

# HAC RF EMISSION TEST REPORT

**Report No.:** SET2015-12152  
**Product:** Mobile phone  
**Model No.:** E245SH  
**Brand Name:** HYUNDAI  
**Applicant:** Hyundai Corporation  
**Address:** 140-2, Kye-dong, Chongro-ku, Seoul, South Korea  
**Test Date** August 12<sup>th</sup>, 2015  
**Issued Date** August 13<sup>th</sup>, 2015  
**Issued by:** CCIC-SET  
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## Test Report

|                                   |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
|-----------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Product..... :</b>             | Mobile phone                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
| <b>Model No. ....:</b>            | E245SH                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
| <b>Brand Name.....:</b>           | HYUNDAI                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
| <b>FCC ID.....:</b>               | RQQHLT-E24FSL                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| <b>Applicant.....:</b>            | Hyundai Corporation                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
| <b>Applicant Address.....:</b>    | 140-2, Kye-dong, Chongro-ku, Seoul, South Korea                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
| <b>Manufacturer.....:</b>         | Shenzhen Fortuneship Technology Co., Ltd                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
| <b>Manufacturer Address.....:</b> | Room 701-716, 7th Floor, Kanghesheng Building, No.1<br>ChuangSheng Road, Nanshan District, Shenzhen,<br>Guangdong, P. R. China                                                                                                                                                                                                                                                                                                                                                                         |
| <b>Test Standards.....:</b>       | ANSI C63.19-2011 American National Standard Methods<br>of Measurement of Compatibility between Wireless<br>Communications Devices and Hearing Aids<br><br>FCC 47CFR § 20.19 American National Standard<br>Methods of Measurement of Compatibility between<br>Wireless Communications Devices and Hearing Aids<br><br>KDB 285076 D01HAC Guidance v04 Provides<br>equipment authorization guidance for mobile handsets<br>subject to the requirements of Section 20.19 for hearing<br>aid compatibility. |
| <b>RF Emission Rating.....:</b>   | M3                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
| <b>Test Result.....:</b>          | Pass                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
| <b>Tested by .....</b>            |                                                                                                                                                                                                                                                                                                                                                                                                                     |
|                                   | Mei chun , Test Engineer                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
| <b>Reviewed by.....:</b>          |                                                                                                                                                                                                                                                                                                                                                                                                                     |
|                                   | Shuangwen Zhang, Senior Engineer                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
| <b>Approved by.....:</b>          |                                                                                                                                                                                                                                                                                                                                                                                                                     |
|                                   | Wu Li'an , Manager                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |

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## **1. GENERAL CONDITIONS**

**1.1 This report only refers to the item that has undergone the test.**

**1.2 This report standalone does not constitute or imply by its own an approval of the product by the certification Bodies or competent Authorities.**

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## 2. ADMINISTRATIVE DATE

### 2.1. Identification of the Responsible Testing Laboratory

**Company Name:** CCIC-SET  
  
**Department:** EMC & RF Department  
**Address:** Electronic Testing Building, Shahe Road, Nanshan District, Shenzhen, P. R. China  
**Telephone:** +86-755-26629676  
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**Responsible Test Lab Managers:** Mr. Wu Li'an

### 2.2. Identification of the Responsible Testing Location(s)

**Company Name:** CCIC-SET  
  
**Address:** Electronic Testing Building, Shahe Road, Nanshan District, Shenzhen, P. R. China

### 2.3. Organization Item

**CCIC-SET Report No.:** SET2015-12152  
**CCIC-SET Project Leader:** Mr. Li Sixiong  
**CCIC-SET Responsible for accreditation scope:** Mr. Wu Li'an  
**Start of Testing:** 2015-08-12  
**End of Testing:** 2015-08-12

### 2.4. Identification of Applicant

**Company Name:** Hyundai Corporation  
  
**Address:** 140-2, Kye-dong, Chongro-ku, Seoul, South Korea  
  
**Manufacturer Name:** Shenzhen Fortuneship Technology Co., Ltd  
  
**Address:** Room 701-716, 7th Floor, Kanghesheng Building, No.1 ChuangSheng Road, Nanshan District, Shenzhen, Guangdong, P. R. China

**Notes:** This data is based on the information by the applicant.

### 3. EQUIPMENT UNDER TEST(EUT)

#### 3.1. Identification of the Equipment under Test

**Sample Name:** Mobile Phone

**Type Name:** E245SH

**Brand Name:** /

|                             |                   |                         |
|-----------------------------|-------------------|-------------------------|
| <b>General description:</b> | Support Band      | GSM850MHz/1900MHz       |
|                             |                   | WCDMA 850MHz/ 1900MHz   |
|                             |                   | Bluetooth 2.4GHz        |
|                             | Test Band         | GSM 850MHz/ GSM 1900MHz |
|                             |                   | WCDMA 850MHz/1900MHz    |
|                             | Development Stage | Identical Prototype     |
|                             | Accessories       | Power Supply            |
|                             | Antenna type      | PIFA Antenna            |
|                             | Operation mode    | GSM/WCDMA               |
|                             | Modulation mode   | GMSK, 8PSK, QPSK, 16QAM |

#### NOTE:

- The EUT is a model of E245SH operating in GSM 850 / 1900, WCDMA 850 /1900 MHz band, Bluetooth 2.4GHz.
- Please refer to Appendix C for the photographs of the EUT. For a more detailed features description about the EUT, please refer to User's Manual.

### 3.2 Summary of test results

#### 3.2.1 Test Standards

| No. | Identity                        | Document Title                                                                                                                           |
|-----|---------------------------------|------------------------------------------------------------------------------------------------------------------------------------------|
| 1   | FCC 47 CFR Part 20.19           | Hearing aid-compatible mobile handsets.                                                                                                  |
| 2   | ANSI C63.19:2011                | American National Standard Methods of Measurement of Compatibility between Wireless Communications Devices and Hearing Aids              |
| 3   | KDB 285076 D01 HAC Guidance v04 | Provides equipment authorization guidance for mobile handsets subject to the requirements of Section 20.19 for hearing aid compatibility |

#### 3.2.2 Summary Of HAC Rating

##### Summary of M-Rating

| Band      | E-field dB(V/m) | M-Rating |
|-----------|-----------------|----------|
| GSM850    | 35.22           | M3       |
| GSM1900   | 24.75           | M3       |
| WCDMA850  | 32.60           | M4       |
| WCDMA1900 | 23.97           | M3       |

## 4. HEARING AID COMPATIBILITY

### 4.1 Introduction

The purpose of the Hearing Aid Compatibility extension is to enable measurements of the near electric and magnetic fields generated by wireless communication devices in the region controlled for use by a hearing aid in accordance with ANSI-C63.19-2011. FCC has granted a request for waiver of the HAC rules in section 20.19 for dual band GSM handsets. The waiver has specific conditions, as stated in the order (FCC 05-166) and expires 1 August 2007.

The purpose of this standard is to establish categories for hearing aids and for WD (wireless communications devices) that can indicate to health care practitioners and hearing aid users which hearing aids are compatible with which WD, and to provide tests that can be used to assess the electromagnetic characteristics of hearing aids and WD and assign them to these categories. The various parameters required, in order to demonstrate compatibility and accessibility are measured. The design of the standard is such that when a hearing aid and WD achieve one of the categories specified, as measured by the methodology of this standard, the indicated performance is realized.

In order to provide for the usability of a hearing aid with a WD, several factors must be coordinated:

- a) Radio frequency (RF) measurements of the near-field electric and magnetic fields emitted by a WD to categorize these emissions for correlation with the RF immunity of a hearing aid.
- b) Magnetic field measurements of a WD emitted via the audio transducer associated with the T-coil mode of the hearing aid, for assessment of hearing aid performance.
- c) Measurements with the hearing aid and a simulation of the categorized WD T-coil emissions to assess the hearing aid RF immunity in the T-coil mode.

The WD radio frequency (RF) and audio band emissions are measured.

Hence, the following are measurements made for the WD:

- a) RF E-Field emissions
- c) T-coil mode, magnetic signal strength in the audio band
- d) T-coil mode, magnetic signal and noise articulation index
- e) T-coil mode, magnetic signal frequency response through the audio band

Corresponding to the WD measurements, the hearing aid is measured for:

- a) RF immunity in microphone mode
- b) RF immunity in T-coil mode



## 4.2 Description of Test System

### 4.2.1 COMOHAC E-FIELD PROBE



|                                                     |                                                                                              |
|-----------------------------------------------------|----------------------------------------------------------------------------------------------|
| Serial Number:                                      | SN 02/12 EPH34                                                                               |
| Frequency:                                          | 0.7GHz – 2.5GHz                                                                              |
| Probe length:                                       | 330mm                                                                                        |
| Length of one dipole:                               | 3.3mm                                                                                        |
| Maximum external diameter:                          | 8mm                                                                                          |
| Probe extremity diameter:                           | 5mm                                                                                          |
| Distance between dipoles/probe extremity:           | 3mm                                                                                          |
| Resistance of the three dipole (at the connector ): | Dipole 1:R1=1.201 M $\Omega$<br>Dipole 2:R1=1.193 M $\Omega$<br>Dipole 3:R3=0.994 M $\Omega$ |

### 4.2.2 System Hardware

The HAC positioning ruler is used to position the phone properly with the regard to the position of the probe during a measurement. The positioning system is made of a dedicated frame that can be fixed on the table. The tip of the probe is positioned on a reference point located on the top of the positioning ruler. The distance between this reference point and the cross located on the ruler being known, the speaker of the phone is positioned on this cross in order to make sure both probe and phone are positioned properly.

During the measurement, the HAC ruler has to be removed so that it does not interfere with the measurement.



Position device

## 5. OPERATIONAL CONDITIONS DURING TEST

### 5.1 Schematic Test Configuration

During SAR test, EUT was operating in Traffic Mode (Channel Allocated) at Normal Voltage Condition. A communication link is set up with a System Simulator (SS) by air link, and a call is established.

The Absolute Radio Frequency Channel Number (ARFCN) was allocated to 128, 190 and 251 respectively in the case of GSM 850MHz, or to 512, 661 and 810 respectively in the case of PCS 1900MHz, or to 4132, 4183 and 4233 respectively in the case of WCDMA 850MHz, or to 9262, 9400 and 9538 respectively in the case of WCDMA 1900MHz. The EUT was commanded to operate at maximum transmitting power.

The EUT should use its internal transmitter. The antenna(s), battery and accessories shall be those specified by the manufacturer. The EUT battery must be fully charged and checked periodically during the test to ascertain uniform power output. If a wireless link was used, the antenna connected to the output of the base station simulator shall be placed at least 50 cm away from the handset.

The signal transmitted by the simulator to the antenna feeding point should be lower than the output power level of the handset by at least 35 dB

| Air-interface | Band (MHz) | Type  | C63.19-2007 Tested | Simultaneous Transmissions Scenarios invoice (Not to be tested) | Reduced power | VOIP |
|---------------|------------|-------|--------------------|-----------------------------------------------------------------|---------------|------|
| GSM           | 850        | Voice | Yes                | Yes: WIFI or BT                                                 | N/A           | N/A  |
|               | 1900       | Voice | Yes                | Yes: WIFI or BT                                                 | N/A           | N/A  |
|               | GPRS       | Data  | N/A                | N/A                                                             | N/A           | N/A  |
| WCDMA         | 850        | Voice | Yes                | Yes: WIFI or BT                                                 | N/A           | N/A  |
|               | 1900       | Voice | Yes                | Yes: WIFI or BT                                                 | N/A           | N/A  |
|               | HSDPA      | Data  | N/A                | N/A                                                             | N/A           | N/A  |
|               | HSUPA      | Data  | N/A                | N/A                                                             | N/A           | N/A  |
| WIFI          | 2.4G       | Data  | N/A                | Yes GSM or WCDMA                                                | N/A           | YES  |
| BT            | 2.4G       | Data  | N/A                | Yes GSM or WCDMA                                                | N/A           | N/A  |

The volume is at the maximum value, and the backlight of the phone is turned off. The Manufacturer doesn't design HAC mode software on the EUT

## 5.2 HAC Measurement System

The HAC measurement system being used is the COMO HAC system, the system is controlled remotely from a PC, which contains the software to control the robot and data acquisition equipment. The software also displays the data obtained from test scans.

In operation, the system first does a 2D scan at a fixed depth within a 50mm\*50mm area. When the maximum HAC point has been found, the system will then carry out a 3D scan centered at that point to determine volume averaged HAC level.



WD reference and plane for RF emission measurements

## 5.3 Magnetic measurement locations for the WD

T-Coil measurement points and reference plane The following figure illustrates the three standard probe orientations. Position 1 is the axial orientation of the probe coil; orientation 2 and orientation 3 are radial orientations. The space between the measurement positions is not fixed. It is recommended that a scan of the EUT be done for each probe coil orientation and that the maximum level recorded be used as the reading for that orientation of the probe coil.

1) The reference plane is the planar area that contains the highest point in the area of the phone that normally rests against the user's ear. It is parallel to the centerline of the receiver.

ver 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.

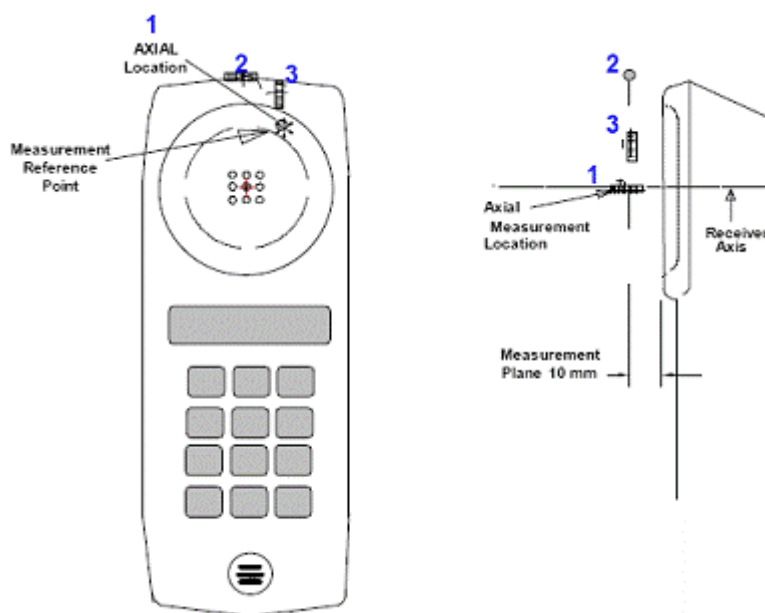
2) The measurement plane is parallel to, and 10 mm in front of, the reference plane.

3) The reference axis is normal to the reference plane and passes through the center of the receiver speaker section (or the center of the hole array); or may be centered on a secondary inductive source. The actual location of the measurement point shall be noted in the test report as the measurement reference point.

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

5) The relative spacing of each measurement orientation is not fixed. The axial and two radial orientations should be chosen to select the optimal position.

6) The measurement point for the axial position is located 10 mm from the reference plane on the measurement axis. The actual location of the measurement point shall be noted in test reports and designated as the measurement reference point.



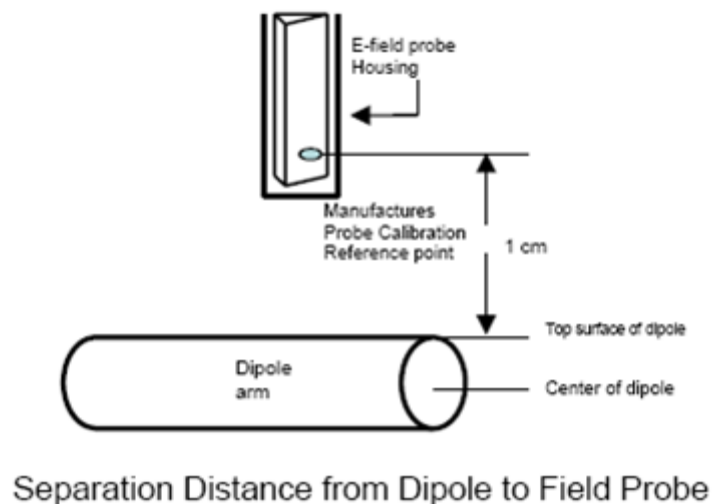
Axis and planes for EUT audio frequency magnetic field measurements

## 5.4 Equipments and results of validation testing

### 5.4.1 System Check Parameters

The input signal was an unmodulated continuous wave. The following points were taken into consideration in performing this check:

- Average Input Power  $P = 100\text{mW RMS}$  (20dBm RMS) after adjustment for return loss
- The test fixture must meet the 2 wavelength separation criterion
- The proper measurement of the 1 cm probe to dipole separation, which is measured from top surface of the dipole to the calibration reference point of the sensor, defined by the probe manufacturer is shown in the following diagram:



RF power was recorded using both an average reading meter and a peak reading meter. Readings of the probe are provided by the measurement system.

To assure proper operation of the near-field measurement probe the input power to the dipole shall be commensurate with the full rated output power of the wireless device (e.g. - for a cellular phone wireless device the average peak antenna input power will be on the order of 100mW (i.e. - 20dBm) RMS after adjustment for any mismatch.

### 5.4.2 Validation Procedure

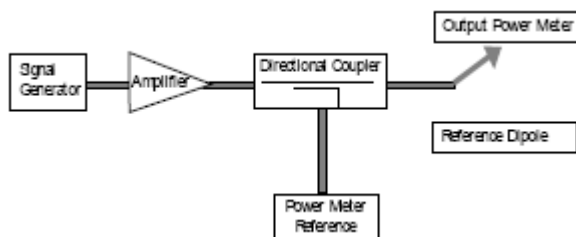
A dipole antenna meeting the requirements given in PC63.19 was placed in the position normally occupied by the WD.

The length of the dipole was scanned with both E-field and H-field probes and the

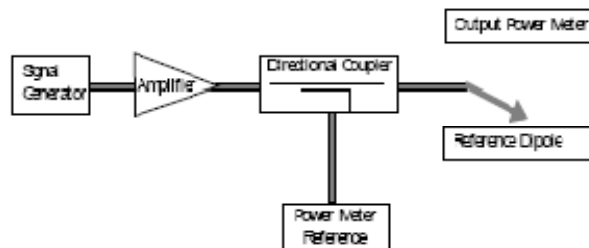
maximum values for each were recorded.

Using the near-field measurement system, scan the antenna over the radiating dipole and record the greatest field reading observed. Due to the nature of E-fields about free-space dipoles, the two E-field peaks measured over the dipole are averaged to compensate for non-parallelity of the setup see manufacturer method on dipole calibration certificates, field strength measurements shall be made only when the probe is stationary.

RF power was recorded using both an average and a peak power reading meter.



Setup for Desired Output Power to Dipole



Setup to Dipole

Using this setup configuration, the signal generator was adjusted for the desired output power (100mW) at a specified frequency. The reference power from the coupled port of the directional coupler is recorded. Next, the output cable is connected to the reference dipole.

### 5.4.3 Test System Validation

Validation Results (20dBm forward input power), System checks the specific test data please see Annex C.

| Frequency                                                 | Input Power (dBm) | E-field Result (dB(V/m)) | Target Field (V/m) | Deviation (%) |
|-----------------------------------------------------------|-------------------|--------------------------|--------------------|---------------|
| 835 MHz                                                   | 20.0              | 226.04                   | 214.26             | 5.50          |
| 1900MHz                                                   | 20.0              | 153.09                   | 147.33             | 3.90          |
| Note: The tolerance limit of System validation $\pm 25\%$ |                   |                          |                    |               |

Note: Target value was referring to the Measured value in the calibration certificate of reference dipole.

#### 5.4.4. Modulation Interference Factor (MIF)

The HAC Standard ANSI C63.19-2011 defines a new scaling using the Modulation Interference Factor (MIF) which replaces the need for the Articulation Weighting Factor (AWF) during the evaluation and is applicable to any modulation scheme.

The Modulation Interference factor (MIF, in dB) is added to the measured average E-field (in dBV/m) and converts it to the RF Audio Interference level (in dBV/m). This level considers the audible amplitude modulation components in the RF E-field. CW fields without amplitude modulation are assumed to not interfere with the hearing aid electronics. Modulations without time slots and low fluctuations at low frequencies have low MIF values, TDMA modulations with narrow transmission and repetition rates of few 100 Hz have high MIF values and give similar classifications as ANSI C63-2007.

Definitions, E-field probes have a bandwidth <10 kHz and can therefore not evaluate the RF envelope in the full audio band. OPENHAC is therefore using the "indirect" measurement method according to ANSI C63.19-2011 which is the primary method. These near field probes read the averaged E-field measurement. Especially for the new high peak-to-average (PAR) signal types, the probes shall be linearized by probe modulation response (PMR) calibration in order to not overestimate the field reading. The evaluation method or the MIF is defined in ANSI C63.19-2011 section D.7. An RMS demodulated RF signal is fed to a spectral filter (similar to an A weighting filter) and forwarded to a temporal filter acting as a quasi-peak detector. The averaged output of these filtering is called to a 1 kHz 80% AM signal as reference. MIF measurement requires additional instrumentation and is not well suited for evaluation by the end user with reasonable uncertainty. It may alternatively be determined through analysis and simulation, because it is constraint and characteristic for a communication signal. OPENHAC uses well defined signals for PMR calibration. The MIF of these signals has been determined by simulation and is automatically applied.

MIF values were not tested by a probe or as specified in the standards but are based on analysis provided by SATIMO for all the air interfaces (GSM, WCDMA, CDMA). The data included in this report are for the worst case operating modes.

| Transmission protocol                              | Modulation interference factor |
|----------------------------------------------------|--------------------------------|
| GSM; full-rate version 2; speech codec/handset low | +3.5dB                         |
| WCDMA; speech; speech codec low; AMR 12.2 kb/s     | -20.0dB                        |
| CDMA; speech; SO3; RC3; full frame rate: 8kEVRC    | -19.0dB                        |
| CDMA; speech; SO3; RC1; 1/8th frame rate; 8kEVRC   | +3.3dB                         |

A PMR calibrated probe is linearized for the selected waveform over the full dynamic range within the uncertainty

specified in its calibration certificate. E-field probes have a bandwidth <10 kHz and can therefore not evaluate the RF envelope in the full audio band. OPENHAC is therefore using the "indirect" measurement method according to ANSI C63.19-2011 which is the primary method. These near field probes read the averaged E-field measurement. Especially for the new high peak-to-average (PAR) signal types, the probes shall be linearized by PMR calibration in order to not overestimate the field reading. The evaluation method for the MIF is defined in ANSI C63.19-2011 section D.7. An RMS demodulated RF signal is fed to a spectral filter (similar to an A weighting filter) and forwarded to a temporal filter acting as a quasi-peak detector. The averaged output of these filtering is scaled to a 1 kHz 80% AM signal as reference. MIF measurement requires additional instrumentation and is not well suited for evaluation by the end user with reasonable uncertainty. It may alternatively be determined through analysis and simulation, because it is constant and characteristic for a communication signal. OPENHAC uses well-defined signals for PMR calibration. The MIF of these signals has been determined by simulation and is automatically applied. The MIF measurement uncertainty is estimated as follows, for modulation frequencies from slotted waveforms with fundamental frequency and at least 2 harmonics within 10

kHz:

0.2 dB for MIF -7 to +5 dB, 0.5 dB for MIF -13 to +11 dB

1 dB for MIF > -20



## 6. CHARACTERISTICS OF THE TEST

### 6.1 Applicable Limit Regulations

Table 1 Telephone near-field categories in linear units (<960MHz)

| Category | E-field emissions |                   |
|----------|-------------------|-------------------|
|          | < 960 MHz         | > 960 MHz         |
| M1       | 50 to 55 dB (V/m) | 40 to 45 dB (V/m) |
| M2       | 45 to 50 dB (V/m) | 35 to 40 dB (V/m) |
| M3       | 40 to 45 dB (V/m) | 30 to 35 dB (V/m) |
| M4       | <40 dB (V/m)      | <30 dB (V/m)      |

### 6.2 Applicable Measurement Standards

**ANSI C63.19-2011:** American National Standard Methods of Measurement of Compatibility between Wireless Communications Devices and Hearing Aids.

**FCC 47CFR § 20.19** American National Standard Methods of Measurement of Compatibility between Wireless Communications Devices and Hearing Aids

It specifies the measurement method for demonstration of compliance with the HAC limits for such equipments.

## 7 LABORATORY ENVIRONMENT

Table 4: The Ambient Conditions during HAC Test

|                          |                            |
|--------------------------|----------------------------|
| Temperature              | Min. = 20 °C, Max. = 25 °C |
| Relative humidity        | Min. = 30%, Max. = 70%     |
| Ground system resistance | < 0.5 $\Omega$             |

Ambient noise is checked and found very low and in compliance with requirement of standards.

Reflection of surrounding objects is minimized and in compliance with requirement of standards.

## 7. TEST RESULTS

### 7.1 Summary of conducted Power Measurement Results

The power level results were listed in the following two tables:

Table 5: Conducted RF Power of GSM850

| Band      | GSM 850 |       |       | GSM 1900 |        |        |
|-----------|---------|-------|-------|----------|--------|--------|
| Channel   | 128     | 190   | 251   | 512      | 661    | 810    |
| Frequency | 824.2   | 836.4 | 848.8 | 1850.2   | 1880.0 | 1909.8 |
| GSM       | 32.54   | 32.42 | 32.50 | 29.77    | 29.22  | 28.82  |

Table 6: Conducted RF Power of WCDMA

| Band       | WCDMA 850 |       |       | WCDMA1900 |        |        |
|------------|-----------|-------|-------|-----------|--------|--------|
| TX Channel | 4132      | 4182  | 4233  | 9262      | 9400   | 9538   |
| Frequency  | 826.4     | 836.6 | 846.6 | 1852.4    | 1880.0 | 1907.6 |
| ARM        | 22.24     | 22.02 | 21.96 | 22.37     | 22.22  | 22.15  |

### 7.2 Summary of Measurement Results

Table 7: RF Emission Values of the EUT

| Temperature: 23.0~23.5°C, humidity: 62~64%. |         |                 |                 |          |
|---------------------------------------------|---------|-----------------|-----------------|----------|
| Band                                        | Channel | Frequency (MHz) | Test Results    | Category |
|                                             |         |                 | E-field dB(V/m) |          |
| GSM850                                      | Low     | 824.2           | 40.54           | M3       |
| GSM850                                      | Mid     | 836.4           | 40.47           | M3       |
| GSM850                                      | High    | 848.8           | 40.40           | M3       |
| GSM1900                                     | Low     | 1850.2          | 32.21           | M3       |
| GSM1900                                     | Mid     | 1880.0          | 31.62           | M3       |
| GSM1900                                     | High    | 1909.8          | 30.66           | M3       |
| WCDMA850                                    | Low     | 826.4           | 39.54           | M4       |
| WCDMA850                                    | Mid     | 836.6           | 39.66           | M4       |
| WCDMA850                                    | High    | 846.6           | 39.55           | M4       |
| WCDMA1900                                   | Low     | 1852.4          | 34.68           | M3       |
| WCDMA1900                                   | Mid     | 1880.0          | 33.94           | M3       |
| WCDMA1900                                   | High    | 1907.6          | 33.56           | M3       |

## 8. MEASUREMENT UNCERTAINTY

Table 9: Measurement Uncertainty of RF Emission Test

| Uncertainty Component            | Uncertainty value | Probe Dist. | Div   | (Ci) E | (Ci) H | Std. Unc.(+-%) |       |
|----------------------------------|-------------------|-------------|-------|--------|--------|----------------|-------|
|                                  |                   |             |       |        |        | E              | H     |
| Measurement System               |                   |             |       |        |        |                |       |
| Probe calibration                | 6.00              | N           | 1.000 | 1      | 1      | 6.00           | 6.00  |
| Axial Isotropy                   | 2.02              | R           | 1.732 | 1      | 1      | 1.17           | 1.17  |
| Sensor Displacement              | 14.30             | R           | 1.732 | 1      | 0.217  | 8.26           | 1.79  |
| Boundary effect                  | 2.50              | R           | 1.732 | 1      | 1      | 0.87           | 0.87  |
| Phantom Boundary effect          | 6.89              | R           | 1.732 | 1      | 0      | 3.52           | 0.00  |
| Linearity                        | 2.58              | R           | 1.732 | 1      | 1      | 1.49           | 1.49  |
| Scaling to PMR Calibration       | 9.02              | N           | 1.000 | 1      | 1      | 9.02           | 9.02  |
| System Detection Limit           | 1.30              | R           | 1.732 | 1      | 1      | 0.75           | 0.75  |
| Readout Electronics              | 0.25              | R           | 1.732 | 1      | 1      | 0.14           | 0.14  |
| Response Time                    | 1.23              | R           | 1.732 | 1      | 1      | 0.71           | 0.71  |
| Integration Time                 | 2.15              | R           | 1.732 | 1      | 1      | 1.24           | 1.24  |
| RF Ambient Conditions            | 2.03              | R           | 1.732 | 1      | 1      | 1.17           | 1.17  |
| RF Reflections                   | 9.09              | R           | 1.732 | 1      | 1      | 5.25           | 5.25  |
| Probe positioner                 | 0.63              | N           | 1.000 | 1      | 0.71   | 0.63           | 0.45  |
| Probe positioning                | 3.12              | N           | 1.000 | 1      | 0.71   | 3.12           | 2.22  |
| Extrapolation and Interpolation  | 1.18              | R           | 1.732 | 1      | 1      | 0.68           | 0.68  |
| Uncertainties of the EUT         |                   |             |       |        |        |                |       |
| Test sample positioning Vertical | 2.73              | R           | 1.732 | 1      | 0.71   | 1.58           | 1.12  |
| Test sample positioning Lateral  | 1.19              | R           | 1.732 | 1      | 1      | 0.69           | 0.69  |
| Device Holder and Phantom        | 2.20              | N           | 1.000 | 1      | 1      | 2.20           | 2.20  |
| Power Drift                      | 4.08              | R           | 1.732 | 1      | 1      | 2.36           | 2.36  |
| Phantom and Setup Related        |                   |             |       |        |        |                |       |
| Phantom Thickness                | 2.00              | N           | 1.000 | 1      | 0.6    | 2.00           | 1.20  |
| Combined Std. Uncertainty(k=1)   |                   |             |       |        |        | 16.18          | 13.25 |
| Expanded Uncertainty on Power    |                   |             |       |        |        | 32.35          | 26.50 |
| Expanded Uncertainty on Field    |                   |             |       |        |        | 16.18          | 13.25 |

Note:

N-Nominal

R-Rectangular

Div.- Divisor used to obtain standard uncertainty

Table 10: Measurement Uncertainty of T-Coil Test

| No.                       | Uncertainty Component                          | Type | Uncertainty Value (%) | Probability Distribution | k     | ci  | Standard Uncertainty (%) $u_i(\%)$ | Degree of freedom $\nu_{eff}$ or $\nu_i$ |
|---------------------------|------------------------------------------------|------|-----------------------|--------------------------|-------|-----|------------------------------------|------------------------------------------|
| <b>Measurement System</b> |                                                |      |                       |                          |       |     |                                    |                                          |
| 1                         | – Probe Calibration                            | B    | 6                     | N                        | 3     | 1   | 3.5                                | $\infty$                                 |
| 2                         | – Axial isotropy                               | B    | 4.7                   | R                        | 1.732 | 0.5 | 4.3                                | $\infty$                                 |
| 3                         | – Hemispherical Isotropy                       | B    | 9.4                   | R                        | 1.732 | 0.5 | 4.3                                | $\infty$                                 |
| 4                         | – Boundary Effect                              | B    | 11.0                  | R                        | 1.732 | 1   | 6.4                                | $\infty$                                 |
| 5                         | – Linearity                                    | B    | 4.7                   | R                        | 1.732 | 1   | 2.7                                | $\infty$                                 |
| 6                         | – System Detection Limits                      | B    | 1.0                   | R                        | 1.732 | 1   | 0.6                                | $\infty$                                 |
| 7                         | – Probe Coil Sensitivity                       | B    | 0.49                  | R                        | 1.732 | 1   | 0.28                               | $\infty$                                 |
| 8                         | – Response Time                                | B    | 0.00                  | R                        | 1.732 | 1   | 0.00                               | $\infty$                                 |
| 9                         | – Integration Time                             | B    | 0.00                  | R                        | 1.732 | 1   | 0.00                               | $\infty$                                 |
| 10                        | – RF Ambient Conditions                        | B    | 3.0                   | R                        | 1.732 | 1   | 1.73                               | $\infty$                                 |
| 11                        | – Probe Position Mechanical tolerance          | B    | 0.4                   | R                        | 1.732 | 1   | 0.2                                | $\infty$                                 |
| 12                        | – Probe Position with respect to Phantom Shell | B    | 2.9                   | R                        | 1.732 | 1   | 1.7                                | $\infty$                                 |

|                                                              |                           |   |      |     |       |   |       |          |
|--------------------------------------------------------------|---------------------------|---|------|-----|-------|---|-------|----------|
| <b>Uncertainties of the DUT</b>                              |                           |   |      |     |       |   |       |          |
| 13                                                           | – Position of the DUT     | A | 4.8  | N   | 3     | 1 | 4.8   | 5        |
| 14                                                           | – Holder of the DUT       | A | 7.1  | N   | 3     | 1 | 7.1   | 5        |
| 15                                                           | – Repeatability of the WD | B | 5.0  | R   | 1.732 | 1 | 2.9   | $\infty$ |
| <b>Acoustic noise</b>                                        |                           |   |      |     |       |   |       |          |
| 16                                                           | – Acoustic noise          | B | 1.0  | R   | 1.732 | 1 | 0.6   | $\infty$ |
| 21                                                           | – Cable loss              | B | 0.46 | N   | 1.732 | 1 | 0.46  | $\infty$ |
| <b>Combined Standard Uncertainty</b>                         |                           |   |      | RSS |       |   | 17.26 | 42.33    |
| <b>Expanded uncertainty</b><br>(Confidence interval of 95 %) |                           |   |      | K=2 |       |   | 34.52 |          |

## 9. MAIN TEST INSTRUMENTS

| No | EQUIPMENT                          | TYPE            | Series No.     | Due Date   |
|----|------------------------------------|-----------------|----------------|------------|
| 1  | E-Field Probe                      | SATIMO/SCE      | SN 02/12 EPH34 | 2016/05/05 |
| 3  | Dipole                             | SATIMO/SIDB835  | SN 18/12 DHA37 | 2015/08/28 |
| 4  | Dipole                             | SATIMO/SIDB1900 | SN 18/12 DHB42 | 2015/08/28 |
| 5  | Vector Network Analyzer            | ZVB8            | 1145.1010.08   | 2016/06/13 |
| 6  | Amplifier                          | Nucletudes      | 143060         | 2016/04/04 |
| 7  | Power Meter                        | NRVS            | 1020.1809.02   | 2016/06/13 |
| 8  | Multimeter                         | Keithley - 2000 | 4014020        | 2016/04/04 |
| 9  | Power Sensor                       | NRV-Z4          | 100069         | 2016/06/10 |
| 10 | Wireless<br>Communication Test Set | CMU200          | A0304212       | 2016/06/10 |

## 10. ANNEX A TEST SETUP



Fig.1 Testing Photo

## 11. ANNEX B EUT PHOTOS

### 1. Appearance



Appearance and size (obverse)



Appearance and size (reverse)

## 12. ANNEX C SYSTEM CHECK

### System Performance Check (E, 835MHz)

Date of measurement: 08/12/2015

Mobile Phone IMEI number: --

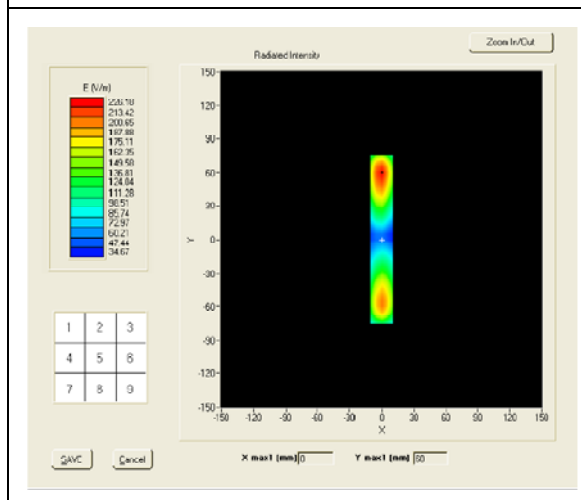
#### A. Experimental conditions.

|             |                |
|-------------|----------------|
| Band        | CUSTOM (CW835) |
| Channel     | MID            |
| Signal      | Duty Cycle: 1  |
| Input power | 20dBm          |

#### B. HAC Measurement Results

Frequency (MHz): 835.000000

##### SURFACE HAC



Probe Modulation Factor= 1.00

Maximum value of total field = 226.04 V/m

E in V/m



## System Performance Check (E, 1900MHz)

Date of measurement: 08/12/2015

Mobile Phone IMEI number: --

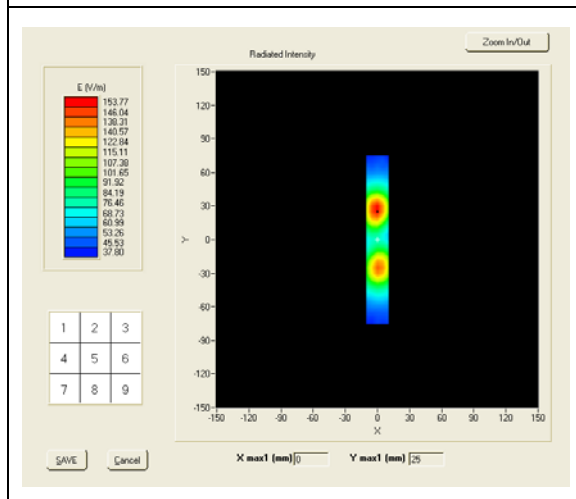
### A. Experimental conditions.

|             |                 |
|-------------|-----------------|
| Band        | CUSTOM (CW1900) |
| Channel     | Middle          |
| Signal      | Duty Cycle: 1   |
| Input Power | 20dBm           |

### B. HAC Measurement Results

Frequency (MHz): 1900.000000

#### SURFACE HAC



Probe Modulation Factor= 1.00

Maximum value of total field = 153.09V/m;

E in V/m

## 13. ANNEX D TEST PLOTS

### Test Results (GSM850, E-Field, Low Channel)

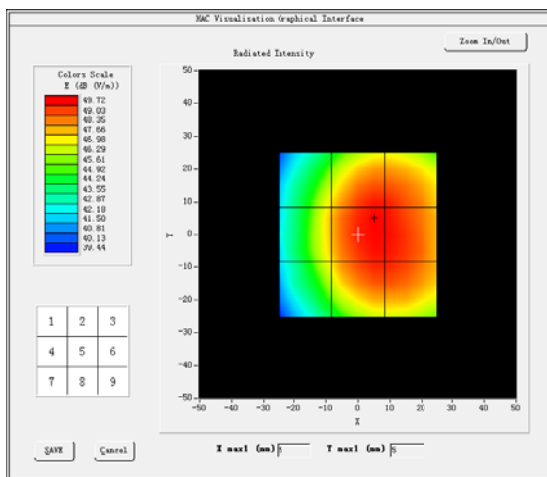
Date of measurement: 08/12/2015

Mobile Phone IMEI number: --

#### A. Experimental conditions.

|                     |            |
|---------------------|------------|
| Grid size (mm x mm) | 50.0, 50.0 |
| Step (mm)           | 5          |
| Band                | GSM850     |
| Channel             | Low        |
| Signal              | GSM        |

#### SURFACE HAC



Maximum value of total field = 40.54 dB (V/m)

Hearing Aid Near-Field Category: M3

|               |                      |                      |
|---------------|----------------------|----------------------|
| Grid 1: 38.08 | <b>Grid 2: 40.31</b> | <b>Grid 3: 40.15</b> |
| Grid 4: 38.62 | <b>Grid 5: 40.54</b> | <b>Grid 6: 40.40</b> |
| Grid 7: 38.18 | Grid 8: 40.27        | Grid 9: 40.18        |

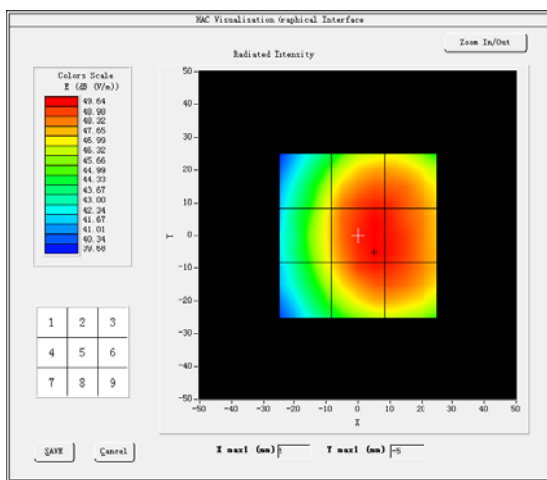
## Test Results (GSM850, E-Field, Mid Channel)

Date of measurement: 08/12/2015

Mobile Phone IMEI number: --

### A. Experimental conditions.

|                     |            |
|---------------------|------------|
| Grid size (mm x mm) | 50.0, 50.0 |
| Step (mm)           | 5          |
| Band                | GSM850     |
| Channel             | Mid        |
| Signal              | GSM        |
| SURFACE HAC         |            |



Maximum value of total field = 40.47 dB (V/m)

Hearing Aid Near-Field Category: M3

|               |                      |                      |
|---------------|----------------------|----------------------|
| Grid 1: 38.17 | Grid 2: 40.11        | Grid 3: 39.99        |
| Grid 4: 38.49 | <b>Grid 5: 40.47</b> | <b>Grid 6: 40.29</b> |
| Grid 7: 38.17 | <b>Grid 8: 40.32</b> | <b>Grid 9: 40.16</b> |

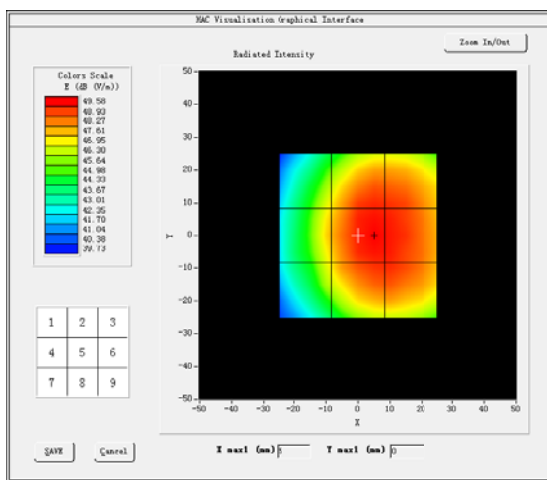
## Test Results (GSM850, E-Field, High Channel)

Date of measurement: 08/12/2015

Mobile Phone IMEI number: --

### A. Experimental conditions.

|                     |            |
|---------------------|------------|
| Grid size (mm x mm) | 50.0, 50.0 |
| Step (mm)           | 5          |
| Band                | GSM850     |
| Channel             | High       |
| Signal              | GSM        |
| SURFACE HAC         |            |



Maximum value of total field = 40.40 dB (V/m)

Hearing Aid Near-Field Category: M3

|               |                      |                      |
|---------------|----------------------|----------------------|
| Grid 1: 37.89 | Grid 2: 40.00        | Grid 3: 39.87        |
| Grid 4: 38.57 | <b>Grid 5: 40.40</b> | <b>Grid 6: 40.17</b> |
| Grid 7: 38.09 | <b>Grid 8: 40.06</b> | <b>Grid 9: 40.03</b> |

## Test Results (GSM1900, E, Low Channel)

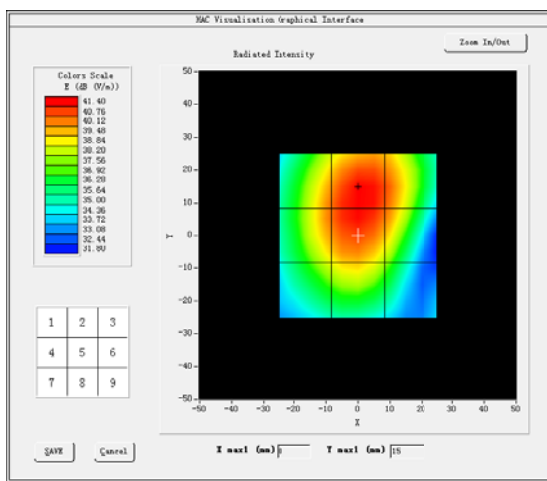
Date of measurement: 08/12/2015

Mobile Phone IMEI number: --

### A. Experimental conditions.

|                     |            |
|---------------------|------------|
| Grid size (mm x mm) | 50.0, 50.0 |
| Step (mm)           | 5          |
| Band                | GSM1900    |
| Channel             | Low        |
| Signal              | GSM        |

### SURFACE HAC



Maximum value of total field = 32.21 dB (V/m)

Hearing Aid Near-Field Category: M3

|                      |                      |               |
|----------------------|----------------------|---------------|
| <b>Grid 1: 31.18</b> | <b>Grid 2: 32.30</b> | Grid 3: 31.21 |
| <b>Grid 4: 31.25</b> | <b>Grid 5: 32.21</b> | Grid 6: 30.90 |
| Grid 7: 29.62        | Grid 8: 30.35        | Grid 9: 28.23 |

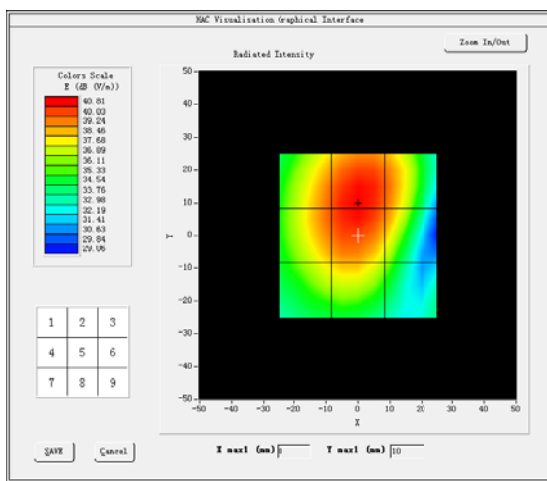
## Test Results (GSM1900, E, Middle Channel)

Date of measurement: 08/12/2015

Mobile Phone IMEI number: --

### A. Experimental conditions.

|                     |            |
|---------------------|------------|
| Grid size (mm x mm) | 50.0, 50.0 |
| Step (mm)           | 5          |
| Band                | GSM1900    |
| Channel             | Middle     |
| Signal              | GSM        |
| SURFACE HAC         |            |



Maximum value of total field = 31.62 dB (V/m)

Hearing Aid Near-Field Category: M3

|                      |                      |               |
|----------------------|----------------------|---------------|
| <b>Grid 1: 30.64</b> | <b>Grid 2: 31.63</b> | Grid 3: 30.18 |
| <b>Grid 4: 30.69</b> | <b>Grid 5: 31.62</b> | Grid 6: 29.81 |
| Grid 7: 29.09        | Grid 8: 29.58        | Grid 9: 26.87 |

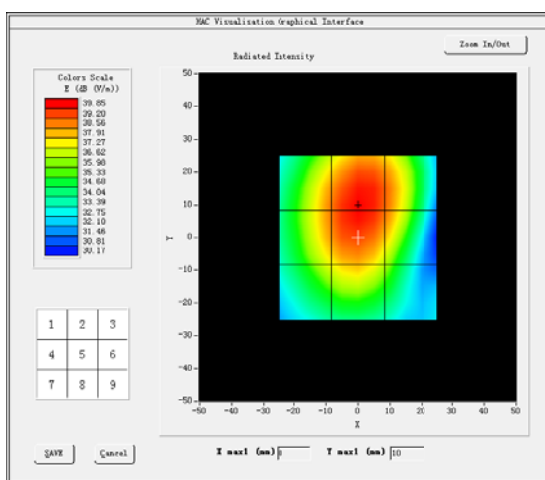
## Test Results (GSM1900, E, High Channel)

Date of measurement: 08/12/2015

Mobile Phone IMEI number: --

### A. Experimental conditions.

|                     |            |
|---------------------|------------|
| Grid size (mm x mm) | 50.0, 50.0 |
| Step (mm)           | 5          |
| Band                | GSM1900    |
| Channel             | High       |
| Signal              | GSM        |
| SURFACE HAC         |            |



Maximum value of total field = 30.66 dB (V/m)

Hearing Aid Near-Field Category: M3

|                      |                      |               |
|----------------------|----------------------|---------------|
| <b>Grid 1: 29.53</b> | <b>Grid 2: 30.67</b> | Grid 3: 29.38 |
| <b>Grid 4: 29.55</b> | <b>Grid 5: 30.66</b> | Grid 6: 29.20 |
| Grid 7: 28.07        | Grid 8: 28.83        | Grid 9: 26.77 |

## Test Results (WCDMA850, E, Low Channel)

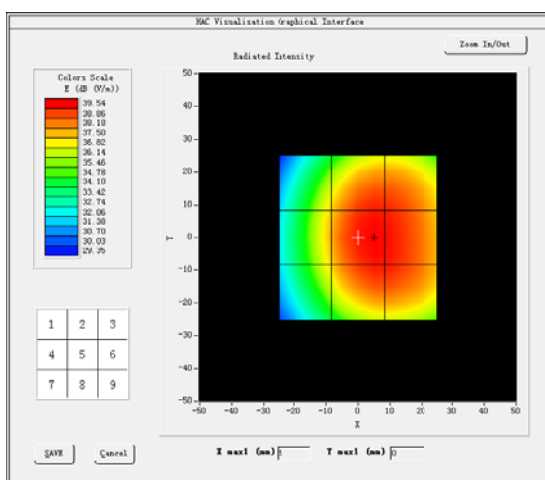
Date of measurement: 08/12/2015

Mobile Phone IMEI number: --

A. Experimental conditions.

|                     |            |
|---------------------|------------|
| Grid size (mm x mm) | 50.0, 50.0 |
| Step (mm)           | 5          |
| Band                | WCDMA850   |
| Channel             | Low        |
| Signal              | WCDMA      |

### SURFACE HAC



Maximum value of total field = 39.54 dB (V/m)

Hearing Aid Near-Field Category: M4

|               |                      |                      |
|---------------|----------------------|----------------------|
| Grid 1: 37.19 | Grid 2: 39.16        | Grid 3: 39.04        |
| Grid 4: 37.73 | <b>Grid 5: 39.54</b> | <b>Grid 6: 39.36</b> |
| Grid 7: 37.31 | <b>Grid 8: 39.35</b> | <b>Grid 9: 39.26</b> |



## Test Results (WCDMA850, E, Middle Channel)

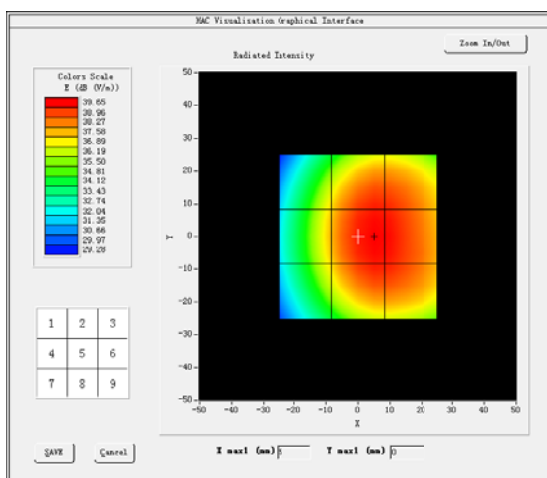
Date of measurement: 08/12/2015

Mobile Phone IMEI number: --

A. Experimental conditions.

|                     |            |
|---------------------|------------|
| Grid size (mm x mm) | 50.0, 50.0 |
| Step (mm)           | 5          |
| Band                | WCDMA850   |
| Channel             | Middle     |
| Signal              | WCDMA      |

### SURFACE HAC



Maximum value of total field = 39.66 dB (V/m)

Hearing Aid Near-Field Category: M4

|               |                      |                      |
|---------------|----------------------|----------------------|
| Grid 1: 37.23 | Grid 2: 39.30        | Grid 3: 39.15        |
| Grid 4: 37.73 | <b>Grid 5: 39.66</b> | <b>Grid 6: 39.54</b> |
| Grid 7: 37.37 | <b>Grid 8: 39.45</b> | <b>Grid 9: 39.34</b> |

## Test Results (WCDMA850, E, High Channel)

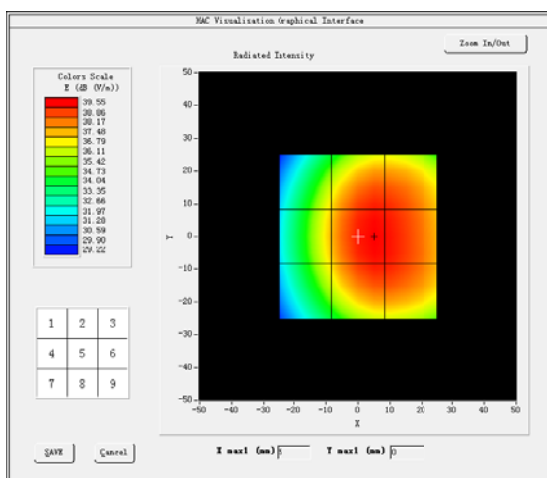
Date of measurement: 08/12/2015

Mobile Phone IMEI number: --

A. Experimental conditions.

|                     |            |
|---------------------|------------|
| Grid size (mm x mm) | 50.0, 50.0 |
| Step (mm)           | 5          |
| Band                | WCDMA850   |
| Channel             | High       |
| Signal              | WCDMA      |

### SURFACE HAC



Maximum value of total field = 39.55 dB (V/m)

Hearing Aid Near-Field Category: M4

|               |                      |                      |
|---------------|----------------------|----------------------|
| Grid 1: 37.11 | Grid 2: 39.21        | Grid 3: 39.05        |
| Grid 4: 37.60 | <b>Grid 5: 39.55</b> | <b>Grid 6: 39.36</b> |
| Grid 7: 37.24 | <b>Grid 8: 39.36</b> | <b>Grid 9: 39.24</b> |

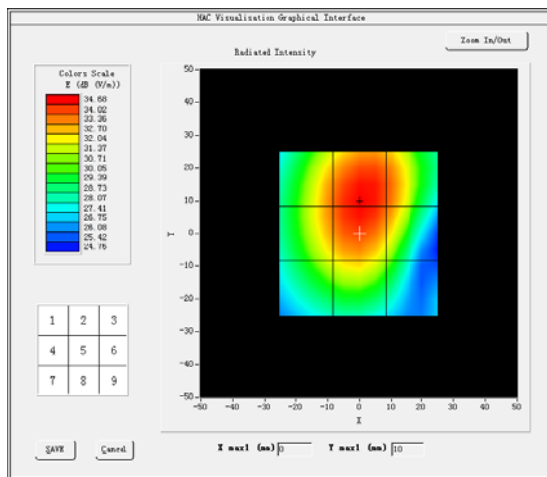
## Test Results (WCDMA1900, E, Low Channel)

Date of measurement: 08/12/2015

Mobile Phone IMEI number: --

### A. Experimental conditions.

|                     |            |
|---------------------|------------|
| Grid size (mm x mm) | 50.0, 50.0 |
| Step (mm)           | 5          |
| Band                | WCDMA1900  |
| Channel             | Low        |
| Signal              | WCDMA      |
| SURFACE HAC         |            |



Maximum value of total field = 34.68 dB (V/m)

Hearing Aid Near-Field Category: M3

|                      |                      |               |
|----------------------|----------------------|---------------|
| <b>Grid 1: 33.63</b> | <b>Grid 2: 34.70</b> | Grid 3: 33.55 |
| <b>Grid 4: 33.64</b> | <b>Grid 5: 34.68</b> | Grid 6: 33.32 |
| Grid 7: 31.99        | Grid 8: 32.69        | Grid 9: 30.47 |

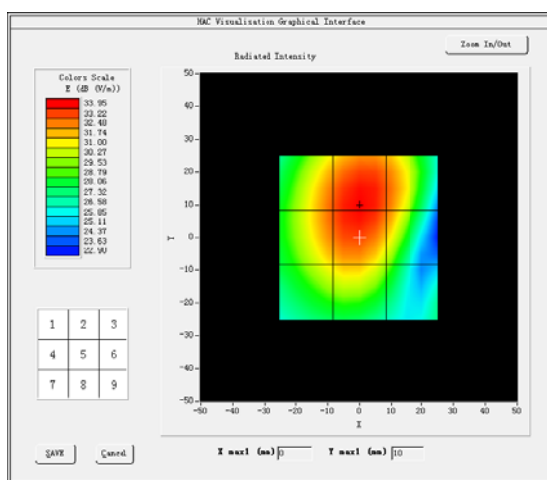
## Test Results (WCDMA1900, E, Middle Channel)

Date of measurement: 08/12/2015

Mobile Phone IMEI number: --

### A. Experimental conditions.

|                     |            |
|---------------------|------------|
| Grid size (mm x mm) | 50.0, 50.0 |
| Step (mm)           | 5          |
| Band                | WCDMA1900  |
| Channel             | Middle     |
| Signal              | WCDMA      |
| SURFACE HAC         |            |



Maximum value of total field = 33.94 dB (V/m)

Hearing Aid Near-Field Category: M3

|                      |                      |               |
|----------------------|----------------------|---------------|
| <b>Grid 1: 33.04</b> | <b>Grid 2: 33.96</b> | Grid 3: 32.57 |
| <b>Grid 4: 33.06</b> | <b>Grid 5: 33.94</b> | Grid 6: 32.29 |
| Grid 7: 31.44        | Grid 8: 31.91        | Grid 9: 29.23 |

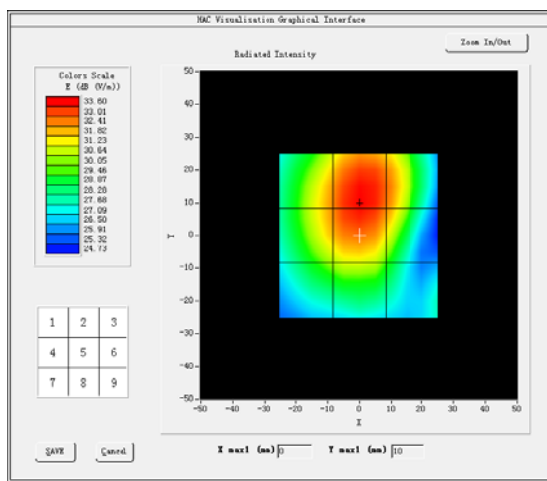
## Test Results (WCDMA1900, E, High Channel)

Date of measurement: 08/12/2015

Mobile Phone IMEI number: --

### A. Experimental conditions.

|                     |            |
|---------------------|------------|
| Grid size (mm x mm) | 50.0, 50.0 |
| Step (mm)           | 5          |
| Band                | WCDMA1900  |
| Channel             | High       |
| Signal              | WCDMA      |
| SURFACE HAC         |            |



Maximum value of total field = 33.56 dB (V/m)

Hearing Aid Near-Field Category: M3

|                      |                      |               |
|----------------------|----------------------|---------------|
| <b>Grid 1: 32.44</b> | <b>Grid 2: 33.63</b> | Grid 3: 32.33 |
| <b>Grid 4: 32.44</b> | <b>Grid 5: 33.56</b> | Grid 6: 32.04 |
| Grid 7: 30.50        | Grid 8: 30.99        | Grid 9: 29.16 |

## 14. ANNEX E CALIBRATION REPORTS



### COMOHAC E-Field Probe Calibration Report

Ref: ACR.125.2.15.SATU.A

**CCIC SOUTHERN ELECTRONIC PRODUCT  
TESTING (SHENZHEN) CO., LTD**  
ELECTRONIC TESTING BUILDING, SHAHE ROAD, XILI  
TOWN  
SHENZHEN, P.R. CHINA (POST CODE:518055)  
**MVG COMOHAC E-FIELD PROBE**  
SERIAL NO.: SN 02/12 EPH34

Calibrated at MVG US  
2105 Barrett Park Dr. - Kennesaw, GA 30144



05/05/15

#### *Summary:*

This document presents the method and results from an accredited COMOHAC E-Field Probe calibration performed in MVG USA using the CALIBAIR test bench, for use with a MVG COMOHAC system only. All calibration results are traceable to national metrology institutions.



## COMOHAC E-FIELD PROBE CALIBRATION REPORT

Ref: ACR.125.2.15.SATU.A

|                      | <i>Name</i>   | <i>Function</i> | <i>Date</i> | <i>Signature</i>     |
|----------------------|---------------|-----------------|-------------|----------------------|
| <i>Prepared by :</i> | Jérôme LUC    | Product Manager | 5/5/2015    | <i>JS</i>            |
| <i>Checked by :</i>  | Jérôme LUC    | Product Manager | 5/5/2015    | <i>JS</i>            |
| <i>Approved by :</i> | Kim RUTKOWSKI | Quality Manager | 5/5/2015    | <i>Kim Rutkowski</i> |

|                       | <i>Customer Name</i>                                                        |
|-----------------------|-----------------------------------------------------------------------------|
| <i>Distribution :</i> | CCIC SOUTHERN<br>ELECTRONIC<br>PRODUCT<br>TESTING<br>(SHENZHEN) Co.,<br>Ltd |

| <i>Issue</i> | <i>Date</i> | <i>Modifications</i> |
|--------------|-------------|----------------------|
| A            | 5/5/2015    | Initial release      |
|              |             |                      |
|              |             |                      |
|              |             |                      |

Page: 2/8

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## COMOHAC E-FIELD PROBE CALIBRATION REPORT

Ref: ACR.125.2.15.SATU.A

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## COMOHAC E-FIELD PROBE CALIBRATION REPORT

Ref: ACR.125.2.15.SATU.A

## 1 DEVICE UNDER TEST

| Device Under Test                        |                                                                         |
|------------------------------------------|-------------------------------------------------------------------------|
| Device Type                              | COMOHAC E FIELD PROBE                                                   |
| Manufacturer                             | MVG                                                                     |
| Model                                    | SCE                                                                     |
| Serial Number                            | SN 02/12 EPII34                                                         |
| Product Condition (new / used)           | Used                                                                    |
| Frequency Range of Probe                 | 0.7GHz-2.5GHz                                                           |
| Resistance of Three Dipoles at Connector | Dipole 1: R1=1.200 MΩ<br>Dipole 2: R2=1.192 MΩ<br>Dipole 3: R3=0.994 MΩ |

A yearly calibration interval is recommended.

## 2 PRODUCT DESCRIPTION

### 2.1 GENERAL INFORMATION

MVG's COMOHAC E field Probes are built in accordance to the ANSI C63.19 and IEEE 1309 standards.



Figure 1 – MVG COMOHAC E field Probe

|                                            |        |
|--------------------------------------------|--------|
| Probe Length                               | 330 mm |
| Length of Individual Dipoles               | 3.3 mm |
| Maximum external diameter                  | 8 mm   |
| Probe Tip External Diameter                | 5 mm   |
| Distance between dipoles / probe extremity | 3 mm   |

## 3 MEASUREMENT METHOD

All methods used to perform the measurements and calibrations comply with the ANSI C63.19 and IEEE 1309 standards.

### 3.1 LINEARITY

The linearity was determined using a standard dipole with the probe positioned 10 mm above the dipole. The input power of the dipole was adjusted from -15 to 36 dBm using a 1dB step (to cover the range 2V/m to 1000A/m).

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## COMOHAC E-FIELD PROBE CALIBRATION REPORT

Ref: ACR.125.2.15.SATU.A

### 3.2 SENSITIVITY

The sensitivity factors of the three dipoles were determined using the waveguide method outlined in the fore mentioned standards.

### 3.3 ISOTROPY

The axial isotropy was evaluated by exposing the probe to a reference wave from a standard dipole. The probe was rotated along its main axis from 0 - 360 degrees in 15 degree steps.

### 3.4 PROBE MODULATION RESPONSE

The modulation factor was determined by illuminating the probe with a reference wave from a standard dipole 10 mm away, applying first a CW signal and then a modulated signal (both at same power level). The modulation factor is the ratio, in linear units, of the CW to modulated signal reading.

## 4 MEASUREMENT UNCERTAINTY

The guidelines outlined in the IEEE 1528 and IEC/CEI 62209 standards were followed to generate the measurement uncertainty associated with an E-field probe calibration using the waveguide technique. All uncertainties listed below represent an expanded uncertainty expressed at approximately the 95% confidence level using a coverage factor of  $k=2$ , traceable to the Internationally Accepted Guides to Measurement Uncertainty.

| Uncertainty analysis of the probe calibration in waveguide |                       |                          |            |    |                          |
|------------------------------------------------------------|-----------------------|--------------------------|------------|----|--------------------------|
| ERROR SOURCES                                              | Uncertainty value (%) | Probability Distribution | Divisor    | ci | Standard Uncertainty (%) |
| Incident or forward power                                  | 3.00%                 | Rectangular              | $\sqrt{3}$ | 1  | 1.732%                   |
| Reflected power                                            | 3.00%                 | Rectangular              | $\sqrt{3}$ | 1  | 1.732%                   |
| Field homogeneity                                          | 3.00%                 | Rectangular              | $\sqrt{3}$ | 1  | 1.732%                   |
| Field probe positioning                                    | 5.00%                 | Rectangular              | $\sqrt{3}$ | 1  | 2.887%                   |
| Field probe linearity                                      | 3.00%                 | Rectangular              | $\sqrt{3}$ | 1  | 1.732%                   |
| Combined standard uncertainty                              |                       |                          |            |    | 4.509%                   |
| Expanded uncertainty<br>95 % confidence level $k = 2$      |                       |                          |            |    | 9.0%                     |

## 5 CALIBRATION MEASUREMENT RESULTS

| Calibration Parameters |       |
|------------------------|-------|
| Lab Temperature        | 21 °C |

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## COMOHAC E-FIELD PROBE CALIBRATION REPORT

Ref: ACR.125.2.15.SATU.A

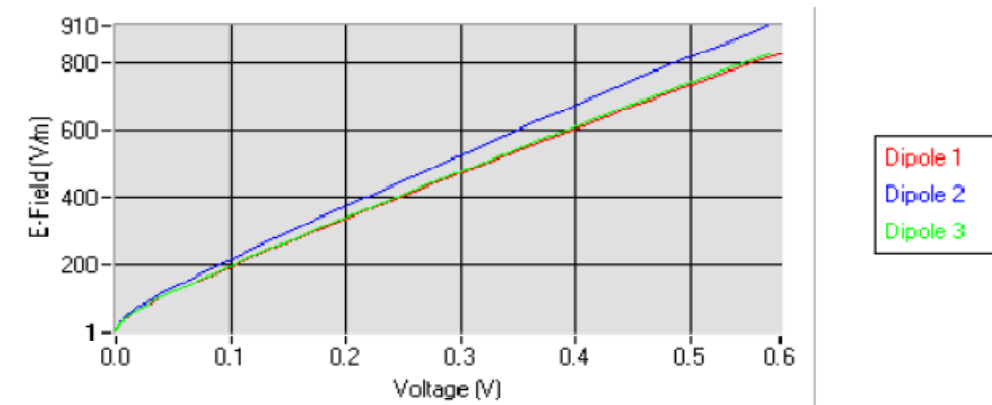
|              |      |
|--------------|------|
| Lab Humidity | 45 % |
|--------------|------|

## 5.1 SENSITIVITY IN AIR

| Normx dipole 1<br>( $\mu\text{V}/(\text{V}/\text{m})^2$ ) | Normy dipole 2<br>( $\mu\text{V}/(\text{V}/\text{m})^2$ ) | Normz dipole 3<br>( $\mu\text{V}/(\text{V}/\text{m})^2$ ) |
|-----------------------------------------------------------|-----------------------------------------------------------|-----------------------------------------------------------|
| 4.54                                                      | 4.42                                                      | 4.44                                                      |

| DCP dipole 1<br>(mV) | DCP dipole 2<br>(mV) | DCP dipole 3<br>(mV) |
|----------------------|----------------------|----------------------|
| 119                  | 120                  | 125                  |

Calibration curves



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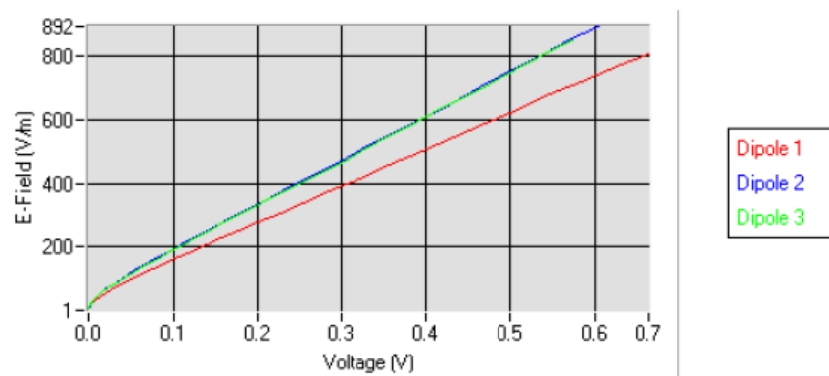


## 5.1 SENSITIVITY IN AIR

| Normx dipole 1<br>( $\mu\text{V}/(\text{V}/\text{m})^2$ ) | Normy dipole 2<br>( $\mu\text{V}/(\text{V}/\text{m})^2$ ) | Normz dipole 3<br>( $\mu\text{V}/(\text{V}/\text{m})^2$ ) |
|-----------------------------------------------------------|-----------------------------------------------------------|-----------------------------------------------------------|
| 4.84                                                      | 4.37                                                      | 4.63                                                      |

| DCP dipole 1<br>(mV) | DCP dipole 2<br>(mV) | DCP dipole 3<br>(mV) |
|----------------------|----------------------|----------------------|
| 120                  | 119                  | 122                  |

Calibration curves



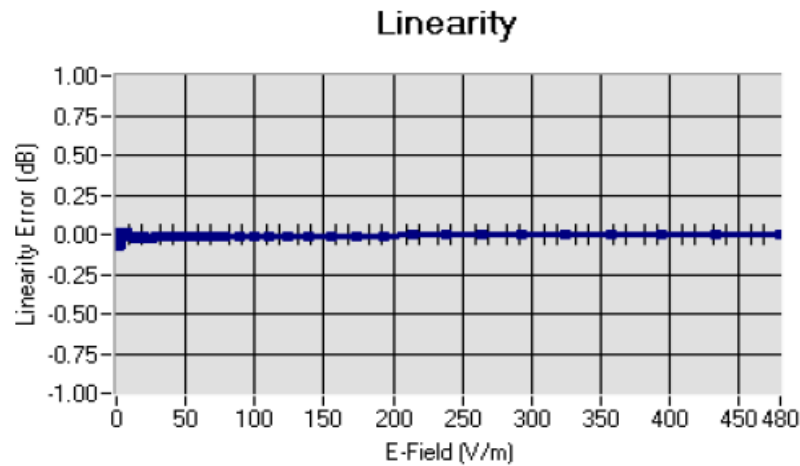
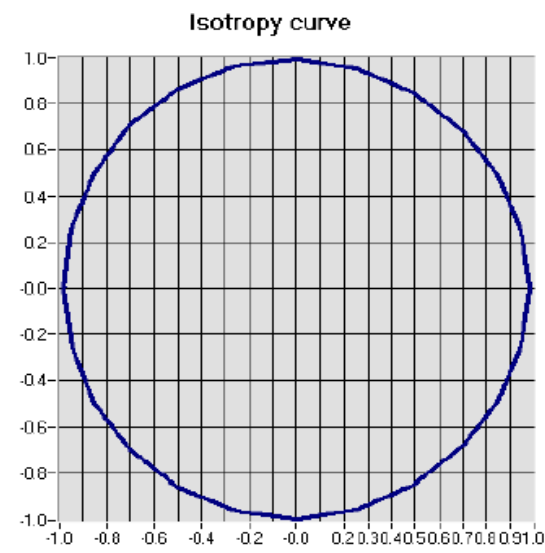
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## COMOHAC E-FIELD PROBE CALIBRATION REPORT

Ref: ACR.125.2.15.SATU.A

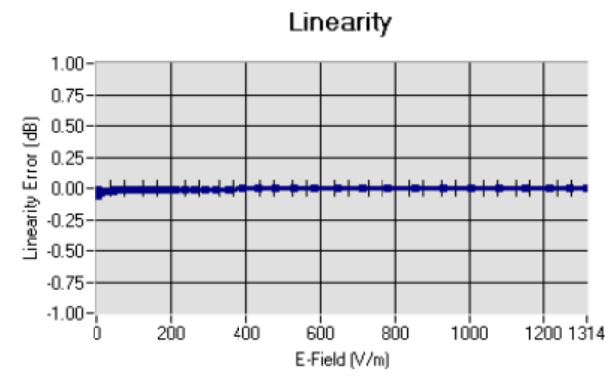
5.2 LINEARITYLinearity:  $\pm 1.60\%$  ( $\pm 0.07\text{dB}$ )5.3 ISOTROPYIsotropy:  $\pm 1.15\%$  ( $\pm 0.05\text{dB}$ )

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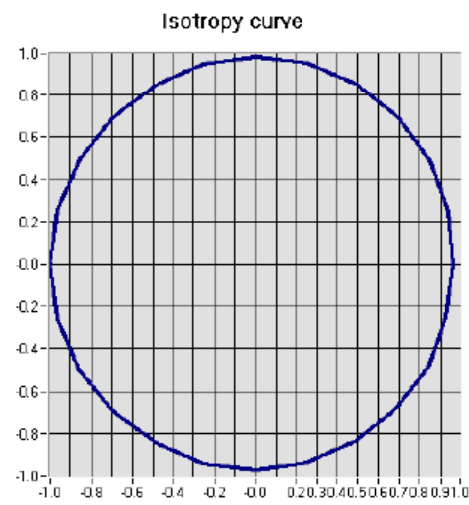


## 5.2 LINEARITY



Linearity:  $\pm 1.49\%$  ( $\pm 0.07\text{dB}$ )

## 5.3 ISOTROPY



Isotropy:  $\pm 2.02\%$  ( $\pm 0.09\text{dB}$ )

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## COMOHAC E-FIELD PROBE CALIBRATION REPORT

Ref: ACR.125.2.15.SATU.A

## 6 LIST OF EQUIPMENT

| Equipment Summary Sheet       |                      |                    |                                               |                                               |
|-------------------------------|----------------------|--------------------|-----------------------------------------------|-----------------------------------------------|
| Equipment Description         | Manufacturer / Model | Identification No. | Current Calibration Date                      | Next Calibration Date                         |
| HAC positioning ruler         | MVG                  | TABH12 SN 42/09    | Validated. No cal required.                   | Validated. No cal required.                   |
| COMOHAC Test Bench            | Version 2            | NA                 | Validated. No cal required.                   | Validated. No cal required.                   |
| Network Analyzer              | Rhode & Schwarz ZVA  | SN100132           | 02/2013                                       | 02/2016                                       |
| Reference Probe               | MVG                  | EPH28 SN 08/11     | 10/2014                                       | 10/2015                                       |
| Reference Probe               | MVG                  | HPH38 SN31/10      | 10/2014                                       | 10/2015                                       |
| Multimeter                    | Keithley 2000        | 1188656            | 12/2013                                       | 12/2016                                       |
| Signal Generator              | Agilent E4438C       | MY49070581         | 12/2013                                       | 12/2016                                       |
| Amplifier                     | Aethercomm           | SN 046             | Characterized prior to test. No cal required. | Characterized prior to test. No cal required. |
| Power Meter                   | HP E4418A            | US38261498         | 12/2013                                       | 12/2016                                       |
| Power Sensor                  | HP ECP-E26A          | US37181460         | 12/2013                                       | 12/2016                                       |
| Directional Coupler           | Narda 4216-20        | 01386              | Characterized prior to test. No cal required. | Characterized prior to test. No cal required. |
| Waveguide                     | Mega Industries      | 069Y7-158-13-712   | Validated. No cal required.                   | Validated. No cal required.                   |
| Waveguide Transition          | Mega Industries      | 069Y7-158-13-701   | Validated. No cal required.                   | Validated. No cal required.                   |
| Waveguide Termination         | Mega Industries      | 069Y7-158-13-701   | Validated. No cal required.                   | Validated. No cal required.                   |
| Temperature / Humidity Sensor | Control Company      | 11-661-9           | 8/2012                                        | 8/2015                                        |

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## HAC Reference Dipole Calibration Report

Ref : ACR.240.7.14.SATU.A

**CCIC SOUTHERN ELECTRONIC PRODUCT  
TESTING (SHENZHEN) CO., LTD**  
ELECTRONIC TESTING BUILDING, SHAHE ROAD, XILI  
TOWN  
SHENZHEN, P.R. CHINA (POST CODE:518055)  
**SATIMO COMOHAC REFERENCE DIPOLE**  
FREQUENCY: 800-950MHZ  
SERIAL NO.: SN 18/12 DHA37

**Calibrated at SATIMO US**  
2105 Barrett Park Dr. - Kennesaw, GA 30144



08/28/14

### *Summary:*

This document presents the method and results from an accredited HAC reference dipole calibration performed in SATIMO USA using the COMOHAC test bench. All calibration results are traceable to national metrology institutions.





## HAC REFERENCE DIPOLE CALIBRATION REPORT

Ref: ACR.240.7.14.SATU.A

|                      | <i>Name</i>   | <i>Function</i> | <i>Date</i> | <i>Signature</i>     |
|----------------------|---------------|-----------------|-------------|----------------------|
| <i>Prepared by :</i> | Jérôme LUC    | Product Manager | 8/29/2014   | <i>JS</i>            |
| <i>Checked by :</i>  | Jérôme LUC    | Product Manager | 8/29/2014   | <i>JS</i>            |
| <i>Approved by :</i> | Kim RUTKOWSKI | Quality Manager | 8/29/2014   | <i>Kim Rutkowski</i> |

|                       | <i>Customer Name</i>                                                        |
|-----------------------|-----------------------------------------------------------------------------|
| <i>Distribution :</i> | CCIC SOUTHERN<br>ELECTRONIC<br>PRODUCT<br>TESTING<br>(SHENZHEN) Co.,<br>Ltd |

| <i>Issue</i> | <i>Date</i> | <i>Modifications</i> |
|--------------|-------------|----------------------|
| A            | 8/29/2014   | Initial release      |
|              |             |                      |
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## 1 INTRODUCTION

This document contains a summary of the requirements set forth by the ANSI C63.19 standard for reference dipoles used for HAC measurement system validations and the measurements that were performed to verify that the product complies with the fore mentioned standards.

## 2 DEVICE UNDER TEST

| Device Under Test              |                                      |
|--------------------------------|--------------------------------------|
| Device Type                    | COMOHAC 800-950 MHz REFERENCE DIPOLE |
| Manufacturer                   | Satimo                               |
| Model                          | SIDB835                              |
| Serial Number                  | SN 18/12 DHA37                       |
| Product Condition (new / used) | Used                                 |

A yearly calibration interval is recommended.

## 3 PRODUCT DESCRIPTION

### 3.1 GENERAL INFORMATION

Satimo's COMOHAC Validation Dipoles are built in accordance to the ANSI C63.19 standard. The product is designed for use with the COMOHAC system only.



**Figure 1 – Satimo COMOHAC Validation Dipole**

## 4 MEASUREMENT METHOD

The ANSI C63.19 standard outlines the requirements for reference dipoles to be used for system validation measurements. The following measurements were performed to verify that the product complies with the fore mentioned standard.

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#### 4.1 RETURN LOSS REQUIREMENTS

The dipole used for HAC system validation measurements and checks must have a return loss of -10 dB or better. The return loss measurement shall be performed in free space.

#### 4.2 REFERENCE DIPOLE CALIBRATION

The IEEE ANSI C63-19 standard states that the dipole used for validation measurements and checks must be scanned with the E and H field probe, with the dipole 10 mm below the probe. The E and H field strength plots are compared to the simulation results obtained by SATIMO.

### 5 MEASUREMENT UNCERTAINTY

All uncertainties listed below represent an expanded uncertainty expressed at approximately the 95% confidence level using a coverage factor of  $k=2$ , traceable to the Internationally Accepted Guides to Measurement Uncertainty.

#### 5.1 RETURN LOSS

The following uncertainties apply to the return loss measurement:

| Frequency band | Expanded Uncertainty on Gain |
|----------------|------------------------------|
| 400-6000MHz    | 0.1 dB                       |

#### 5.2 VALIDATION MEASUREMENT

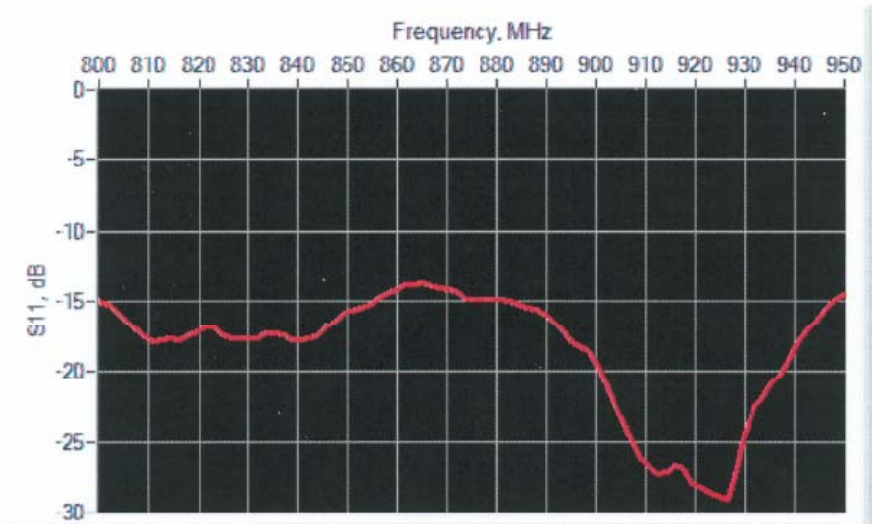
The guideline outlined in the IEEE ANSI C63.19 standard was followed to generate the measurement uncertainty for validation measurements.

| Uncertainty analysis of the probe calibration in waveguide               |                       |                          |            |                  |                          |
|--------------------------------------------------------------------------|-----------------------|--------------------------|------------|------------------|--------------------------|
| ERROR SOURCES                                                            | Uncertainty value (%) | Probability Distribution | Divisor    | Uncertainty (dB) | Standard Uncertainty (%) |
| RF reflections                                                           | 0.1                   | R                        | $\sqrt{3}$ | 0.06             |                          |
| Field probe conv. Factor                                                 | 0.4                   | R                        | $\sqrt{3}$ | 0.23             |                          |
| Field probe anisotropy                                                   | 0.25                  | R                        | $\sqrt{3}$ | 0.14             |                          |
| Positioning accuracy                                                     | 0.2                   | R                        | $\sqrt{3}$ | 0.12             |                          |
| Probe cable placement                                                    | 0.1                   | R                        | $\sqrt{3}$ | 0.06             |                          |
| System repeatability                                                     | 0.2                   | R                        | $\sqrt{3}$ | 0.12             |                          |
| EUT repeatability                                                        | 0.4                   | N                        | 1          | 0.40             |                          |
| <b>Combined standard uncertainty</b>                                     |                       |                          |            | 0.52             |                          |
| <b>Expanded uncertainty<br/>95 % confidence level <math>k = 2</math></b> |                       |                          |            | 1.00             | 13.0                     |



## 6 CALIBRATION MEASUREMENT RESULTS

### 6.1 RETURN LOSS



| Frequency (MHz) | Worst Case Return Loss (dB) | Requirement (dB) |
|-----------------|-----------------------------|------------------|
| 800-950 MHz     | -13.78                      | -10              |

### 6.2 VALIDATION MEASUREMENT

The IEEE ANSI C63.19 standard states that the system validation measurements must be performed using a reference dipole meeting the fore mentioned return loss requirements. The system validations measurement results are then compared to SATIMO's simulated results.

#### Measurement Condition

|                                           |                 |
|-------------------------------------------|-----------------|
| Software Version                          | OpenHAC V2      |
| HAC positioning ruler                     | SN 42/09 TABH12 |
| E-Field probe                             | SN 08/11 EPH28  |
| H-Field probe                             | SN 31/10 HPH38  |
| Distance between dipole and sensor center | 10 mm           |
| E-field scan size                         | X=150mm/Y=20mm  |
| H-field scan size                         | X=40mm/Y=20mm   |
| Scan resolution                           | dx=5mm/dy=5mm   |
| Frequency                                 | 835 MHz         |
| Input power                               | 20 dBm          |
| Lab Temperature                           | 21°C            |
| Lab Humidity                              | 45%             |

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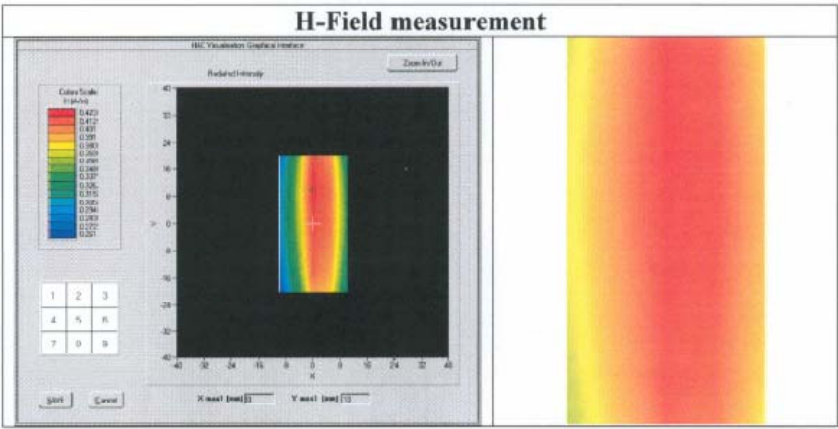
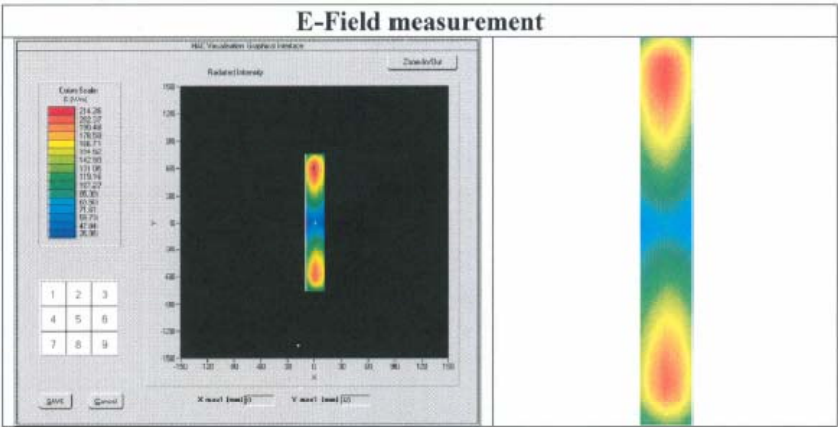


IAC REFERENCE DIPOLE CALIBRATION REPORT

Ref: ACR 240.7.14.SAT.UA

Measurement Result

|               | Measured | Internal Requirement |
|---------------|----------|----------------------|
| E field (V/m) | 214.26   | 220.4                |
| H field (A/m) | 0.42     | 0.445                |





## 7 LIST OF EQUIPMENT

| Equipment Summary Sheet         |                      |                    |                                               |                                               |
|---------------------------------|----------------------|--------------------|-----------------------------------------------|-----------------------------------------------|
| Equipment Description           | Manufacturer / Model | Identification No. | Current Calibration Date                      | Next Calibration Date                         |
| HAC positioning ruler           | Satimo               | TABH12 SN 42/09    | Validated. No cal required.                   | Validated. No cal required.                   |
| COMOHAC Test Bench              | Version 2            | NA                 | Validated. No cal required.                   | Validated. No cal required.                   |
| Network Analyzer                | Rhode & Schwarz ZVA  | SN100132           | 02/2013                                       | 02/2016                                       |
| Reference Probe                 | Satimo               | EPH28 SN 08/11     | 10/2013                                       | 10/2014                                       |
| Reference Probe                 | Satimo               | HPH38 SN31/10      | 10/2013                                       | 10/2014                                       |
| Multimeter                      | Keithley 2000        | 1188656            | 12/2013                                       | 12/2016                                       |
| Signal Generator                | Agilent E4438C       | MY49070581         | 12/2013                                       | 12/2016                                       |
| Amplifier                       | Aethercomm           | SN 046             | Characterized prior to test. No cal required. | Characterized prior to test. No cal required. |
| Power Meter                     | HP E4418A            | US38261498         | 12/2013                                       | 12/2016                                       |
| Power Sensor                    | HP ECP-E26A          | US37181460         | 12/2013                                       | 12/2016                                       |
| Directional Coupler             | Narda 4216-20        | 01386              | Characterized prior to test. No cal required. | Characterized prior to test. No cal required. |
| Temperature and Humidity Sensor | Control Company      | 11-661-9           | 8/2012                                        | 8/2015                                        |



## HAC Reference Dipole Calibration Report

Ref : ACR.240.8.14.SATU.A

**CCIC SOUTHERN ELECTRONIC PRODUCT  
TESTING (SHENZHEN) CO., LTD**  
ELECTRONIC TESTING BUILDING, SHAHE ROAD, XILI  
TOWN  
SHENZHEN, P.R. CHINA (POST CODE:518055)  
**SATIMO COMOHAC REFERENCE DIPOLE**  
FREQUENCY: 1700-2000MHZ  
SERIAL NO.: SN 18/12 DHB42

**Calibrated at SATIMO US**  
2105 Barrett Park Dr. - Kennesaw, GA 30144



08/28/14

### *Summary:*

This document presents the method and results from an accredited HAC reference dipole calibration performed in SATIMO USA using the COMOHAC test bench. All calibration results are traceable to national metrology institutions.





## HAC REFERENCE DIPOLE CALIBRATION REPORT

Ref: ACR.240.8.14.SATU.A

|                      | <i>Name</i>   | <i>Function</i> | <i>Date</i> | <i>Signature</i>     |
|----------------------|---------------|-----------------|-------------|----------------------|
| <i>Prepared by :</i> | Jérôme LUC    | Product Manager | 8/29/2014   | <i>JS</i>            |
| <i>Checked by :</i>  | Jérôme LUC    | Product Manager | 8/29/2014   | <i>JS</i>            |
| <i>Approved by :</i> | Kim RUTKOWSKI | Quality Manager | 8/29/2014   | <i>Kim Rutkowski</i> |

|                       | <i>Customer Name</i>                                                        |
|-----------------------|-----------------------------------------------------------------------------|
| <i>Distribution :</i> | CCIC SOUTHERN<br>ELECTRONIC<br>PRODUCT<br>TESTING<br>(SHENZHEN) Co.,<br>Ltd |

| <i>Issue</i> | <i>Date</i> | <i>Modifications</i> |
|--------------|-------------|----------------------|
| A            | 8/29/2014   | Initial release      |
|              |             |                      |
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## 1 INTRODUCTION

This document contains a summary of the requirements set forth by the ANSI C63.19 standard for reference dipoles used for HAC measurement system validations and the measurements that were performed to verify that the product complies with the fore mentioned standards.

## 2 DEVICE UNDER TEST

| Device Under Test              |                                        |
|--------------------------------|----------------------------------------|
| Device Type                    | COMOHAC 1700-2000 MHz REFERENCE DIPOLE |
| Manufacturer                   | Satimo                                 |
| Model                          | SIDB1900                               |
| Serial Number                  | SN 18/12 DHB42                         |
| Product Condition (new / used) | Used                                   |

A yearly calibration interval is recommended.

## 3 PRODUCT DESCRIPTION

### 3.1 GENERAL INFORMATION

Satimo's COMOHAC Validation Dipoles are built in accordance to the ANSI C63.19 standard. The product is designed for use with the COMOHAC system only.



Figure 1 – Satimo COMOHAC Validation Dipole

## 4 MEASUREMENT METHOD

The ANSI C63.19 standard outlines the requirements for reference dipoles to be used for system validation measurements. The following measurements were performed to verify that the product complies with the fore mentioned standard.

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#### 4.1 RETURN LOSS REQUIREMENTS

The dipole used for HAC system validation measurements and checks must have a return loss of -10 dB or better. The return loss measurement shall be performed in free space.

#### 4.2 REFERENCE DIPOLE CALIBRATION

The IEEE ANSI C63-19 standard states that the dipole used for validation measurements and checks must be scanned with the E and H field probe, with the dipole 10 mm below the probe. The E and H field strength plots are compared to the simulation results obtained by SATIMO.

### 5 MEASUREMENT UNCERTAINTY

All uncertainties listed below represent an expanded uncertainty expressed at approximately the 95% confidence level using a coverage factor of  $k=2$ , traceable to the Internationally Accepted Guides to Measurement Uncertainty.

#### 5.1 RETURN LOSS

The following uncertainties apply to the return loss measurement:

| Frequency band | Expanded Uncertainty on Gain |
|----------------|------------------------------|
| 400-6000MHz    | 0.1 dB                       |

#### 5.2 VALIDATION MEASUREMENT

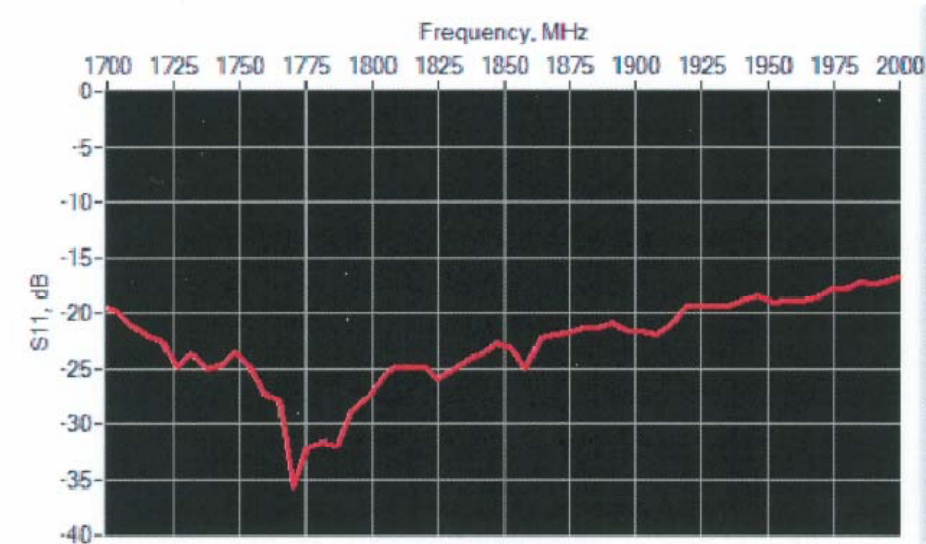
The guideline outlined in the IEEE ANSI C63.19 standard was followed to generate the measurement uncertainty for validation measurements.

| Uncertainty analysis of the probe calibration in waveguide               |                       |                          |            |                  |                          |
|--------------------------------------------------------------------------|-----------------------|--------------------------|------------|------------------|--------------------------|
| ERROR SOURCES                                                            | Uncertainty value (%) | Probability Distribution | Divisor    | Uncertainty (dB) | Standard Uncertainty (%) |
| RF reflections                                                           | 0.1                   | R                        | $\sqrt{3}$ | 0.06             |                          |
| Field probe conv. Factor                                                 | 0.4                   | R                        | $\sqrt{3}$ | 0.23             |                          |
| Field probe anisotropy                                                   | 0.25                  | R                        | $\sqrt{3}$ | 0.14             |                          |
| Positioning accuracy                                                     | 0.2                   | R                        | $\sqrt{3}$ | 0.12             |                          |
| Probe cable placement                                                    | 0.1                   | R                        | $\sqrt{3}$ | 0.06             |                          |
| System repeatability                                                     | 0.2                   | R                        | $\sqrt{3}$ | 0.12             |                          |
| EUT repeatability                                                        | 0.4                   | N                        | 1          | 0.40             |                          |
| <b>Combined standard uncertainty</b>                                     |                       |                          |            | 0.52             |                          |
| <b>Expanded uncertainty<br/>95 % confidence level <math>k = 2</math></b> |                       |                          |            | 1.00             | 13.0                     |



## 6 CALIBRATION MEASUREMENT RESULTS

### 6.1 RETURN LOSS



| Frequency (MHz) | Worst Case Return Loss (dB) | Requirement (dB) |
|-----------------|-----------------------------|------------------|
| 1700-2000 MHz   | -17.29                      | -10              |

### 6.2 VALIDATION MEASUREMENT

The IEEE ANSI C63.19 standard states that the system validation measurements must be performed using a reference dipole meeting the fore mentioned return loss requirements. The system validations measurement results are then compared to SATIMO's simulated results.

#### Measurement Condition

|                                           |                 |
|-------------------------------------------|-----------------|
| Software Version                          | OpenHAC V2      |
| HAC positioning ruler                     | SN 42/09 TABH12 |
| E-Field probe                             | SN 08/11 EPH28  |
| H-Field probe                             | SN 31/10 HPH38  |
| Distance between dipole and sensor center | 10 mm           |
| E-field scan size                         | X=150mm/Y=20mm  |
| H-field scan size                         | X=40mm/Y=20mm   |
| Scan resolution                           | dx=5mm/dy=5mm   |
| Frequency                                 | 1900 MHz        |
| Input power                               | 20 dBm          |
| Lab Temperature                           | 21°C            |
| Lab Humidity                              | 45%             |



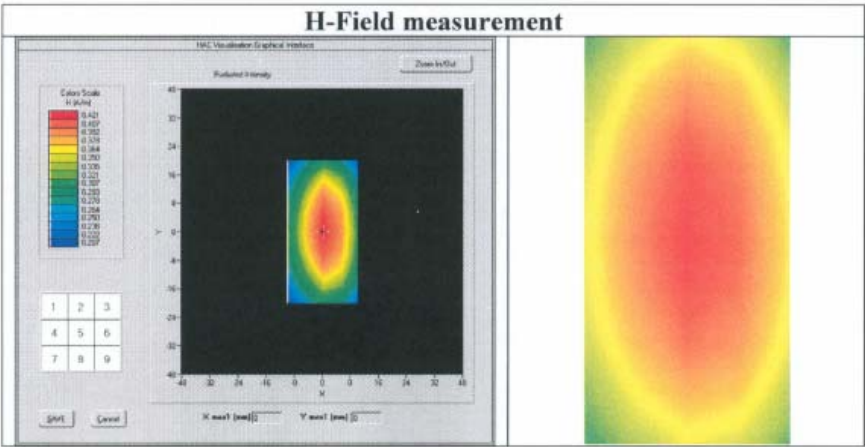
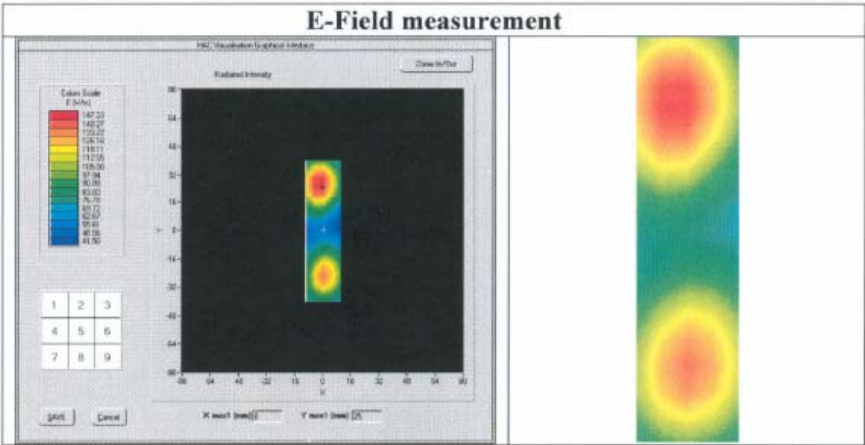


HAC REFERENCE DIPOLE CALIBRATION REPORT

Ref: ACR.240.8.14.SATU.A

Measurement Result

|               | Measured | Internal Requirement |
|---------------|----------|----------------------|
| E field (V/m) | 147.33   | 153.4                |
| H field (A/m) | 0.42     | 0.445                |





## 7 LIST OF EQUIPMENT

| Equipment Summary Sheet         |                      |                    |                                               |                                               |
|---------------------------------|----------------------|--------------------|-----------------------------------------------|-----------------------------------------------|
| Equipment Description           | Manufacturer / Model | Identification No. | Current Calibration Date                      | Next Calibration Date                         |
| HAC positioning ruler           | Satimo               | TABH12 SN 42/09    | Validated. No cal required.                   | Validated. No cal required.                   |
| COMOHAC Test Bench              | Version 2            | NA                 | Validated. No cal required.                   | Validated. No cal required.                   |
| Network Analyzer                | Rhode & Schwarz ZVA  | SN100132           | 02/2013                                       | 02/2016                                       |
| Reference Probe                 | Satimo               | EPH28 SN 08/11     | 10/2013                                       | 10/2014                                       |
| Reference Probe                 | Satimo               | HPH38 SN31/10      | 10/2013                                       | 10/2014                                       |
| Multimeter                      | Keithley 2000        | 1188656            | 12/2013                                       | 12/2016                                       |
| Signal Generator                | Agilent E4438C       | MY49070581         | 12/2013                                       | 12/2016                                       |
| Amplifier                       | Aethercomm           | SN 046             | Characterized prior to test. No cal required. | Characterized prior to test. No cal required. |
| Power Meter                     | HP E4418A            | US38261498         | 12/2013                                       | 12/2016                                       |
| Power Sensor                    | HP ECP-E26A          | US37181460         | 12/2013                                       | 12/2016                                       |
| Directional Coupler             | Narda 4216-20        | 01386              | Characterized prior to test. No cal required. | Characterized prior to test. No cal required. |
| Temperature and Humidity Sensor | Control Company      | 11-661-9           | 8/2012                                        | 8/2015                                        |

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————End of the Report————