)** | **-1.83** | **-43.00** | **41.17** | **T4** |
| 5 | WCDMA Band II | Voice (speech codec low) | 9400 | Axial (Z) | 5.77 | -39.40 | 45.17 | T4 |
| | | | | **Transversal (Y)** | **-0.12** | **-40.30** | **40.18** | **T4** |

**Table 7.1 Test Result for Various Positions**

**Remark:**

1. There is no special HAC mode software on this EUT.
2. The volume was adjusted to maximum level and the backlight turned off during T-Coil testing.
3. Test Engineer：Fulu Hu

## 7.2 Frequency Response Plots

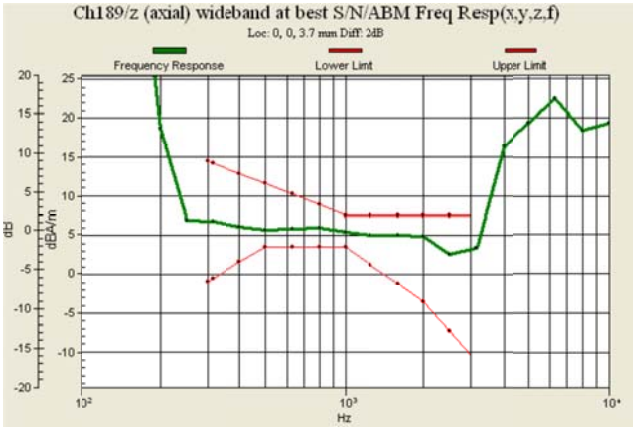



Fig 7.1 GSM850 Ch189

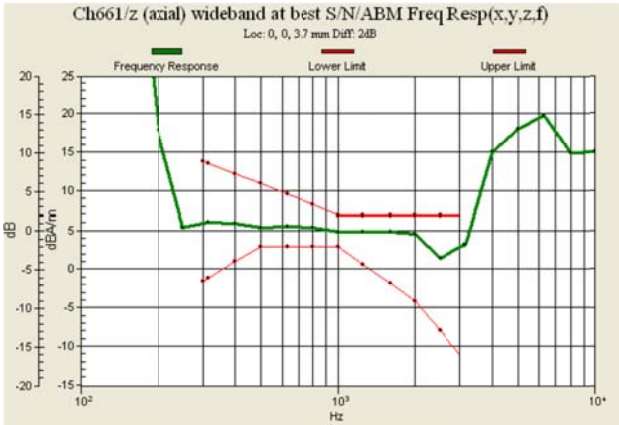



Fig 7.2 GSM1900 Ch661

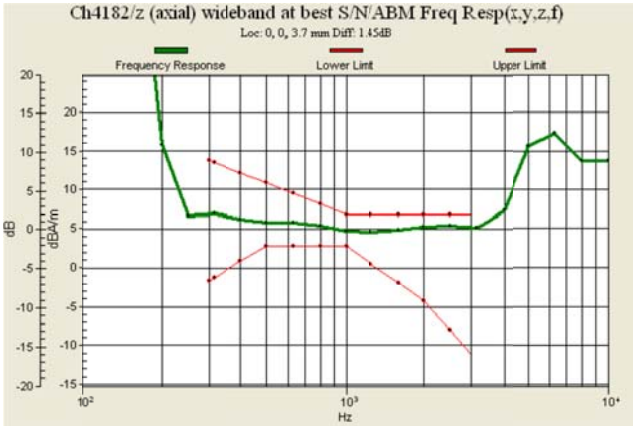



Fig 7.3 WCDMA Band V Ch4182

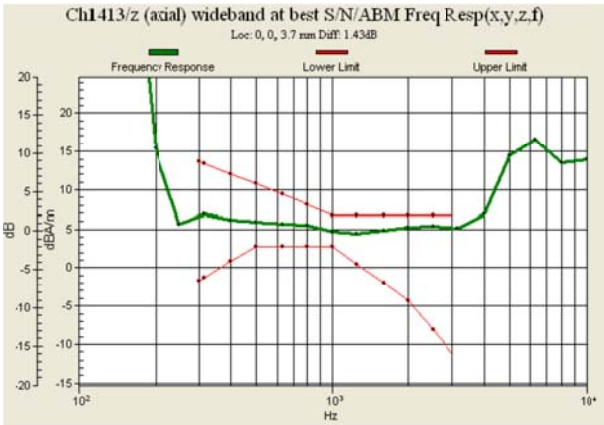



Fig 7.4 WCDMA Band IV Ch1413

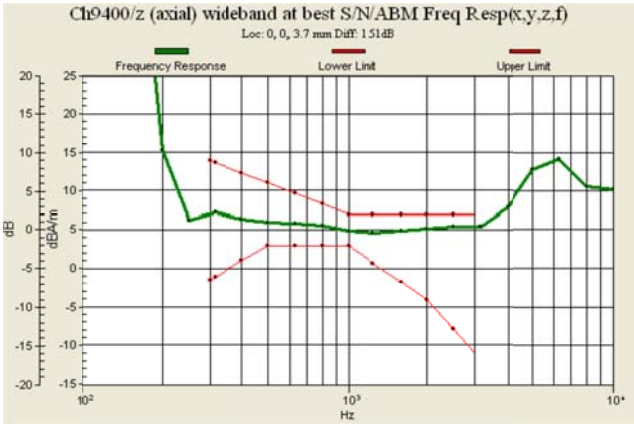



Fig 7.5 WCDMA Band II Ch9400

# 8. Uncertainty Assessment

The evaluation of uncertainly 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) |
|---|---|---|---|---|---|---|---|
| **Probe Sensitivity** | | | | | | | |
| 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 % |
| **Probe System** | | | | | | | |
| 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 % |
| **Test Signal** | | | | | | | |
| Reference Signal Spectral Response | 0.6 | Rectangular | √3 | 0 | 1 | ± 0.0 % | ± 0.4 % |
| **Positioning** | | | | | | | |
| 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 % |
| **External Contributions** | | | | | | | |
| 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**

# 9. 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] SPEAG DASY System Handbook

# Appendix A. Plots of T-Coil Measurement

The plots are shown as follows.

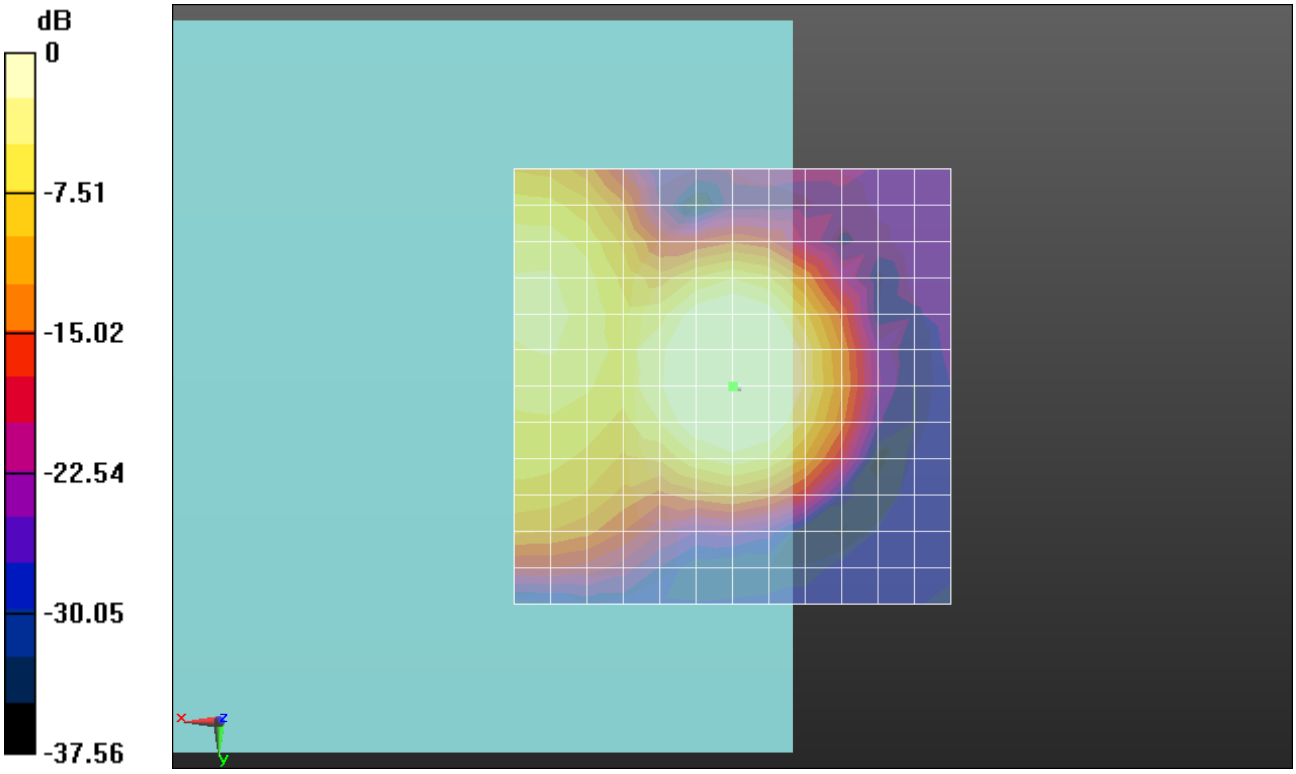
Test Laboratory: Sporton International Inc. SAR/HAC Testing Lab Date: 2014.08.06

**01 HAC T-Coil GSM850_Voice_Ch189(Z)**

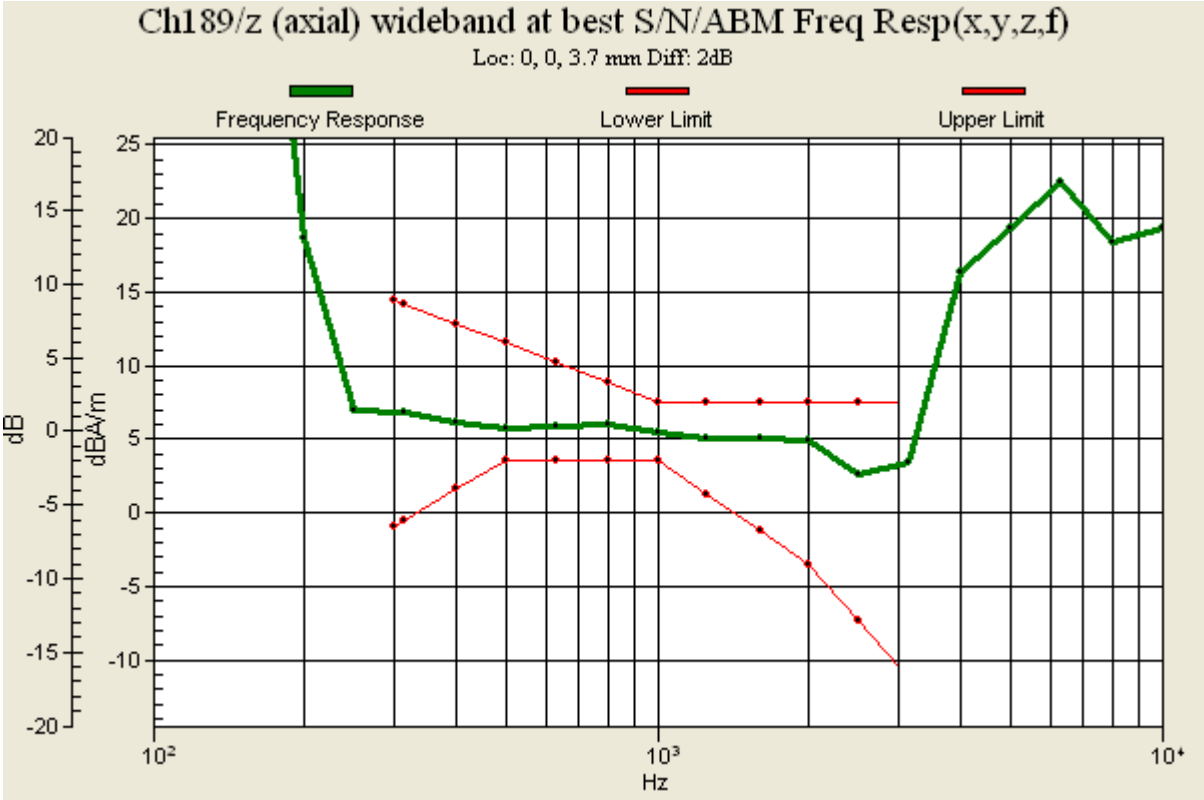
Communication System: UID 0, General GSM (0); Frequency: 836.4 MHz;Duty Cycle: 1:8.3
Medium: Air Medium parameters used: $\sigma = 0$ S/m, $\varepsilon_r = 1$; $\rho = 0$ kg/m$^3$
Ambient Temperature：23.5 ℃

DASY5 Configuration:
- Probe: AM1DV3 - 3093; ; Calibrated: 2014.05.20
- Sensor-Surface: 0mm (Fix Surface)
- Electronics: DAE4 Sn1210; Calibrated: 2014.05.19
- Phantom: HAC Test Arch with AMCC; Type: SD HAC P01 BA;
- Measurement SW: DASY52, Version 52.8 (8); SEMCAD X Version 14.6.10 (7331)

**Ch189/z (axial) 4.2mm 50 x 50/ABM SNR(x,y,z) (13x13x1):** Measurement grid: dx=10mm, dy=10mm
ABM1/ABM2 = 36.00 dB
ABM1 comp = 5.02 dBA/m
Location: 0, 0, 3.7 mm




0 dB = 1.000 A/m = 0.00 dBA/m

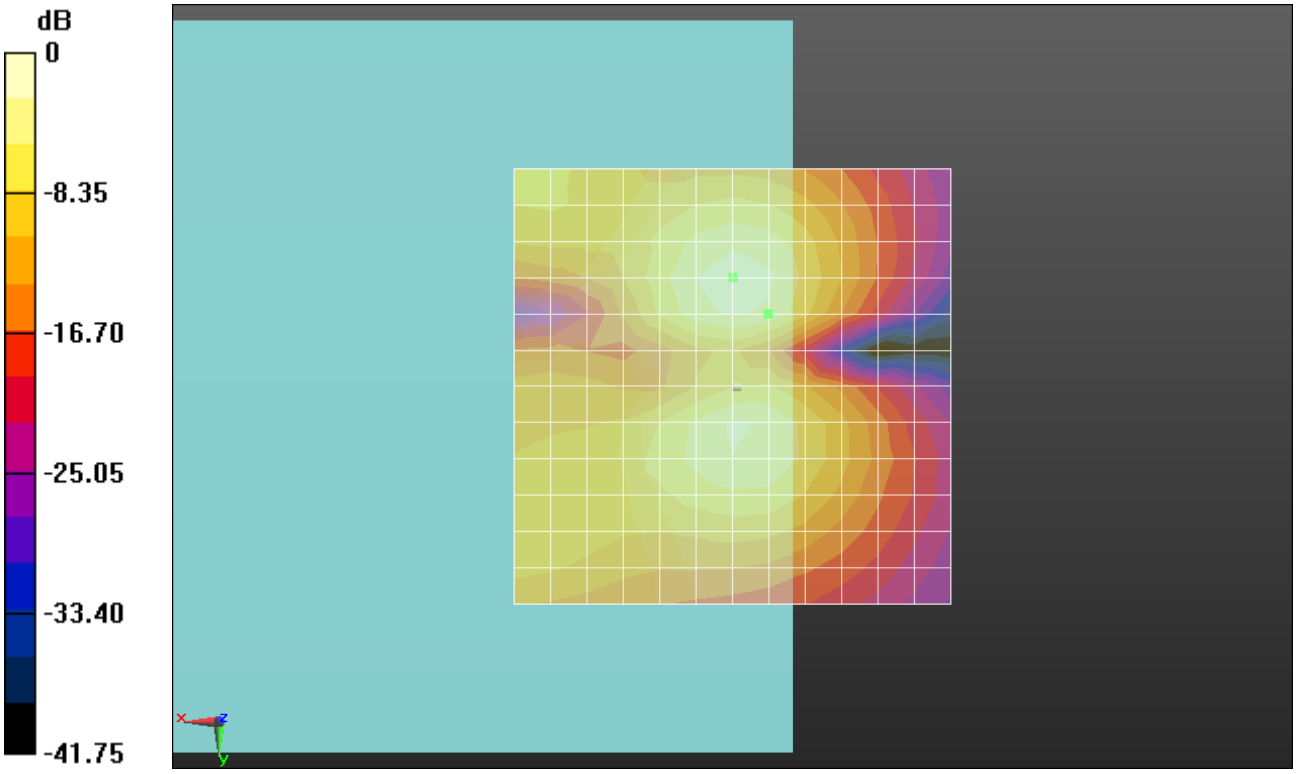

Ch189/z (axial) wideband at best S/N/ABM Freq Resp(x,y,z,f)
Loc: 0, 0, 3.7 mm Diff: 2dB
Frequency Response
Lower Limit
Upper Limit
dB
dBA/m
Hz

**01 HAC T-Coil GSM850_Voice_Ch189(Y)**

Communication System: UID 0, General GSM (0); Frequency: 836.4 MHz;Duty Cycle: 1:8.3
Medium: Air Medium parameters used: $\sigma = 0$ S/m, $\varepsilon_r = 1$; $\rho = 0$ kg/m$^3$
Ambient Temperature：23.5 ℃

DASY5 Configuration:
- Probe: AM1DV3 - 3093; ; Calibrated: 2014.05.20
- Sensor-Surface: 0mm (Fix Surface)
- Electronics: DAE4 Sn1210; Calibrated: 2014.05.19
- Phantom: HAC Test Arch with AMCC; Type: SD HAC P01 BA;
- Measurement SW: DASY52, Version 52.8 (8); SEMCAD X Version 14.6.10 (7331)

**Ch189/y (transversal) 4.2mm 50 x 50/ABM SNR(x,y,z) (13x13x1):** Measurement grid: dx=10mm, dy=10mm
ABM1/ABM2 = 30.91 dB
ABM1 comp = -3.33 dBA/m
Location: -4.2, -8.3, 3.7 mm



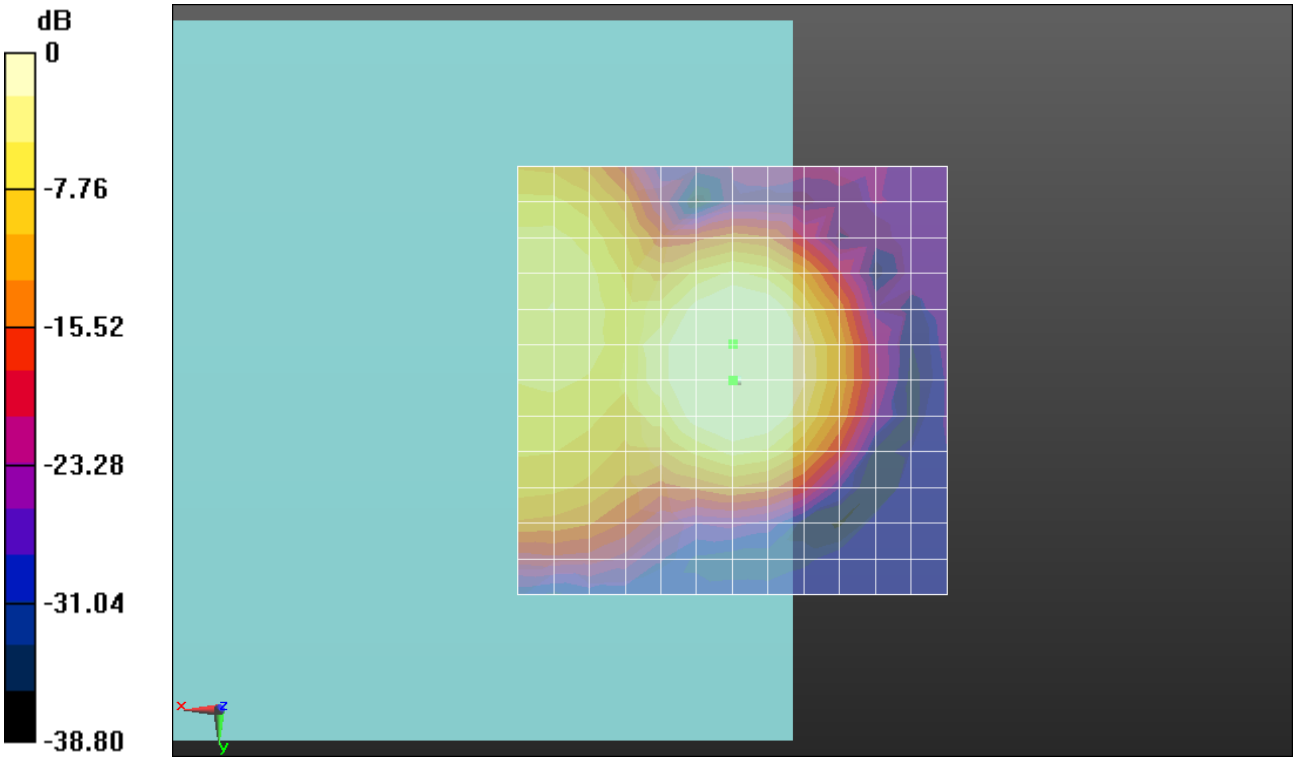

0 dB = 1.000 A/m = 0.00 dBA/m

**02 HAC T-Coil GSM1900_Voice_Ch661(Z)**

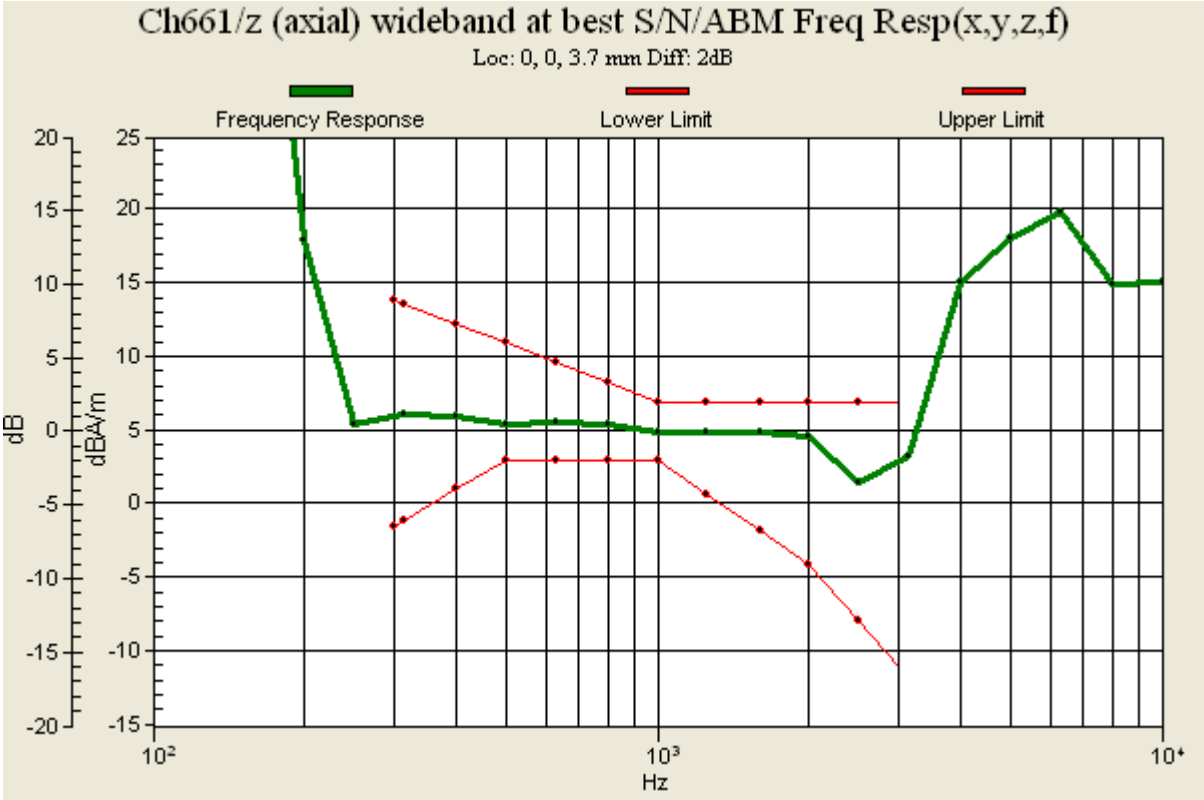
Communication System: UID 0, General GSM (0); Frequency: 1880 MHz;Duty Cycle: 1:8.3
Medium: Air Medium parameters used: $\sigma = 0$ S/m, $\varepsilon_r = 1$; $\rho = 0$ kg/m$^3$
Ambient Temperature：23.5 ℃

DASY5 Configuration:
- Probe: AM1DV3 - 3093; ; Calibrated: 2014.05.20
- Sensor-Surface: 0mm (Fix Surface)
- Electronics: DAE4 Sn1210; Calibrated: 2014.05.19
- Phantom: HAC Test Arch with AMCC; Type: SD HAC P01 BA;
- Measurement SW: DASY52, Version 52.8 (8); SEMCAD X Version 14.6.10 (7331)

**Ch661/z (axial) 4.2mm 50 x 50/ABM SNR(x,y,z) (13x13x1):** Measurement grid: dx=10mm, dy=10mm
ABM1/ABM2 = 37.15 dB
ABM1 comp = 4.64 dBA/m
Location: 0, 0, 3.7 mm




0 dB = 1.000 A/m = 0.00 dBA/m

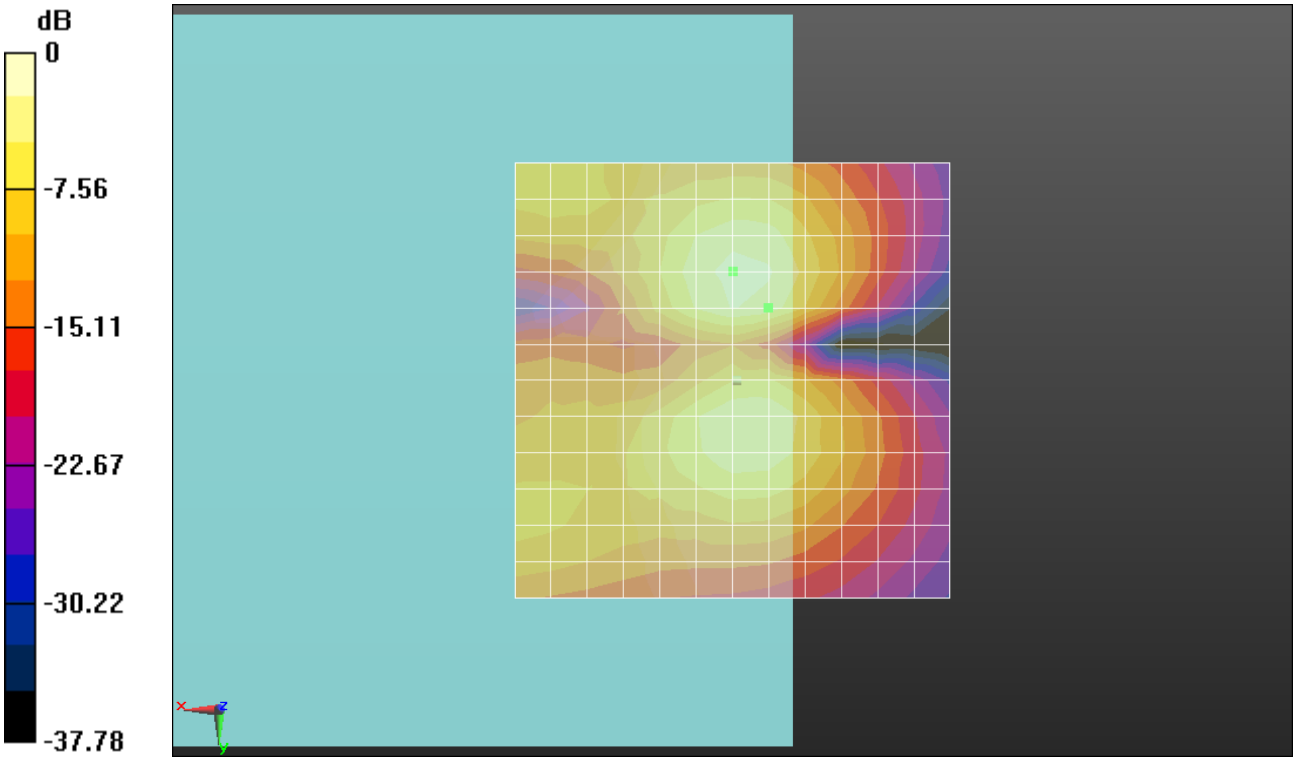

Ch661/z (axial) wideband at best S/N/ABM Freq Resp(x,y,z,f)
Loc: 0, 0, 3.7 mm Diff: 2dB
Frequency Response
Lower Limit
Upper Limit
dB
dBA/m
Hz

**02 HAC T-Coil GSM1900_Voice_Ch661(Y)**

Communication System: UID 0, General GSM (0); Frequency: 1880 MHz;Duty Cycle: 1:8.3
Medium: Air Medium parameters used: $\sigma = 0$ S/m, $\varepsilon_r = 1$; $\rho = 0$ kg/m$^3$
Ambient Temperature：23.5 ℃

DASY5 Configuration:
- Probe: AM1DV3 - 3093; ; Calibrated: 2014.05.20
- Sensor-Surface: 0mm (Fix Surface)
- Electronics: DAE4 Sn1210; Calibrated: 2014.05.19
- Phantom: HAC Test Arch with AMCC; Type: SD HAC P01 BA;
- Measurement SW: DASY52, Version 52.8 (8); SEMCAD X Version 14.6.10 (7331)

**Ch661/y (transversal) 4.2mm 50 x 50/ABM SNR(x,y,z) (13x13x1):** Measurement grid: dx=10mm, dy=10mm
ABM1/ABM2 = 31.13 dB
ABM1 comp = -3.48 dBA/m
Location: -4.2, -8.3, 3.7 mm



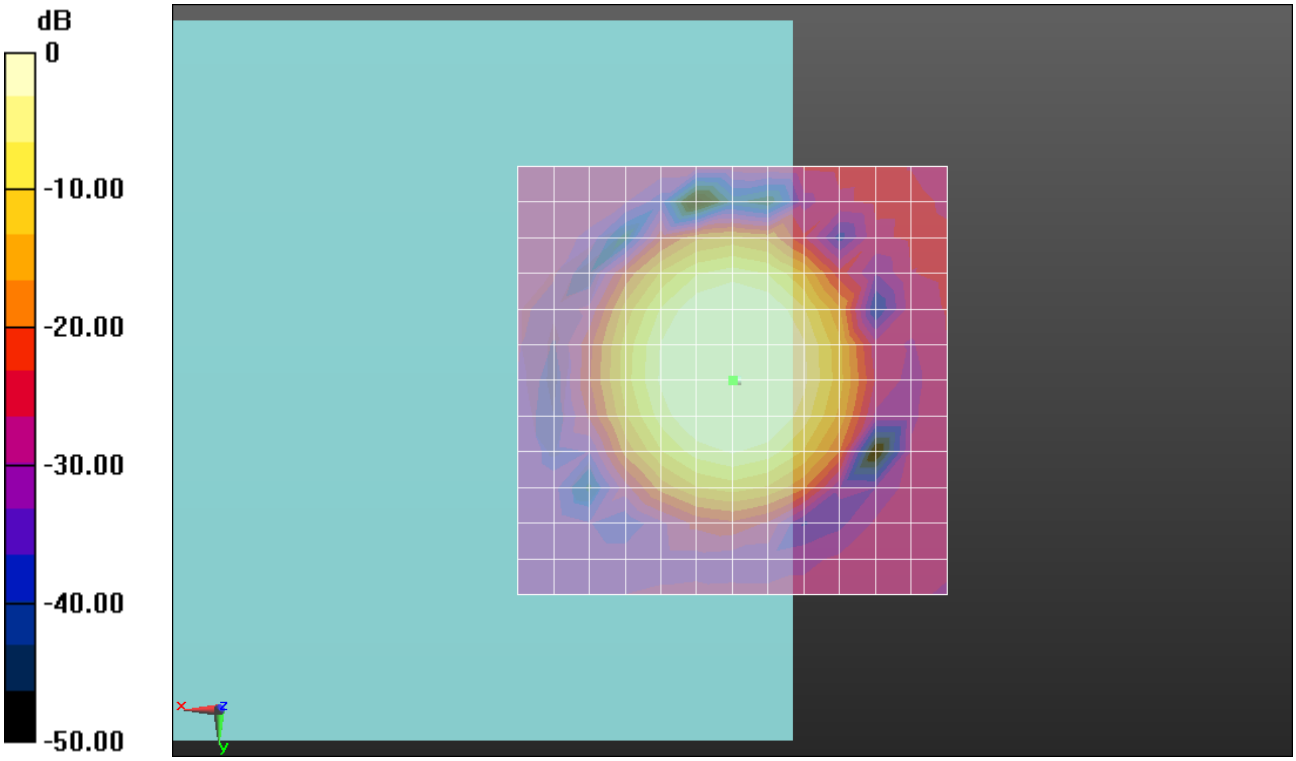

0 dB = 1.000 A/m = 0.00 dBA/m

**03 HAC T-Coil WCDMA Band V_Voice_Ch4182(Z)**

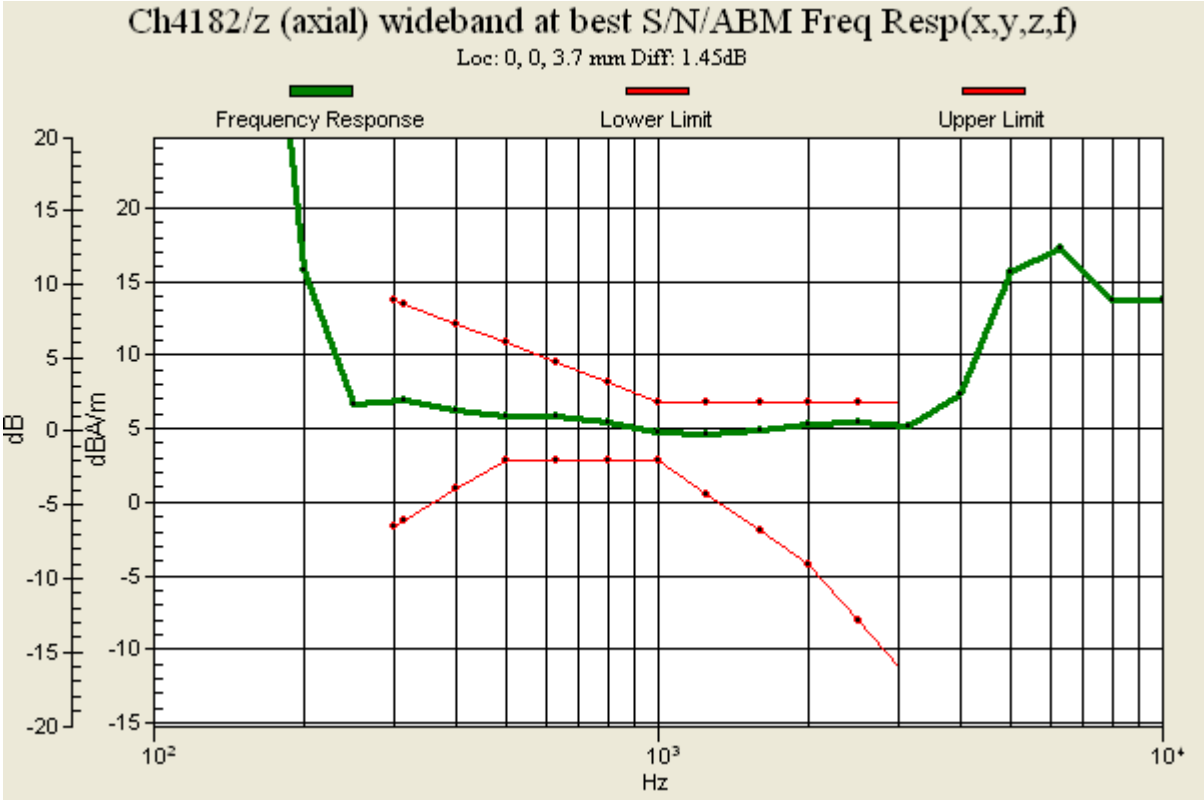
Communication System: UID 0, UMTS (0); Frequency: 836.4 MHz;Duty Cycle: 1:1
Medium: Air Medium parameters used: $\sigma = 0$ S/m, $\varepsilon_r = 1$; $\rho = 0$ kg/m$^3$
Ambient Temperature：23.5 ℃

DASY5 Configuration:
- Probe: AM1DV3 - 3093; ; Calibrated: 2014.05.20
- Sensor-Surface: 0mm (Fix Surface)
- Electronics: DAE4 Sn1210; Calibrated: 2014.05.19
- Phantom: HAC Test Arch with AMCC; Type: SD HAC P01 BA;
- Measurement SW: DASY52, Version 52.8 (8); SEMCAD X Version 14.6.10 (7331)

**Ch4182/z (axial) 4.2mm 50 x 50/ABM SNR(x,y,z) (13x13x1):** Measurement grid: dx=10mm, dy=10mm
ABM1/ABM2 = 45.53 dB
ABM1 comp = 5.60 dBA/m
Location: 0, 0, 3.7 mm




0 dB = 1.000 A/m = 0.00 dBA/m

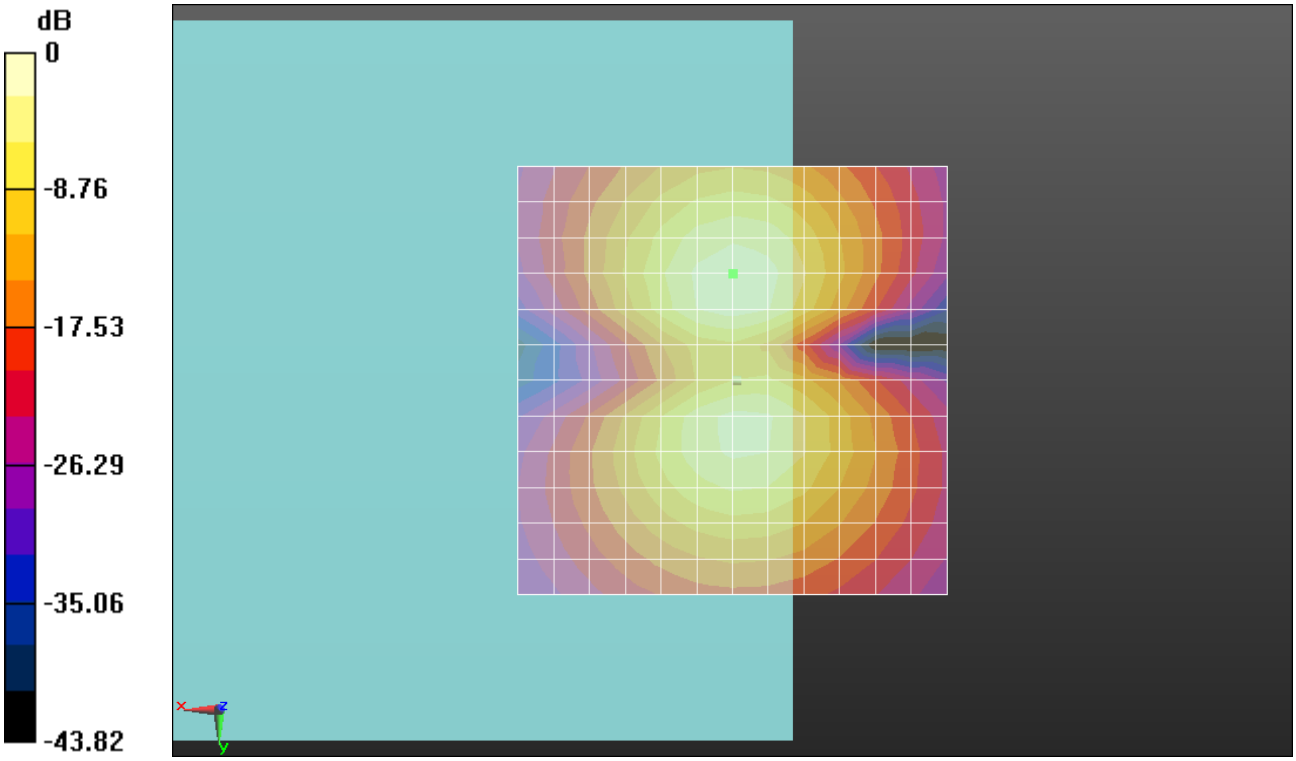

Ch4182/z (axial) wideband at best S/N/ABM Freq Resp(x,y,z,f)
Loc: 0, 0, 3.7 mm Diff: 1.45dB
Frequency Response
Lower Limit
Upper Limit
dB
dBA/m
Hz

**03 HAC T-Coil WCDMA Band V_Voice_Ch4182(Y)**

Communication System: UID 0, UMTS (0); Frequency: 836.4 MHz;Duty Cycle: 1:1
Medium: Air Medium parameters used: $\sigma = 0$ S/m, $\varepsilon_r = 1$; $\rho = 0$ kg/m$^3$
Ambient Temperature：23.5 ℃

DASY5 Configuration:
- Probe: AM1DV3 - 3093; ; Calibrated: 2014.05.20
- Sensor-Surface: 0mm (Fix Surface)
- Electronics: DAE4 Sn1210; Calibrated: 2014.05.19
- Phantom: HAC Test Arch with AMCC; Type: SD HAC P01 BA;
- Measurement SW: DASY52, Version 52.8 (8); SEMCAD X Version 14.6.10 (7331)

**Ch4182/y (transversal) 4.2mm 50 x 50/ABM SNR(x,y,z) (13x13x1):** Measurement grid: dx=10mm, dy=10mm
ABM1/ABM2 = 39.83 dB
ABM1 comp = -0.71 dBA/m
Location: 0, -12.5, 3.7 mm



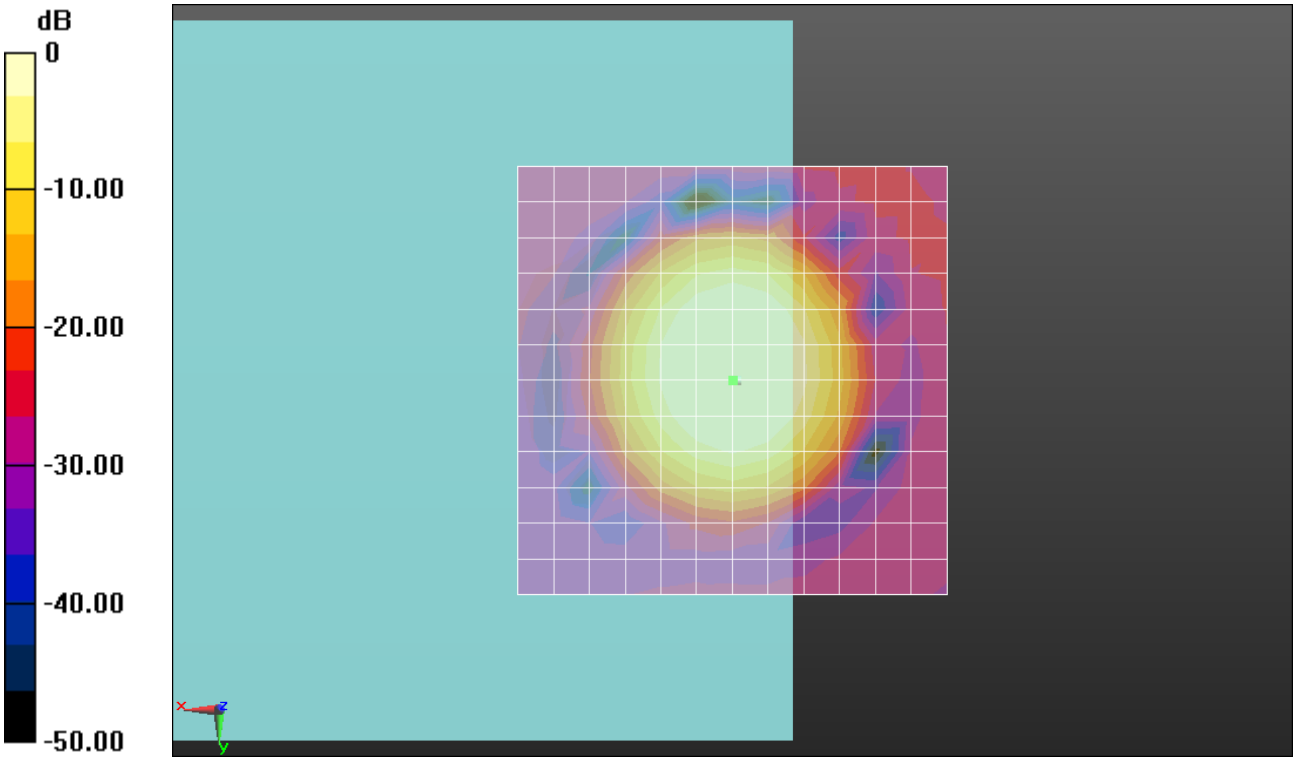

0 dB = 1.000 A/m = 0.00 dBA/m

**04 HAC T-Coil WCDMA Band IV_Voice_Ch1413(Z)**

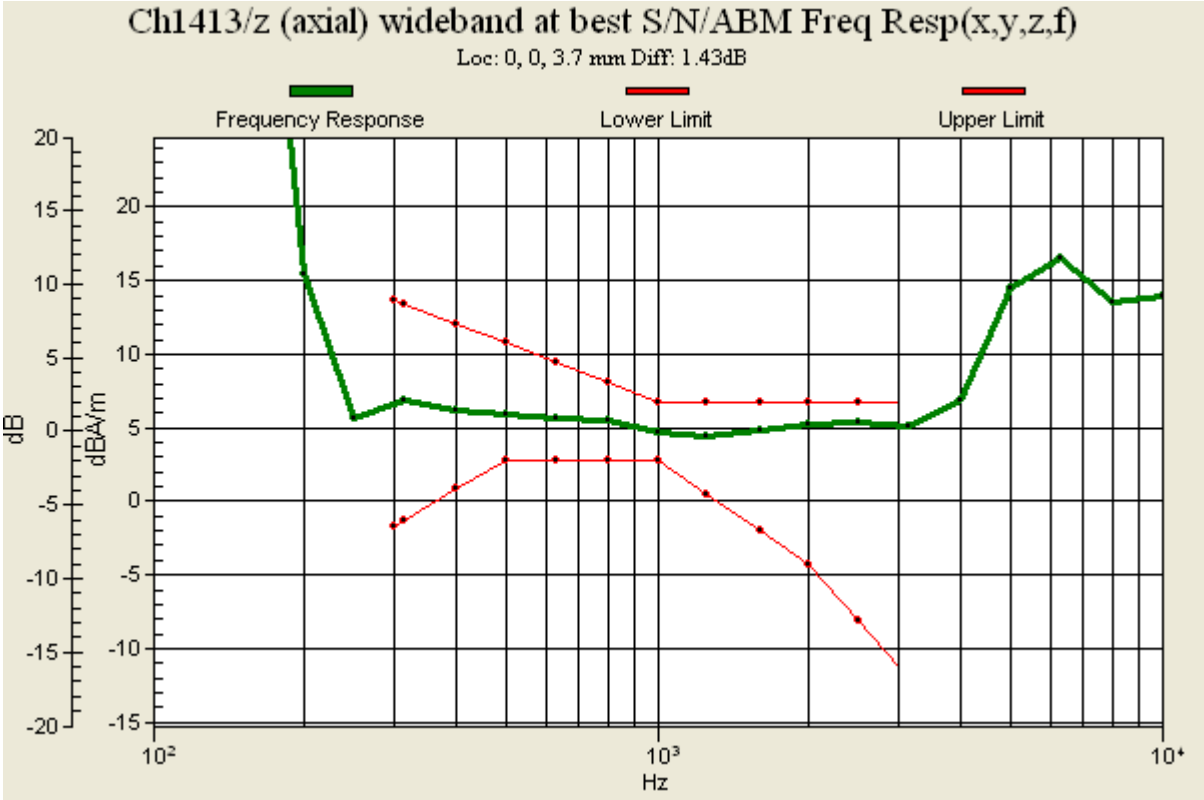
Communication System: UID 0, UMTS (0); Frequency: 1732.6 MHz;Duty Cycle: 1:1
Medium: Air Medium parameters used: $\sigma = 0$ S/m, $\varepsilon_r = 1$; $\rho = 0$ kg/m$^3$
Ambient Temperature：23.5 ℃

DASY5 Configuration:
- Probe: AM1DV3 - 3093; ; Calibrated: 2014.05.20
- Sensor-Surface: 0mm (Fix Surface)
- Electronics: DAE4 Sn1210; Calibrated: 2014.05.19
- Phantom: HAC Test Arch with AMCC; Type: SD HAC P01 BA;
- Measurement SW: DASY52, Version 52.8 (8); SEMCAD X Version 14.6.10 (7331)

**Ch1413/z (axial) 4.2mm 50 x 50/ABM SNR(x,y,z) (13x13x1):** Measurement grid: dx=10mm, dy=10mm
ABM1/ABM2 = 44.73 dB
ABM1 comp = 5.57 dBA/m
Location: 0, 0, 3.7 mm




0 dB = 1.000 A/m = 0.00 dBA/m

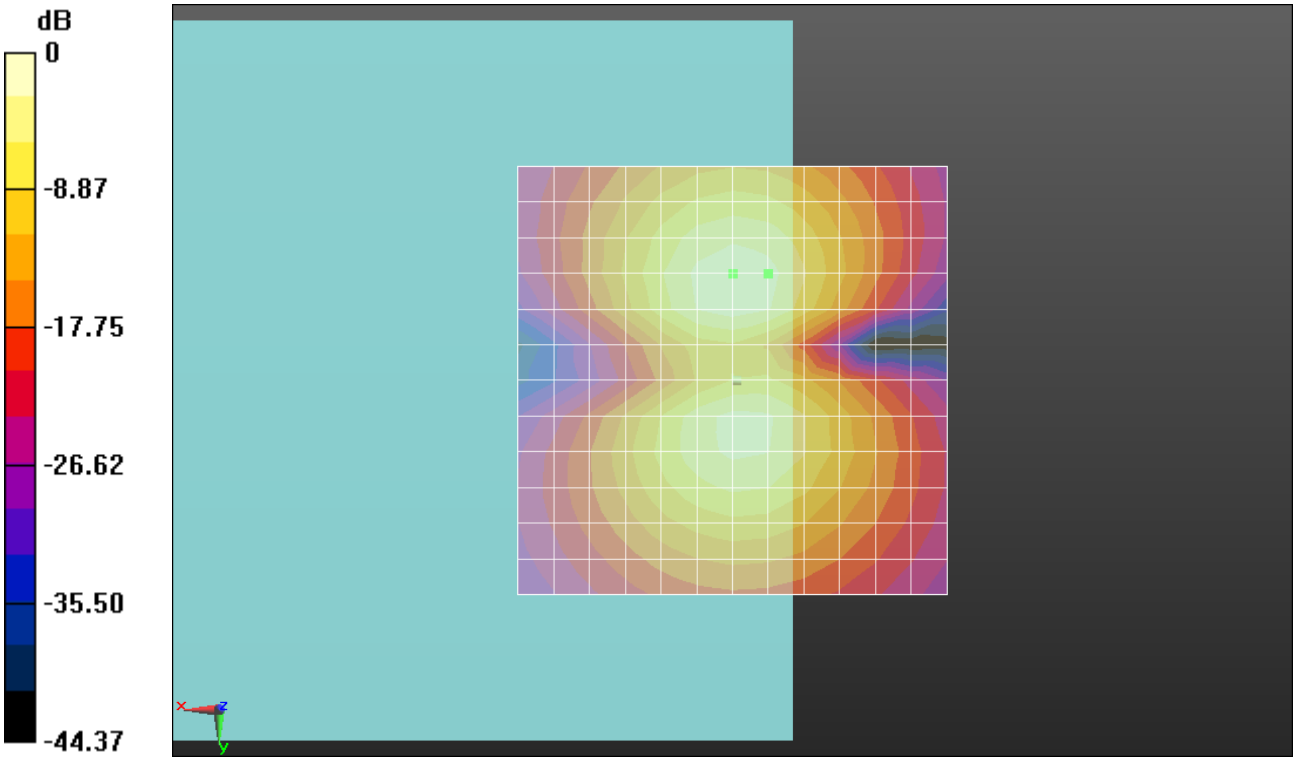

Ch1413/z (axial) wideband at best S/N/ABM Freq Resp(x,y,z,f)
Loc: 0, 0, 3.7 mm Diff: 1.43dB
Frequency Response
Lower Limit
Upper Limit
dB
dBA/m
Hz

**04 HAC T-Coil WCDMA Band IV_Voice_Ch1413(Y)**

Communication System: UID 0, UMTS (0); Frequency: 1732.6 MHz;Duty Cycle: 1:1
Medium: Air Medium parameters used: $\sigma = 0$ S/m, $\varepsilon_r = 1$; $\rho = 0$ kg/m$^3$
Ambient Temperature：23.5 ℃

DASY5 Configuration:
- Probe: AM1DV3 - 3093; ; Calibrated: 2014.05.20
- Sensor-Surface: 0mm (Fix Surface)
- Electronics: DAE4 Sn1210; Calibrated: 2014.05.19
- Phantom: HAC Test Arch with AMCC; Type: SD HAC P01 BA;
- Measurement SW: DASY52, Version 52.8 (8); SEMCAD X Version 14.6.10 (7331)

**Ch1413/y (transversal) 4.2mm 50 x 50/ABM SNR(x,y,z) (13x13x1):** Measurement grid: dx=10mm, dy=10mm
ABM1/ABM2 = 41.17 dB
ABM1 comp = -1.83 dBA/m
Location: -4.2, -12.5, 3.7 mm



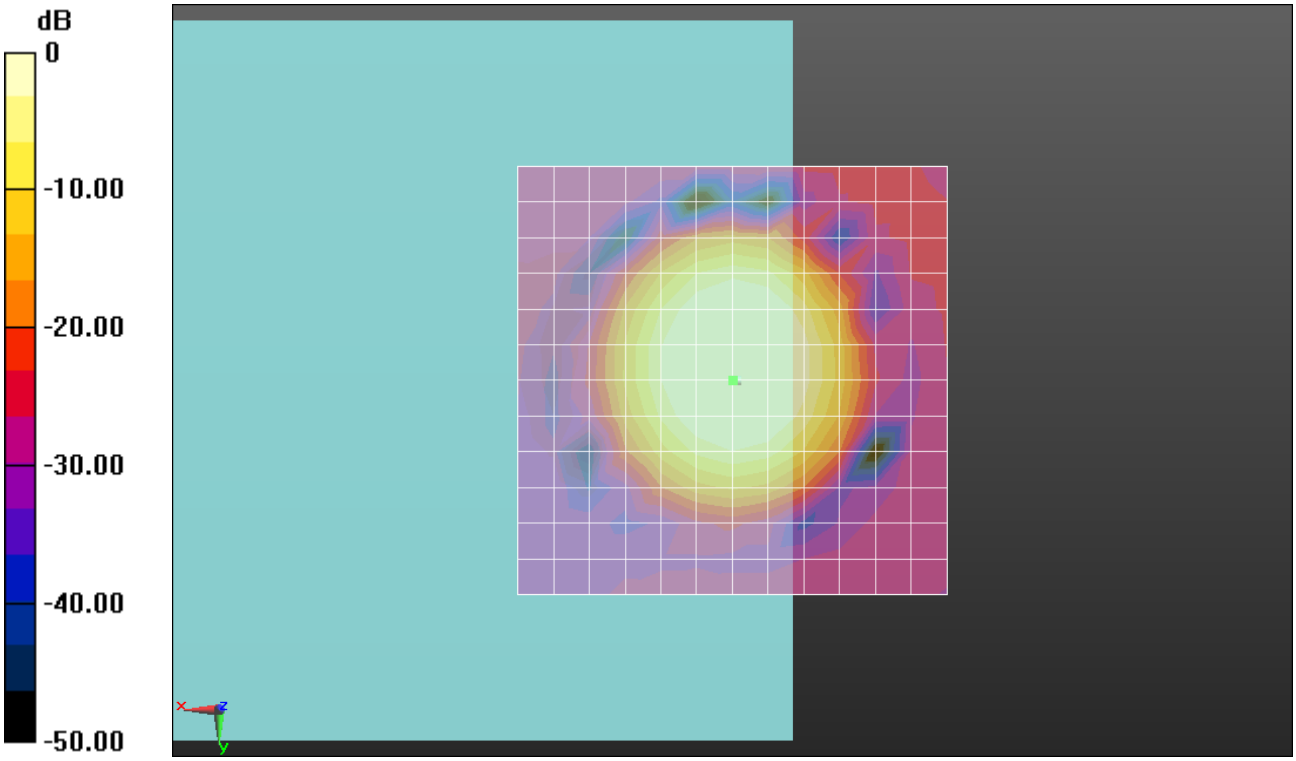

0 dB = 1.000 A/m = 0.00 dBA/m

**05 HAC T-Coil WCDMA Band II_Voice_Ch9400(Z)**

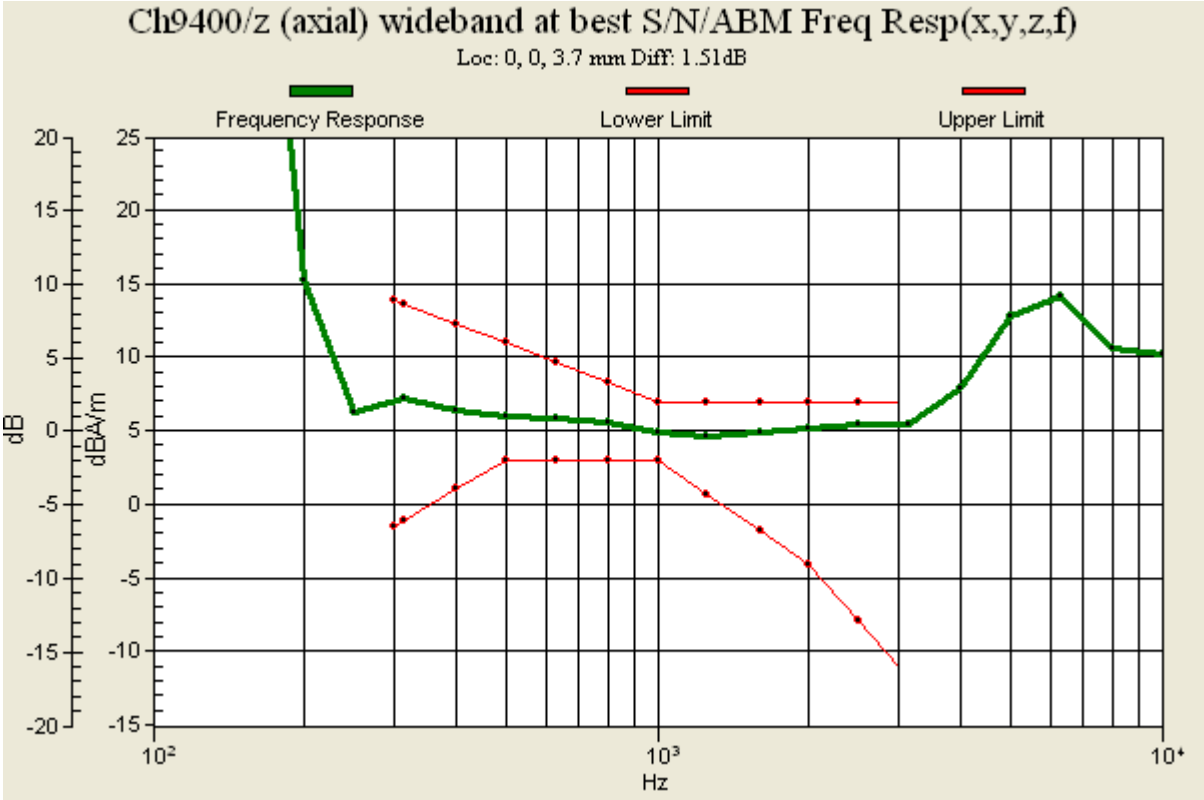
Communication System: UID 0, UMTS (0); Frequency: 1880 MHz;Duty Cycle: 1:1
Medium: Air Medium parameters used: $\sigma = 0$ S/m, $\varepsilon_r = 1$; $\rho = 0$ kg/m$^3$
Ambient Temperature：23.5 ℃

DASY5 Configuration:
- Probe: AM1DV3 - 3093; ; Calibrated: 2014.05.20
- Sensor-Surface: 0mm (Fix Surface)
- Electronics: DAE4 Sn1210; Calibrated: 2014.05.19
- Phantom: HAC Test Arch with AMCC; Type: SD HAC P01 BA;
- Measurement SW: DASY52, Version 52.8 (8); SEMCAD X Version 14.6.10 (7331)

**Ch9400/z (axial) 4.2mm 50 x 50/ABM SNR(x,y,z) (13x13x1):** Measurement grid: dx=10mm, dy=10mm
ABM1/ABM2 = 45.17 dB
ABM1 comp = 5.77 dBA/m
Location: 0, 0, 3.7 mm




0 dB = 1.000 A/m = 0.00 dBA/m

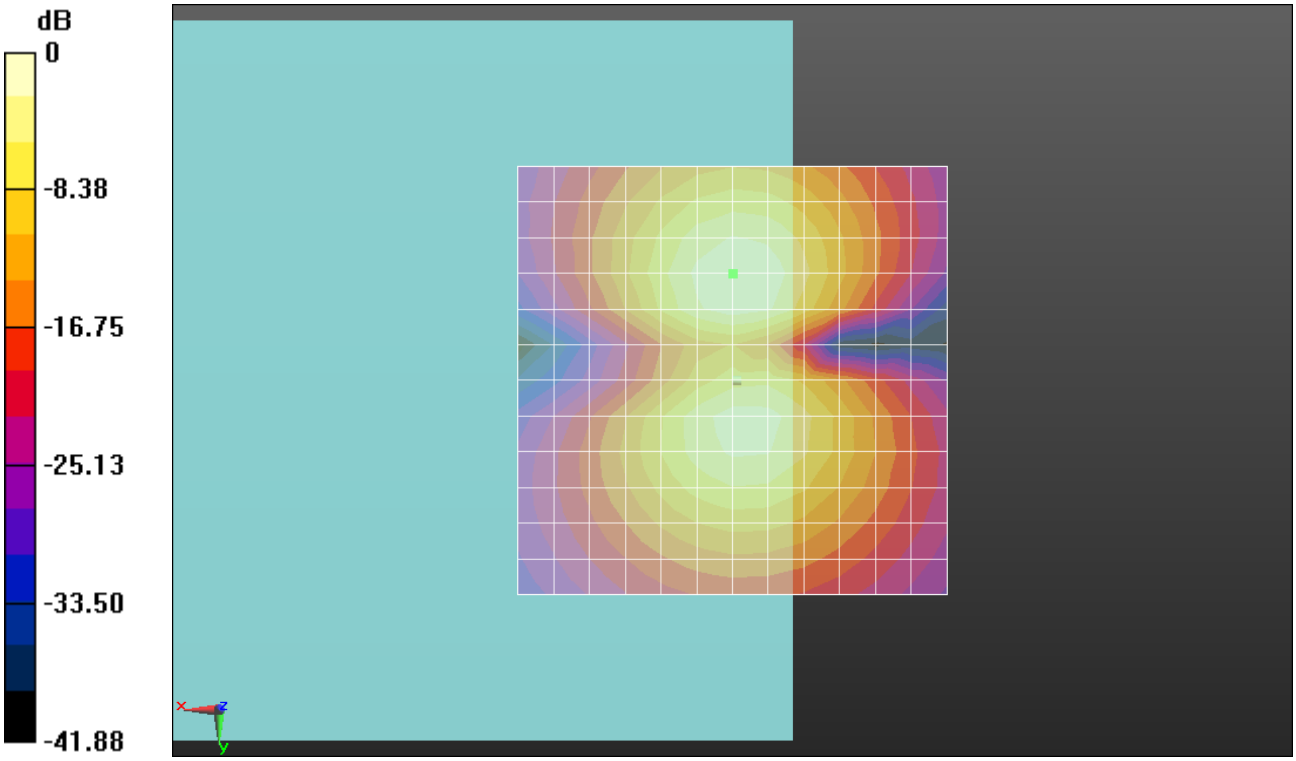

Ch9400/z (axial) wideband at best S/N/ABM Freq Resp(x,y,z,f)
Loc: 0, 0, 3.7 mm Diff: 1.51dB
Frequency Response
Lower Limit
Upper Limit
dB
dBA/m
Hz

**05 HAC T-Coil WCDMA Band II_Voice_Ch9400(Y)**

Communication System: UID 0, UMTS (0); Frequency: 1880 MHz;Duty Cycle: 1:1
Medium: Air Medium parameters used: $\sigma = 0$ S/m, $\varepsilon_r = 1$; $\rho = 0$ kg/m$^3$
Ambient Temperature：23.5 ℃

DASY5 Configuration:
- Probe: AM1DV3 - 3093; ; Calibrated: 2014.05.20
- Sensor-Surface: 0mm (Fix Surface)
- Electronics: DAE4 Sn1210; Calibrated: 2014.05.19
- Phantom: HAC Test Arch with AMCC; Type: SD HAC P01 BA;
- Measurement SW: DASY52, Version 52.8 (8); SEMCAD X Version 14.6.10 (7331)

**Ch9400/y (transversal) 4.2mm 50 x 50/ABM SNR(x,y,z) (13x13x1):** Measurement grid: dx=10mm, dy=10mm
ABM1/ABM2 = 40.18 dB
ABM1 comp = -0.12 dBA/m
Location: 0, -12.5, 3.7 mm




0 dB = 1.000 A/m = 0.00 dBA/m

# Appendix B. Calibration Data

The DASY calibration certificates are shown as follows.

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

**S** Schweizerischer Kalibrierdienst
**C** Service suisse d'étalonnage
Servizio svizzero di taratura
**S** 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 108**

**Client** **Sporton-CN (Auden)**

**Certificate No: AM1DV3-3093_May14**

# CALIBRATION CERTIFICATE

| | |
|---|---|
| Object | AM1DV3 - SN: 3093 |
| Calibration procedure(s) | QA CAL-24.v3<br>Calibration procedure for AM1D magnetic field probes and TMFS in the audio range |
| Calibration date: | May 20, 2014 |

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 | 01-Oct-13 (No:13976) | Oct-14 |
| Reference Probe AM1DV2 | SN: 1008 | 14-Jan-14 (No. AM1D-1008_Jan14) | Jan-15 |
| DAE4 | SN: 781 | 13-Sep-13 (No. DAE4-781_Sep13) | Sep-14 |

| Secondary Standards | ID # | Check Date (in house) | Scheduled Check |
|---|---|---|---|
| AMCC | 1050 | 01-Oct-13 (in house check Oct-13) | Oct-15 |
| AMMI Audio Measuring Instrument | 1062 | 26-Sep-12 (in house check Sep-12) | Sep-14 |

| | Name | Function | Signature |
|---|---|---|---|
| Calibrated by: | Leif Klysner | Laboratory Technician | |
| Approved by: | Fin Bomholt | Deputy Technical Manager | i.v. |

Issued: May 20, 2014

This calibration certificate shall not be reproduced except in full without written approval of the laboratory.

[**References**

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

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

[3] DASY5 manual, Chapter: Hearing Aid Compatibility (HAC) T-Coil Extension

**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 | **AM1DV3** Audio Magnetic 1D Field Probe |
| Type No | SP AM1 001 BA |
| Serial No | **3093** |

| | |
|---|---|
| Overall length | 296 mm |
| Tip diameter | 6.0 mm (at the tip) |
| Sensor offset | 3.0 mm (centre of sensor from tip) |
| Internal Amplifier | 20 dB |

| | |
|---|---|
| Manufacturer / Origin | Schmid & Partner Engineering AG, Zürich, Switzerland |
| Manufacturing date | March 03, 2011 |
| Last calibration date | May 07, 2013 |

## Calibration data

| | | | |
|---|---|---|---|
| Connector rotation angle | (in DASY system) | **170.7 °** | +/- 3.6 ° (k=2) |
| Sensor angle | (in DASY system) | **0.93 °** | +/- 0.5 ° (k=2) |
| Sensitivity at 1 kHz | (in DASY system) | **0.00728 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%.

Zeughausstrasse 43, 8004 Zurich, Switzerland
Phone +41 44 245 9700, Fax +41 44 245 9779
info@speag.com, http://www.speag.com

# IMPORTANT NOTICE

## USAGE OF THE DAE 4

The DAE unit is a delicate, high precision instrument and requires careful treatment by the user. There are no serviceable parts inside the DAE. Special attention shall be given to the following points:

**Battery Exchange**: The battery cover of the DAE4 unit is closed using a screw, over tightening the screw may cause the threads inside the DAE to wear out.

**Shipping of the DAE**: Before shipping the DAE to SPEAG for calibration, remove the batteries and pack the DAE in an antistatic bag. This antistatic bag shall then be packed into a larger box or container which protects the DAE from impacts during transportation. The package shall be marked to indicate that a fragile instrument is inside.

**E-Stop Failures**: Touch detection may be malfunctioning due to broken magnets in the E-stop. Rough handling of the E-stop may lead to damage of these magnets. Touch and collision errors are often caused by dust and dirt accumulated in the E-stop. To prevent E-stop failure, the customer shall always mount the probe to the DAE carefully and keep the DAE unit in a non-dusty environment if not used for measurements.

**Repair**: Minor repairs are performed at no extra cost during the annual calibration. However, SPEAG reserves the right to charge for any repair especially if rough unprofessional handling caused the defect.

**DASY Configuration Files:** Since the exact values of the DAE input resistances, as measured during the calibration procedure of a DAE unit, are not used by the DASY software, a nominal value of 200 MOhm is given in the corresponding configuration file.

**Important Note:**
**Warranty and calibration is void if the DAE unit is disassembled partly or fully by the Customer.**

**Important Note:**
**Never attempt to grease or oil the E-stop assembly. Cleaning and readjusting of the E-stop assembly is allowed by certified SPEAG personnel only and is part of the annual calibration procedure.**

**Important Note:**
**To prevent damage of the DAE probe connector pins, use great care when installing the probe to the DAE. Carefully connect the probe with the connector notch oriented in the mating position. Avoid any rotational movement of the probe body versus the DAE while turning the locking nut of the connector. The same care shall be used when disconnecting the probe from the DAE.**

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

**S** Schweizerischer Kalibrierdienst
**C** Service suisse d'étalonnage
Servizio svizzero di taratura
**S** 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 108**

**Client** **Sporton-CN (Auden)**

**Certificate No: DAE4-1210_May14**

# CALIBRATION CERTIFICATE

| | |
|---|---|
| Object | DAE4 - SD 000 D04 BM - SN: 1210 |
| Calibration procedure(s) | QA CAL-06.v26<br>Calibration procedure for the data acquisition electronics (DAE) |
| Calibration date: | May 19, 2014 |

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 | 01-Oct-13 (No:13976) | Oct-14 |
| **Secondary Standards** | **ID #** | **Check Date (in house)** | **Scheduled Check** |
| Auto DAE Calibration Unit | SE UWS 053 AA 1001 | 07-Jan-14 (in house check) | In house check: Jan-15 |
| Calibrator Box V2.1 | SE UMS 006 AA 1002 | 07-Jan-14 (in house check) | In house check: Jan-15 |

| | Name | Function | Signature |
|---|---|---|---|
| Calibrated by: | Dominique Steffen | Technician | |
| Approved by: | Fin Bomholt | Deputy Technical Manager | i.V. |

Issued: May 20, 2014

This calibration certificate shall not be reproduced except in full without written approval of the laboratory.

## 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 following parameters as documented in the Appendix contain technical information as a result from the performance test and require no uncertainty.
  - *DC Voltage Measurement Linearity:* Verification of the Linearity at +10% and -10% of the nominal calibration voltage. Influence of offset voltage is included in this measurement.
  - *Common mode sensitivity:* Influence of a positive or negative common mode voltage on the differential measurement.
  - *Channel separation:* Influence of a voltage on the neighbor channels not subject to an input voltage.
  - *AD Converter Values with inputs shorted:* Values on the internal AD converter corresponding to zero input voltage
  - *Input Offset Measurement*: Output voltage and statistical results over a large number of zero voltage measurements.
  - *Input Offset Current:* Typical value for information; Maximum channel input offset current, not considering the input resistance.
  - *Input resistance:* Typical value for information: DAE input resistance at the connector, during internal auto-zeroing and during measurement.
  - *Low Battery Alarm Voltage:* Typical value for information. Below this voltage, a battery alarm signal is generated.
  - *Power consumption:* Typical value for information. Supply currents in various operating modes.

## 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** | 404.126 ± 0.02% (k=2) | 404.956 ± 0.02% (k=2) | 405.065 ± 0.02% (k=2) |
| **Low Range** | 4.00002 ± 1.50% (k=2) | 3.98327 ± 1.50% (k=2) | 4.00021 ± 1.50% (k=2) |

## Connector Angle

| | |
|---|---|
| **Connector Angle** to be used in DASY system | 123.5 ° ± 1 ° |

## Appendix

### 1. DC Voltage Linearity

| High Range | | Reading (µV) | Difference (µV) | Error (%) |
|---|---|---|---|---|
| Channel X | + Input | 199993.16 | -3.08 | -0.00 |
| Channel X | + Input | 20001.58 | 0.86 | 0.00 |
| Channel X | - Input | -19997.88 | 2.96 | -0.01 |
| Channel Y | + Input | 199997.46 | 1.25 | 0.00 |
| Channel Y | + Input | 20001.02 | 0.31 | 0.00 |
| Channel Y | - Input | -20000.67 | 0.41 | -0.00 |
| Channel Z | + Input | 199997.96 | 1.16 | 0.00 |
| Channel Z | + Input | 20000.22 | -0.47 | -0.00 |
| Channel Z | - Input | -20000.31 | 0.71 | -0.00 |

| Low Range | | Reading (µV) | Difference (µV) | Error (%) |
|---|---|---|---|---|
| Channel X | + Input | 2001.44 | 0.40 | 0.02 |
| Channel X | + Input | 201.65 | 0.25 | 0.12 |
| Channel X | - Input | -198.86 | -0.60 | 0.30 |
| Channel Y | + Input | 2001.05 | 0.10 | 0.01 |
| Channel Y | + Input | 200.89 | -0.51 | -0.25 |
| Channel Y | - Input | -198.70 | -0.35 | 0.18 |
| Channel Z | + Input | 2001.15 | 0.23 | 0.01 |
| Channel Z | + Input | 200.32 | -1.08 | -0.54 |
| Channel Z | - Input | -199.61 | -1.14 | 0.57 |

### 2. Common mode sensitivity

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

| | Common mode Input Voltage (mV) | High Range Average Reading (µV) | Low Range Average Reading (µV) |
|---|---|---|---|
| Channel X | 200 | -5.19 | -7.07 |
| | - 200 | 7.82 | 6.50 |
| Channel Y | 200 | -3.56 | -3.90 |
| | - 200 | 4.19 | 4.35 |
| Channel Z | 200 | 12.21 | 11.95 |
| | - 200 | -14.51 | -14.28 |

### 3. Channel separation

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

| | Input Voltage (mV) | Channel X (µV) | Channel Y (µV) | Channel Z (µV) |
|---|---|---|---|---|
| Channel X | 200 | - | 1.78 | -3.94 |
| Channel Y | 200 | 8.13 | - | 2.67 |
| Channel Z | 200 | 9.14 | 6.43 | - |

## 4. AD-Converter Values with inputs shorted

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

| | High Range (LSB) | Low Range (LSB) |
|---|---|---|
| **Channel X** | 15954 | 15797 |
| **Channel Y** | 15962 | 16451 |
| **Channel Z** | 15874 | 16936 |

## 5. Input Offset Measurement

DASY measurement parameters: Auto Zero Time: 3 sec; Measuring time: 3 sec
Input 10MΩ

| | Average (μV) | min. Offset (μV) | max. Offset (μV) | Std. Deviation (μV) |
|---|---|---|---|---|
| **Channel X** | -0.85 | -1.82 | -0.15 | 0.34 |
| **Channel Y** | -0.27 | -1.81 | 0.54 | 0.39 |
| **Channel Z** | -0.30 | -1.29 | 0.94 | 0.43 |

## 6. Input Offset Current

Nominal Input circuitry offset current on all channels: <25fA

## 7. Input Resistance (Typical values for information)

| | Zeroing (kOhm) | Measuring (MOhm) |
|---|---|---|
| **Channel X** | 200 | 200 |
| **Channel Y** | 200 | 200 |
| **Channel Z** | 200 | 200 |

## 8. Low Battery Alarm Voltage (Typical values for information)

| Typical values | Alarm Level (VDC) |
|---|---|
| **Supply (+ Vcc)** | +7.9 |
| **Supply (- Vcc)** | -7.6 |

## 9. Power Consumption (Typical values for information)

| Typical values | Switched off (mA) | Stand by (mA) | Transmitting (mA) |
|---|---|---|---|
| **Supply (+ Vcc)** | +0.01 | +6 | +14 |
| **Supply (- Vcc)** | –0.01 | -8 | -9 |