# SAR TEST REPORT

| | |
|---|---|
| Report No.: | BCTC2205933622-3E |
| Applicant: | FIREWALLA INC |
| Product Name: | Firewalla Wi-Fi SD |
| Model/Type Ref.: | Firewalla Wi-Fi SD |
| Tested Date: | 2022-05-26 to 2022-05-27 |
| Issued Date: | 2022-06-24 |

**Shenzhen BCTC Testing Co., Ltd.**

# FCC ID: 2A2QB-WIFISD

| | |
|---|---|
| Product Name: | Firewalla Wi-Fi SD |
| Trademark: | FIREWALLA |
| Model/Type Ref.: | Firewalla Wi-Fi SD |
| Applicant: | FIREWALLA INC |
| Address: | 19630 Allendale Ave #2217 Saratoga, CA 95070 United States |
| Manufacturer: | FIREWALLA INC |
| Address: | 19630 Allendale Ave #2217 Saratoga, CA 95070 United States |
| Factory: | N/A |
| Address: | N/A |
| Prepared By: | Shenzhen BCTC Testing Co., Ltd. |
| Address: | 1-2/F., Building B, Pengzhou Industrial Park, No.158, Fuyuan 1st Road, Tangwei, Fuhai Subdistrict, Bao'an District, Shenzhen, Guangdong, China |
| Sample Received Date: | 2022-05-26 |
| Sample tested Date: | 2022-05-26 to 2022-05-27 |
| Issue Date: | 2022-06-24 |
| Test Standards: | IEEE Std C95.1-2019/IEEE Std 1528™-2013/FCC Part 2.1093 |
| Test Results: | PASS |
| Remark: | This is SAR test report |

| Tested by: | Approved by: |
|---|---|
| Jack Li | |
| Jack Li/Project Handler | Zero Zhou/Reviewer |

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(Note: N/A Means Not Applicable)

## 1. Version

| Report No. | Issue Date | Description | Approved |
|---|---|---|---|
| BCTC2205933622-3E | 2022-06-24 | Original | Valid |
| | | | |

## 2. Test Standards

IEEE Std C95.1-2019: IEEE Standard for Safety Levels with Respect to Human Exposure to Electric, Magnetic, and Electromagnetic Fields, 0 Hz to 300 GHz.It specifies the maximum exposure limit of 1.6 W/kg as averaged over any 1 gram of tissue for portable devices being used within 20 cm of the user in the uncontrolled environment.
IEEE Std 1528™-2013: IEEE Recommended Practice for Determining the Peak Spatial-Average Specific Absorption Rate (SAR) in the Human Head from Wireless Communications Devices: Measurement Techniques.
FCC Part 2.1093 Radiofrequency Radiation Exposure Evaluation:Portable Devices
KDB447498 D01 General RF Exposure Guidance v06 : Mobile and Portable Device RF Exposure Procedures and Equipment Authorization Policies
KDB447498 D02 SAR Procedures for Dongle Xmtr v02r01: SAR Measurement Procedures For USB Dongle Transmitters.
KDB865664 D01 SAR Measurement 100 MHz to 6 GHz v01r04 : SAR Measurement Requirements for 100 MHz to 6 GHz
KDB865664 D02 RF Exposure Reporting v01r02: RF Exposure Compliance Reporting and Documentation Considerations
KDB 248227 D01 802.11 Wi-Fi SAR v02r02: SAR GUIDANCE FOR IEEE 802.11 (Wi-Fi) TRANSMITTERS

## 3. Test Summary

The maximum results of Specific Absorption Rate (SAR) have found during testing are as follows:

| Frequency Band | Head SAR | Body (0mm Gap) | $SAR_{1g}$ Limit (W/kg) |
|---|---|---|---|
| | Report $SAR_{1g}$ (W/kg) | Report $SAR_{1g}$ (W/kg) | |
| WIFI2.4G | NA | **1.381** | 1.6 |
| WIFI5.8G | NA | 0.134 | 1.6 |

The device is in compliance with Specific Absorption Rate (SAR) for general population/uncontrolled exposure limits (1.6 W/kg) specified in FCC 47 CFR part 2 (2.1093) and ANSI/IEEE C95.1-2019, and had been tested in accordance with the measurement methods and procedure specified in IEEE 1528-2013.

## 4. SAR Limits

FCC Limit (1g Tissue)

| EXPOSURE LIMITS | SAR (W/kg) | |
|---|---|---|
| | (General Population / Uncontrolled Exposure Environment) | (Occupational / Controlled Exposure Environment) |
| Spatial Average(averaged over the whole body) | 0.08 | 0.4 |
| Spatial Peak(averaged over any 1 g of tissue) | 1.6 | 8.0 |
| Spatial Peak(hands/wrists/ feet/anklesaveraged over 10 g) | 4.0 | 20.0 |

Population/Uncontrolled Environments are defined as locations where there is the exposure of individual who have no knowledge or control of their exposure.
Occupational/Controlled Environments are defined as locations where there is exposure that may be incurred by people who are aware of the potential for exposure (i.e. as a result of employment or occupation).

## 5. Measurement Uncertainty

Not required as SAR measurement uncertainty analysis is required in SAR reports only when the highestmeasured SAR in a frequency band is ≥ 1.5 W/kg for 1-g SAR accoridng to KDB865664D01.

| Uncertainty Component | Tol (+- %) | Prob. Dist. | Div. | Ci (1g) | Ci (10g) | 1g Ui (+-%) | 10g Ui (+-%) | Veff |
|---|---|---|---|---|---|---|---|---|
| **Measurement System** | | | | | | | | |
| Probe calibration | 5.8 | N | 1 | 1 | 1 | 5.80 | 5.80 | ∞ |
| Axial Isotropy | 3.5 | R | √3 | $\sqrt{1-C_p}$ | $\sqrt{1-C_p}$ | 1.43 | 1.43 | ∞ |
| Hemispherical Isotropy | 5.9 | R | √3 | $\sqrt{C_p}$ | $\sqrt{C_p}$ | 2.41 | 2.41 | ∞ |
| Boundary effect | 1.0 | R | √3 | 1 | 1 | 0.58 | 0.58 | ∞ |
| Linearity | 4.7 | R | √3 | 1 | 1 | 2.71 | 2.71 | ∞ |
| System detection limits | 1.0 | R | √3 | 1 | 1 | 0.58 | 0.58 | ∞ |
| Readout Electronics | 0.5 | N | 1 | 1 | 1 | 0.50 | 0.50 | ∞ |
| Response Time | 0.0 | R | √3 | 1 | 1 | 0.00 | 0.00 | ∞ |
| Integration Time | 1.4 | R | √3 | 1 | 1 | 0.81 | 0.81 | ∞ |
| RF ambient Conditions - Noise | 3.0 | R | √3 | 1 | 1 | 1.73 | 1.73 | ∞ |
| RF ambient Conditions - Reflections | 3.0 | R | √3 | 1 | 1 | 1.73 | 1.73 | ∞ |
| Probe positioner Mechanical Tolerance | 1.4 | R | √3 | 1 | 1 | 0.81 | 0.81 | ∞ |
| Probe positioning with respect to Phantom Shell | 1.4 | R | √3 | 1 | 1 | 0.81 | 0.81 | ∞ |
| Max. SAR Evaluation | 1.0 | R | √3 | 1 | 1 | 0.6 | 0.6 | ∞ |
| Test sample Related | | | | | | | | |
| Device positioning | 2.6 | N | 1 | 1 | 1 | 2.6 | 2.6 | 11 |
| Device holder | 3.0 | N | 1 | 1 | 1 | 3.0 | 3.0 | 7 |
| Drift of output power | 5.0 | N | √3 | 1 | 1 | 2.89 | 2.89 | ∞ |
| Phantom and Tissue Parameters | | | | | | | | |
| Phantom uncertainty | 4.00 | R | √3 | 1 | 1 | 2.31 | 2.31 | ∞ |
| Liquid conductivity (target) | 2.50 | N | 1 | 0.78 | 0.71 | 1.95 | 1.78 | 5 |
| Liquid conductivity (meas) | 4.00 | N | 1 | 0.23 | 0.26 | 0.92 | 1.04 | 5 |
| Liquid Permittivity (target) | 2.50 | N | 1 | 0.78 | 0.71 | 1.95 | 1.78 | ∞ |
| Liquid Permittivity (meas) | 5.00 | N | 1 | 0.23 | 0.26 | 1.15 | 1.30 | ∞ |
| Combined Standard | | RSS | $U_c = \sqrt{\sum_{i=1}^{n} C_i^2 U_i^2}$ | | | 10.63 % | 10.54% | |
| Expanded Uncertainty (95% Confidence interval) | U = k UC , k=2 | | | | | 21.26 % | 21.08% | |

# 6. Product Information And Test Setup

## 6.1 Product Information

| | |
|---|---|
| Model/Type Ref.: | Firewalla Wi-Fi SD |
| Model differences: | N/A |
| Hardware Version: | N/A |
| Software Version: | N/A |
| Ratings: | DC 5V From PC |
| Adapter: | N/A |

WIFI 2.4GHz

| | | |
|---|---|---|
| Operation Frequency: | WiFi (2.4GHz): | 802.11b/g/n20MHz:2412~2462 MHz<br>802.11n40MHz:2422~2452 MHz |
| Type of Modulation: | WiFi: DSSS, OFDM | |
| Bit Rate of Transmitter | 802.11b:11/5.5/2/1 Mbps<br>802.11g:54/48/36/24/18/12/9/6Mbps<br>802.11n Up to 150Mbps | |
| Number Of Channel | 802.11b/g/n20MHz:11 CH<br>802.11n40MHz: 7 CH | |
| Antenna installation: | External antenna | |
| Antenna Gain: | 5 dBi | |

WIFI 5.8GHz

| | |
|---|---|
| Operation Frequency: | 5745-5825 MHz for 802.11a/n/ac(HT20);<br>5755-5795 MHz for 802.11a/n/ac(HT40);<br>5775MHz for 802.11 ac80 |
| Type of Modulation: | OFDM with BPSK/QPSK/16QAM/64QAM/256QAM for 802.11a/n/ac; |
| IEEE 802.11 WLAN Mode Supported | 802.11a/n/ac(20MHz channel bandwidth)<br>802.11n/ac(40MHz channel bandwidth)<br>802.11ac(80MHz channel bandwidth) |
| Data Rate | 802.11a: 6,9,12,18,24,36,48,54Mbps;<br>802.11n(HT20/HT40):MCS0-MCS15;<br>802.11ac(VHT20): NSS1, MCS0-MCS8<br>802.11ac(VHT40/VHT80):NSS1, MCS0-MCS |
| Number Of Channel | 5 channels for 802.11a/n20 in the 5745-5825MHz band ;<br>2 channels for 802.11 n40 in the 5755-5795MHz band ;<br>1 channels for 802.11 ac80 in the 5775MHz band |
| Antenna installation: | External antenna |
| Antenna Gain: | 5 dBi |

## 6.2 Test Setup Configuration

See test photographs attached in EUT TEST SETUP PHOTOGRAPHS for the actual connections between Product and support equipment.

## 6.3 Support Equipment

Cable of Product

| No. | Cable Type | Quantity | Provider | Length (m) | Shielded | Note |
|---|---|---|---|---|---|---|
| 1 | -- | -- | Applicant | --- | Yes/No | -- |
| 2 | -- | -- | BCTC | -- | Yes/No | -- |

| No. | Device Type | Brand | Model | Series No. | Note |
|---|---|---|---|---|---|
| 1. | --- | --- | --- | --- | --- |
| 2. | -- | -- | -- | -- | -- |

Notes:
1. All the equipment/cables were placed in the worst-case configuration to maximize the emission during the test.
2. Grounding was established in accordance with the manufacturer's requirements and conditions for the intended use.

## 6.4 Test Environment

1. Normal Test Conditions:

| | |
|---|---|
| Humidity(%): | 40-65 |
| Atmospheric Pressure(kPa): | 95-105 |
| Temperature(℃): | 18-25 |

2.Extreme Test Conditions:
N/A

# 7. Test Facility And Test Instrument Used

## 7.1 Test Facility

All measurement facilities used to collect the measurement data are located at Shenzhen BCTC Testing Co., Ltd. Address: 1-2/F., Building B, Pengzhou Industrial Park, No.158, Fuyuan 1st Road, Tangwei, Fuhai Subdistrict, Bao'an District, Shenzhen, Guangdong, China. The site and apparatus are constructed in conformance with the requirements of ANSI C63.4 and CISPR 16-1-1 other equivalent standards.

## 7.2 Test Instrument Used

| Equipment | Manufacturer | Model# | Serial# | Last Cal. | Next Cal. |
|---|---|---|---|---|---|
| PC | DELL | \ | \ | N/A | N/A |
| SAR Measurement system | SATIMO | \ | \ | N/A | N/A |
| Signal Generator | Agilent | 83712A | \ | May 28, 2021 | May 27, 2022 |
| Multimeter | Keithley | 1160271 | \ | Nov. 12, 2021 | Nov 11, 2022 |
| S-parameter Network Analyzer | R&S | ZVB 8 | 101353 | Dec. 09, 2021 | Dec. 08, 2022 |
| Wideband Radio Communication Tester | R&S | CMW500 | \ | Nov. 12, 2021 | Nov 11, 2022 |
| E SAR PROBE 6GHz | MVG | SSE2 | SN EPGO362 | Nov. 20, 2021 | Nov. 19, 2022 |
| DIPOLE 2450 | SATIMO | SID 2450 | SN 47/21 DIP 2G450-627 | Nov. 20, 2021 | Nov. 19, 2024 |
| DIPOLE 5000 | SATIMO | SID5000 | SN 47/21 DIP 5G000-629 | Nov. 20, 2021 | Nov. 19, 2024 |
| COMOSAR OPENCoaxial Probe | SATIMO | \ | \ | Nov. 20, 2021 | Nov. 19, 2022 |
| SAR Locator | SATIMO | \ | \ | Nov. 20, 2021 | Nov. 19, 2022 |
| Communication Antenna | SATIMO | \ | \ | Nov. 20, 2021 | Nov. 19, 2022 |
| FEATURE PHONEPOSITIONING DEVICE | SATIMO | \ | \ | N/A | N/A |
| DUMMY PROBE | SATIMO | \ | \ | N/A | N/A |
| SAM Phantom | MVG | \ | SN 13/09 SAM68 | N/A | N/A |
| Liquid measurement Kit | HP | 85033D | 3423A08186 | Nov. 20, 2021 | Nov. 19, 2022 |
| Power meter | Agilent | E4419 | \ | May 28, 2021 | May 27, 2022 |
| Power meter | Agilent | E4419 | \ | May 28, 2021 | May 27, 2022 |
| Power sensor | Agilent | E9300A | \ | May 28, 2021 | May 27, 2022 |
| Power sensor | Agilent | E9300A | \ | May 28, 2021 | May 27, 2022 |
| Directional Coupler | Krytar 158020 | 131467 | \ | Nov. 12, 2021 | Nov 11, 2022 |

Note:
Per KDB865664D01 requirements for dipole calibration, the test laboratory has adopted three year extended calibration interval. Each measured dipole is expected to evalute with following criteria at least on annual interval.

1. There is no physical damage on the dipole;
2. System check with specific dipole is within 10% of calibrated values;

3. The most recent return-loss results,measued at least annually,deviates by no more than 20% from the previous measurement;
4. The most recent measurement of the real or imaginary parts of the impedance, measured at least annually is within 5Ω from the provious measurement.

Network analyzer probe calibration against air, distilled water and a shorting block performed before measuring liquid parameters.

# 8. Specific Absorption Rate (SAR)

## 8.1 Introduction

SAR is related to the rate at which energy is absorbed per unit mass in an object exposed to a radio field. The SAR distribution in a biological body is complicated and is usually carried out by experimental techiques or numerical modeling. The standard recommends limits for two tiers of groups, occupational/controlled and general population/uncontrolled, based on a person's awareness and ability to exercise control over his or her exposure. In general, occupational/controlled exposure limits are higher than the limits for general population/uncontrolled.

## 8.2 SAR Definition

The SAR definition is the time derivative (rate) of the incremental energy (dW) absorbed by (dissipated in) an incremental mass (dm) contained in a volume element (dv) of a given density ( $\rho$ ). The equation description is as below:

$$\mathrm{SAR} = \frac{d}{dt}\left(\frac{dW}{dm}\right) = \frac{d}{dt}\left(\frac{dW}{\rho dv}\right)$$

SAR is expressed in units of Watts per kilogram (W/kg)

SAR measurement can be either related to the temperature elevation in tissue by

$$\mathrm{SAR} = C\left(\frac{\delta T}{\delta t}\right)$$

Where: C is the specific heat capacity, $\delta$T is the temperature rise and $\delta$t is the exposure duration, or related to the

electrical field in the tissue by

$$\mathrm{SAR} = \frac{\sigma |E|^2}{\rho}$$

Where: $\sigma$ is the conductivity of the tissue, $\rho$ is the mass density of the tissue and E is the RMS electrical field strength.

However for evaluating SAR of low power transmitter, electrical field measurement is typically applied.

# 9. SAR Measurement System

## 9.1 The Measurement System

Comosar is a system that is able to determine the SAR distribution inside a phantom of human being according to different standards. The Comosar system consists of the following items:
- Main computer to control all the system
- 6 axis robot
- Data acquisition system
- Miniature E-field probe
- Phone holder
- Head simulating tissue

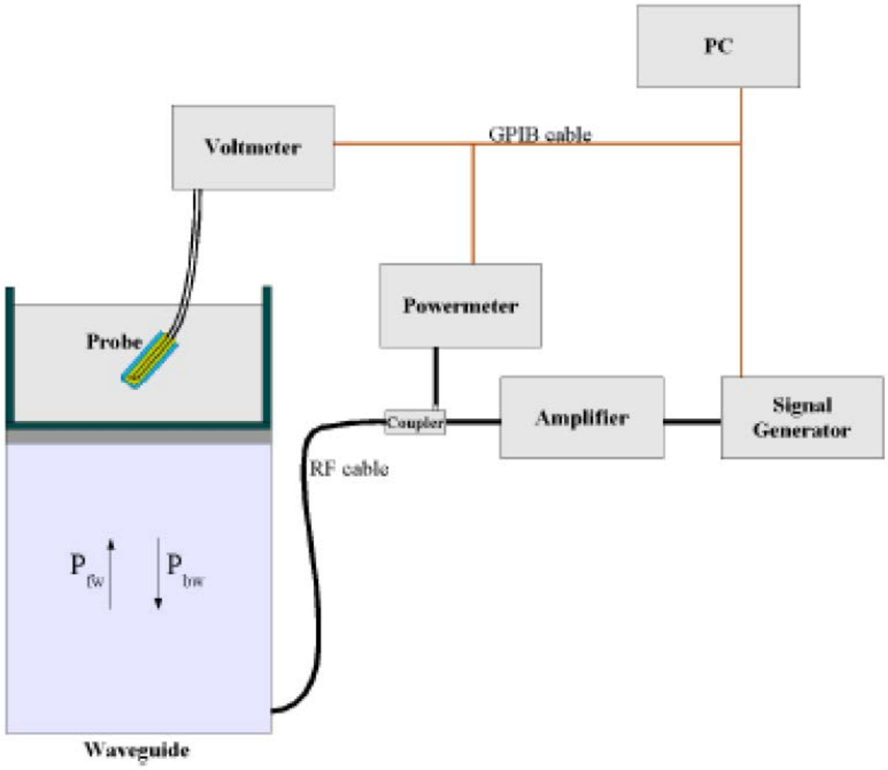
The following figure shows the system.

The EUT under test operating at the maximum power level is placed in the phone holder, under the phantom, which is filled with head simulating liquid. The E-Field probe measures the electric field inside the phantom. The OpenSAR software computes the results to give a SAR value in a 1g or 10g mass.

## 9.2 Probe

For the measurements the Specific Dosimetric E-Field Probe SN 46/21 EPGO362 with following specifications is used
- Dynamic range: 0.01-100 W/kg
- Tip Diameter : 5 mm
- Distance between probe tip and sensor center: 2.10mm
- Distance between sensor center and the inner phantom surface: 4 mm (repeatability better than +/- 1mm)
- Probe linearity: <0.25 dB
- Axial Isotropy: <0.25 dB
- Spherical Isotropy: <0.50 dB
- Calibration range: 835 to 2500MHz for head & body simulating liquid.

Angle between probe axis (evaluation axis) and surface normal line:1ess than 30°
Probe calibration is realized, in compliance with EN 62209-1 and IEEE 1528 STD, with CALISAR, Antennessa proprietary calibration system. The calibration is performed with the EN 62209-1 annex technique using reference guide at the five frequencies.




$$SAR = \frac{4(p_{fw} - p_{Pbw})}{ab\delta} cos^2 (\pi \frac{y}{a}) \; c^{(2\pi/\delta)}$$

Where :
Pfw = Forward Power
Pbw = Backward Power
a and b =Waveguide dimensions
l = Skin depth

Keithley configuration:
Rate = Medium; Filter = ON; RDGS = 10; Filter type = Moving Average; Range auto after each calibration, a SAR measurement is performed on a validation dipole and compared with a NPL calibrated probe, to verify it.

The calibration factors, CF(N), for the 3 sensors corresponding to dipole 1, dipole 2 and dipole 3 are:

CF(N)=SAR(N)/Vlin(N) (N=1,2,3)

The linearised output voltage Vlin(N) is obtained from the displayed output voltage V(N) using

Vlin(N)=V(N)*(1+V(N)/DCP(N)) (N=1,2,3)

where DCP is the diode compression point in mV.

## 9.3 Test Procedure

**Dosimetric Assessment Procedure**
Each E-Probe/Probe Amplifier combination has unique calibration parameters. SATIMO Probe calibration procedure is conducted to determine the proper amplifier settings to enter in the probe parameters. The amplifier settings are determined for a given frequency by subjecting the probe to a known E-field density (1 mW/cm2) using an with CALISAR, Antenna proprietary calibration system.

**Free Space Assessment Procedure**
The free space E-field from amplified probe outputs is determined in a test chamber. This calibration can be performed in a TEM cell if the frequency is below 1 GHz and in a waveguide or other methodologies above 1 GHz for free space. For the free space calibration, the probe is placed in the volumetric center of the cavity and at the proper orientation with the field. The probe is rotated 360 degrees until the three channels show the maximum reading. The power density readings equates to 1mW/cm2.

**Temperature Assessment Procedure**
E-field temperature correlation calibration is performed in a flat phantom filled with the appropriate simulated head tissue. The E-field in the medium correlates with the temperature rise in the dielectric medium. For temperature correlation calibration a RF transparent thermistor-based temperature probe is used in conjunction with the E-field probe.

$$\text{SAR} = C\frac{\Delta T}{\Delta t}$$

Where:

$\Delta t$ = exposure time (30 seconds),

C = heat capacity of tissue (brain or muscle),

$\Delta T$ = temperature increase due to RF exposure.

SAR is proportional to ΔT/Δt, the initial rate of tissue heating, before thermal diffusion takes place. The electric field in the simulated tissue can be used to estimate SAR by equating the thermally derived SAR to that with the E- field component.

$$\text{SAR} = \frac{|E|^2 \cdot \sigma}{\rho}$$

Where:

$\sigma$ = simulated tissue conductivity,

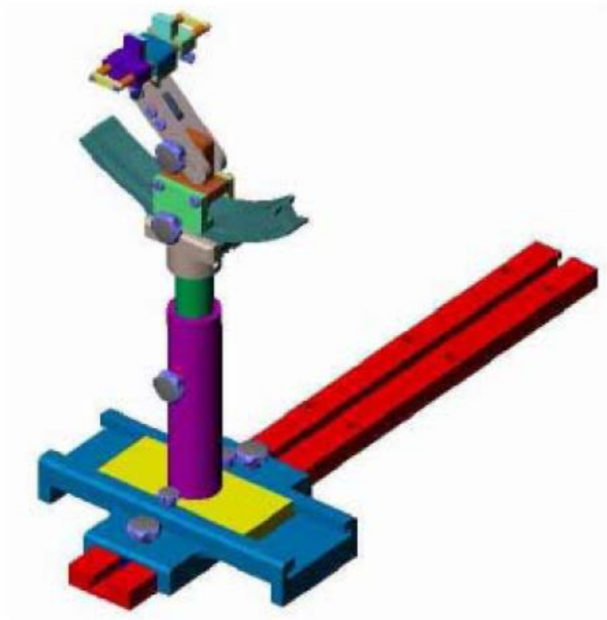
$\rho$ = Tissue density (1.25 g/cm3 for brain tissue)

## 9.4 Phantom

For the measurements the Specific Anthropomorphic Mannequin (SAM) defined by the IEEE SCC-34/SC2 group is used. The phantom is a polyurethane shell integrated in a wooden table. The thickness of the phantom amounts to 2mm +/- 0.2mm. It enables the dosimetric evaluation of left and right phone usage and includes an additional flat phantom part for the simplified performance check. The phantom set-up includes a cover, which prevents the evaporation of the liquid.

## 9.5 Phantom

The positioning system allows obtaining cheek and tilting position with a very good accuracy. In compliance with CENELEC, the tilt angle uncertainty is lower than 1°.



| System Material | Permittivity | Loss Tangent |
|---|---|---|
| Delrin | 3.7 | 0.005 |

## 10. Tissue Simulating Liquids

### 10.1 Composition of Tissue Simulating Liquid

For the measurement of the field distribution inside the SAM phantom with SMTIMO, the phantom must be filled with around 25 liters of homogeneous body tissue simulating liquid. For head SAR testing, the liquid height from the ear reference point (ERP) of the phantom to the liquid top surface is larger than 15 cm. For body SAR testing, the liquid height from the center of the flat phantom to the liquid top surface is larger than 15 cm. Please see the following photos for the liquid height.

Liquid Height for Body SAR

The Composition of Tissue Simulating Liquid

| Frequency (MHz) | Water (%) | Salt (%) | 1,2-Propane diol (%) | HEC (%) | Preventol (%) | DGBE (%) |
|---|---|---|---|---|---|---|
| Head/Body | | | | | | |
| 835 | 40.3 | 1.4 | 57.9 | 0.2 | 0.2 | 0 |
| 900 | 40.3 | 1.4 | 57.9 | 0.2 | 0.2 | 0 |
| 1800-2000 | 55.2 | 0.3 | 0 | 0 | 0 | 44.5 |
| 2450 | 55.0 | 0.1 | 0 | 0 | 0 | 44.9 |
| 2600 | 54.9 | 0.1 | 0 | 0 | 0 | 45.0 |

| Frequency (MHz) | Water (%) | Hexyl Carbitol (%) | Triton X-100 (%) |
|---|---|---|---|
| Head/Body | | | |
| 5000-6000 | 65.52 | 17.24 | 17.24 |

## 10.2 Limit

The head tissue dielectric parameters recommended by the IEEE SCC-34/SC-2 in P1528 have been incorporated in the following table. These head parameters are derived from planar layer models simulating the highest expected SAR for the dielectric properties and tissue thickness variations in a human head. Other head and body tissue parameters that have not been specified in P1528 are derived from the tissue dielectric parameters

computed from the 4-Cole-Cole equations described in Reference [12] and extrapolated according to the head parameters specified in P1528.

| Target Frequency (MHz) | Head/Body | |
|---|---|---|
| | Conductivity ( $\sigma$ ) | Permittivity ( $\varepsilon_r$ ) |
| 150 | 0.76 | 52.3 |
| 300 | 0.87 | 45.3 |
| 450 | 0.87 | 43.5 |
| 750 | 0.89 | 41.9 |
| **835** | **0.90** | **41.5** |
| **900** | **0.97** | **41.5** |
| 915 | 0.98 | 41.5 |
| 1450 | 1.20 | 40.5 |
| 1610 | 1.29 | 40.3 |
| **1800-2000** | **1.40** | **40.0** |
| **2450** | **1.80** | **39.2** |
| **2600** | **1.96** | **39.0** |
| 3000 | 2.40 | 38.5 |
| 5200 | 4.66 | 36.0 |
| 5400 | 4.86 | 35.8 |
| 5600 | 5.07 | 35.5 |
| 5800 | 5.27 | 35.3 |

## 10.3 Tissue Calibration Result

The dielectric parameters of the liquids were verified prior to the SAR evaluation using an R&S ZVB 8. Dielectric Probe Kit and an Agilent Network Analyzer.

Calibration Result for Dielectric Parameters of Tissue Simulating Liquid

| Frequency(MHz) | Liquid | Target Permitivity (F/m) | Target Conductivity (S/m) | Measured Permitivity (F/m) | Measured Conductivity (S/m) | Deviation Perm.\|Cond.(%) | Date | Temp. Ambient\|TSL (°C) |
|---|---|---|---|---|---|---|---|---|
| 2450 | Head | 39.09 | 1.89 | 39.09 | 1.89 | -0.01\|-0.16 | 05/26/2022 | 20.0 \| 20.0 |
| 5800 | Head | 35.30 | 5.27 | 32.62 | 5.21 | -7.59\|-1.14 | 05/27/2022 | 20.0 \| 20.0 |

# 11. SAR Measurement Evaluation

## 11.1 Purpose of System Performance Check

At the device test frequencies. System check verifies the measurement repeatability of a SAR system before compliance testing and is not a validation of all system specifications. The latter is not required for testing a device but is mandatory before the system is deployed. The system check detects possible short-term drift and unacceptable measurement errors or uncertainties in the system.

## 11.2 System Setup

In the simplified setup for system evaluation, the EUT is replaced by a calibrated dipole and the power source is replaced by a continuous wave which comes from a signal generator at frequency 850MHz,900 MHz,1800MHz,2000MHz, 2450MHz,2600MHz. The calibrated dipole must be placed beneath the flat phantom section of the SAM twin phantom with the correct distance holder. The distance holder should touch the phantom surface with a light pressure at the reference marking and be oriented parallel to the long side of the phantom. The output power on dipole port must be calibrated to 24 dBm (250 mW) before dipole is connected.

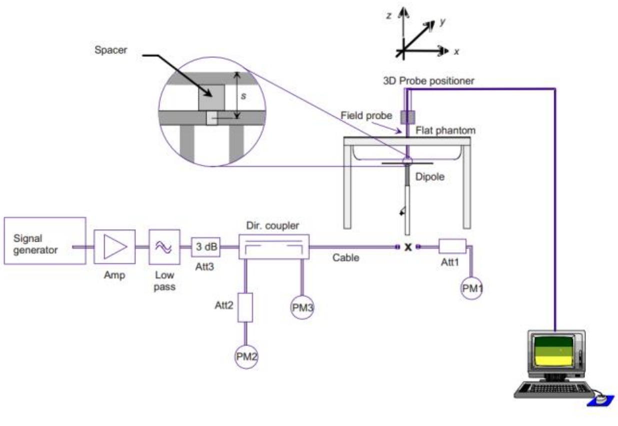



Figure B.1 – Set-up for the system check

## 11.3 Validation Results

Comparing to the original SAR value provided by SATIMO, the validation data should be within its specification of 10 %. The following table shows the target SAR and measured SAR after normalized to 1W input power. The table below indicates the system performance check can meet the variation criterion.

| Mixture Type | Frequency (MHz) | Power | $SAR_{1g}$ (W/Kg) | $SAR_{10g}$ (W/Kg) | Drift (%) | 1W Target | | Difference percentage | | Liquid Temp | Date |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | $SAR_{1g}$ (W/Kg) | $SAR_{10g}$ (W/Kg) | 1g | 10g | | |
| Head | 2450 | 100 mW | 55.16 | 24.15 | 0.24 | 5.24 | 2.40 | 0.01% | 0.01% | 20.0 | 05/26/2022 |
| | | Normalize to 1 Watt | 5.52 | 2.41 | | | | | | | |
| Head | 5800 | 100 mW | 76.49 | 22.03 | 0.24 | 7.80 | 2.19 | 0.01% | 0.01% | 20.0 | 05/27/2022 |
| | | Normalize to 1 Watt | 7.65 | 2.20 | | | | | | | |

## 12. SAR measurement procedure

### 12.1 Conducted power measurement

a. For WWAN power measurement, use base station simulator connection with RF cable, at maximum power in each supported wireless interface and frequency band.
b. Read the WWAN RF power level from the base station simulator.
c. For WLAN/BT power measurement, use engineering software to configure EUT WLAN/BT continuously Transmission, at maximum RF power in each supported wireless interface and frequency band.
d. Connect EUT RF port through RF cable to the power meter, and measure WLAN/BT output power.

### 12.2 WIFI Test Configuration

The SAR measurement and test reduction procedures are structured according to either the DSSS or OFDM transmission mode configurations used in each standalone frequency band and aggregated band. For devices that operate in exposure configurations that require multiple test positions, additional SAR test reduction may be applied. The maximum output power specified for production units, including tune-up tolerance, are used to determine initial SAR test requirements for the 802.11 transmission modes in a frequency band. SAR is measured using the highest measured maximum output power channel for the initial test configuration. SAR measurement and test reduction for the remaining 802.11 modes and test channels are determined according to measured or specified maximum output power and reported SAR of the initial measurements. The general test reduction and SAR measurement approaches are summarized in the following:
1. The maximum output power specified for production units are determined for all applicable 802.11 transmission modes in each standalone and aggregated frequency band. Maximum output power is measured for the highest maximum output power configuration(s) in each frequency band according to the default power measurement procedures.
2. For OFDM transmission configurations in the 2.4 GHz and 5 GHz bands, an “initial test configuration” is first determined for each standalone and aggregated frequency band according to the maximum output power and tune-up tolerance specified for production units.
a. When the same maximum power is specified for multiple transmission modes in a frequency band, the largest channel bandwidth, lowest order modulation, lowest data rate and lowest order 802.11a/g/n/ac mode is used for SAR measurement, on the highest measured output power channel in the initial test configuration, for each frequency band.
b. SAR is measured for OFDM configurations using the initial test configuration procedures. Additional frequency band specific SAR test reduction may be considered for individual frequency bands
c. Depending on the reported SAR of the highest maximum output power channel tested in the initial test configuration, SAR test reduction may apply to subsequent highest output channels in the initial test configuration to reduce the number of SAR measurements.
3. The Initial test configuration does not apply to DSSS. The 2.4 GHz band SAR test requirements and 802.11b DSSS procedures are used to establish the transmission configurations required for SAR measurement.
4. An “initial test position”is applied to further reduce the number of SAR tests for devices operating in next to the ear, UMPC mini-tablet or hotspot mode exposure configurations that require multiple test positions .
a. SAR is measured for 802.11b according to the 2.4 GHz DSSS procedure using the exposure condition established by the initial test position.
b. SAR is measured for 2.4 GHz and 5 GHz OFDM configurations using the initial test configuration. 802.11b/g/n operating modes are tested independently according to the service requirements in each frequency band. 802.11b/g/n modes are tested on the maximum average output channel.

5. The Initial test position does not apply to devices that require a fixed exposure test position. SAR is measured in a fixed exposure test position for these devices in 802.11b according to the 2.4 GHz DSSS procedure or in 2.4 GHz and 5 GHz OFDM configurations using the initial test configuration procedures .
6. The “subsequent test configuration”procedures are applied to determine if additional SAR measurements are required for the remaining OFDM transmission modes that have not been tested in the initial test configuration. SAR test exclusion is determined according to reported SAR in the initial test configuration and maximum output power specified or measured for these other OFDM configurations.

2.4 GHz and 5GHz SAR Procedures
Separate SAR procedures are applied to DSSS and OFDM configurations in the 2.4 GHz band to simplify DSSS test requirements. For 802.11b DSSS SAR measurements, DSSS SAR procedure applies to fixed exposure test position and initial test position procedure applies to multiple exposure test positions. When SAR measurement is required for an OFDM configuration, the initial test configuration, subsequent test configuration and initial test position procedures are applied. The SAR test exclusion requirements for 802.11g/n OFDM configurations are described in section 5.2.2.
1. 802.11b DSSS SAR Test Requirements
SAR is measured for 2.4 GHz 802.11b DSSS using either a fixed test position or, when applicable, the initial test position procedure. SAR test reduction is determined according to the following:
a. When the reported SAR of the highest measured maximum output power channel (section 3.1) for the exposure configuration is ≤ 0.8 W/kg, no further SAR testing is required for 802.11b DSSS in that exposure configuration.
b. When the reported SAR is > 0.8 W/kg, SAR is required for that exposure configuration using the next highest measured output power channel. When any reported SAR is > 1.2 W/kg, SAR is required for the third channel; i.e., all channels require testing.
2. 2.4 GHz 802.11g/n OFDM SAR Test Exclusion Requirements
When SAR measurement is required for 2.4 GHz 802.11g/n OFDM configurations, the measurement and test reduction procedures for OFDM are applied (section 5.3). SAR is not required for the following 2.4 GHz OFDM conditions.
a. When KDB Publication 447498 SAR test exclusion applies to the OFDM configuration
b. When the highest reported SAR for DSSS is adjusted by the ratio of OFDM to DSSS specified maximum output power and the adjusted SAR is ≤ 1.2 W/kg.
3. SAR Test Requirements for OFDM Configurations
When SAR measurement is required for 802.11 a/g/n/ac OFDM configurations, each standalone and frequency aggregated band is considered separately for SAR test reduction. When the same transmitter and antenna(s) are used for U-NII-1 and U-NII-2A bands, additional SAR test reduction applies. When band gap channels between U-NII-2C band and 5.8 GHz U-NII-3 or §15.247 band are supported, the highest maximum output power transmission mode configuration and maximum output power channel across the bands must be used to determine SAR test reduction, according to the initial test configuration and subsequent test configuration requirements.20 In applying the initial test configuration and subsequent test configuration procedures, the 802.11 transmission configuration with the highest specified maximum output power and the channel within a test configuration with the highest measured maximum output power should be clearly distinguished to apply the procedures.
4. OFDM Transmission Mode SAR Test Configuration and Channel Selection Requirements
The initial test configuration for 2.4 GHz and 5 GHz OFDM transmission modes is determined by the 802.11 configuration with the highest maximum output power specified for production units, including tune-up tolerance, in each standalone and aggregated frequency band. SAR for the initial test configuration is measured using the highest maximum output power channel determined by the default power measurement procedures (section 4). When multiple configurations in a frequency band have the same specified maximum output power, the initial test configuration is determined according to the following steps applied sequentially.
a. The largest channel bandwidth configuration is selected among the multiple configurations with the same specified maximum output power.
b. If multiple configurations have the same specified maximum output power and largest channel bandwidth, the lowest order modulation among the largest channel bandwidth configurations is selected.

c. If multiple configurations have the same specified maximum output power, largest channel bandwidth and lowest order modulation, the lowest data rate configuration among these configurations is selected.
d. When multiple transmission modes (802.11a/g/n/ac) have the same specified maximum output power, largest channel bandwidth, lowest order modulation and lowest data rate, the lowest order 802.11 mode is selected; i.e., 802.11a is chosen over 802.11n then 802.11ac or 802.11g is chosen over 802.11n.

5. After an initial test configuration is determined, if multiple test channels have the same measured maximum output power, the channel chosen for SAR measurement is determined according to the following. These channel selection procedures apply to both the initial test configuration and subsequent test configuration(s), with respect to the default power measurement procedures or additional power measurements required for further SAR test reduction. The same procedures also apply to subsequent highest output power channel(s) selection.
a. Channels with measured maximum output power within ¼ dB of each other are considered to have the same maximum output.
b. When there are multiple test channels with the same measured maximum output power, the channel closest to mid-band frequency is selected for SAR measurement.
c. When there are multiple test channels with the same measured maximum output power and equal separation from mid-band frequency; for example, high and low channels or two mid-band channels, the higher frequency (number) channel is selected for SAR measurement.

6. Initial Test Configuration Procedures

An initial test configuration is determined for OFDM transmission modes according to the channel bandwidth, modulation and data rate combination(s) with the highest maximum output power specified for production units in each standalone and aggregated frequency band. SAR is measured using the highest measured maximum output power channel. For configurations with the same specified or measured maximum output power, additional transmission mode and test channel selection procedures are required (see section 5.3.2). SAR test reduction of subsequent highest output test channels is based on the reported SAR of the initial test configuration.

For next to the ear, hotspot mode and UMC mini-tablet exposure configurations where multiple test positions are required, the initial test position procedure is applied to minimize the number of test positions required for SAR measurement using the initial test configuration transmission mode.23

For fixed exposure conditions that do not have multiple SAR test positions, SAR is measured in the transmission mode determined by the initial test configuration. When the reported SAR of the initial test configuration is > 0.8 W/kg, SAR measurement is required for the subsequent next highest measured output power channel(s) in the initial test configuration until the reported SAR is ≤ 1.2 W/kg or all required channels are tested.

7. Subsequent Test Configuration Procedures

SAR measurement requirements for the remaining 802.11 transmission mode configurations that have not been tested in the initial test configuration are determined separately for each standalone and aggregated frequency band, in each exposure condition, according to the maximum output power specified for production units. The initial test position procedure is applied to next to the ear, UMPC mini-tablet and hotspot mode configurations. When the same maximum output power is specified for multiple transmission modes, the procedures in section 5.3.2 are applied to determine the test configuration. Additional power measurements may be required to determine if SAR measurements are required for subsequent highest output power channels in a subsequent test configuration. The subsequent test configuration and SAR measurement procedures are described in the following.

a. When SAR test exclusion provisions of KDB Publication 447498 are applicable and SAR measurement is not required for the initial test configuration, SAR is also not required for the next highest maximum output power transmission mode subsequent test configuration(s) in that frequency band or aggregated band and exposure configuration.
b. When the highest reported SAR for the initial test configuration (when applicable, include subsequent highest output channels), according to the initial test position or fixed exposure position requirements, is adjusted by the ratio of the subsequent test configuration to initial test configuration specified maximum output power and the adjusted SAR is ≤ 1.2 W/kg, SAR is not required for that subsequent test configuration.

8. The number of channels in the initial test configuration and subsequent test configuration can be different due to differences in channel bandwidth. When SAR measurement is required for a subsequent test configuration and the channel bandwidth is smaller than that in the initial test configuration, all channels in the subsequent test configuration that overlap with the larger

bandwidth channel tested in the initial test configuration should be used to determine the highest maximum output power channel. This step requires additional power measurement to identify the highest maximum output power channel in the subsequent test configuration to determine SAR test reduction.

a. SAR should first be measured for the channel with highest measured output power in the subsequent test configuration.
b. SAR for subsequent highest measured maximum output power channels in the subsequent test configuration is required only when the reported SAR of the preceding higher maximum output power channel(s) in the subsequent test configuration is > 1.2 W/kg or until all required channels are tested.

9. For channels with the same measured maximum output power, SAR should be measured using the channel closest to the center frequency of the larger channel bandwidth channel in the initial test configuration.

a. SAR measurements for the remaining highest specified maximum output power OFDM transmission mode configurations that have not been tested in the initial test configuration (highest maximum output) or subsequent test configuration(s) (subsequent next highest maximum output power) is determined by applying the subsequent test configuration procedures in this section to the remaining configurations according to the following:
b. replace “subsequent test configuration” with “next subsequent test configuration” (i.e., subsequent next highest specified maximum output power configuration)
c. replace “initial test configuration” with “all tested higher output power configurations.

## 12.3 Configuration and Peripherals

The EUT was tested in the following configuration(s) unless otherwise stated:
• Powered via a USB port.
• Test all USB orientations [see figure below: (A) Horizontal-Up, (B) Horizontal-Down, (C) Vertical-Front, and (D) Vertical-Back] with a device-to-phantom separation distance of 5 mm or less, according to KDB Publication 447498 D01 requirements.

(A) Horizontal-Up (B) Horizontal-Down (C) Vertical-Front (D) Vertical-Back

These test orientations are intended for the exposure conditions found in typical laptop/notebook/netbook or tablet computers with either horizontal or vertical USB connector configurations at various locations in the keyboard section of the computer. Current generation portable host computers should be used to establish the required SAR measurement separation distance.The same test separation distance must be used to test all frequency bands and modes in each USB orientation. The typical Horizontal-Up USB connection (A), found in the majority of host computers, must be tested using an appropriate host computer. A host computer with either Vertical-Front (C) or Vertical-Back (D) USB connection should be used to test one of the vertical USB orientations. If a suitable host computer is not available for testing the Horizontal-Down (B) or the remaining Vertical USB orientation, a high quality USB cable, 12 inches or less, may be used for testing these other orientations. It must be documented that the USB cable does not influence the radiating characteristics and output power of the transmitter

## 12.4 Power Reduction/Power Drift

The product without any power reduction.

# 13. SAR Measurement Procedures

## 13.1 Measurement Procedures

The measurement procedures are as follows:
(a) Use base station simulator (if applicable) or engineering software to transmit RF power continuously (continuous Tx) in the highest power channel.
(b) Keep EUT to radiate maximum output power or 100% factor (if applicable)
(c) Measure output power through RF cable and power meter.
(d) Place the EUT in the positions as Annex D demonstrates.
(e) Set scan area, grid size and other setting on the SATIMO software.
(f) Measure SAR results for the highest power channel on each testing position.
(g) Find out the largest SAR result on these testing positions of each band
(h) Measure SAR results for other channels in worst SAR testing position if the SAR of highest power channel is larger than 0.8 W/kg

According to the test standard, the recommended procedure for assessing the peak spatial-average SAR value consists of the following steps:
(a) Power reference measurement
(b) Area scan
(c) Zoom scan
(d) Power drift measurement

## 13.2 Spatial Peak SAR Evaluation

The procedure for spatial peak SAR evaluation has been implemented according to the test standard. It can be conducted for 1g and 10g, as well as for user-specific masses. The SATIMO software includes all numerical procedures necessary to evaluate the spatial peak SAR value.
The base for the evaluation is a "cube" measurement. The measured volume must include the 1g and 10g cubes with the highest averaged SAR values. For that purpose, the center of the measured volume is aligned to the interpolated peak SAR value of a previously performed area scan.
The entire evaluation of the spatial peak values is performed within the post-processing engine. The system always gives the maximum values for the 1g and 10g cubes. The algorithm to find the cube with highest averaged SAR is divided into the following stages:
(a) Extraction of the measured data (grid and values) from the Zoom Scan
(b) Calculation of the SAR value at every measurement point based on all stored data
(c) Generation of a high-resolution mesh within the measured volume
(d) Interpolation of all measured values form the measurement grid to the high-resolution grid
(e) Extrapolation of the entire 3D field distribution to the phantom surface over the distance from sensor to surface
(f) Calculation of the averaged SAR within masses of 1g and 10g

## 13.3 Area & Zoom Scan Procedures

First Area Scan is used to locate the approximate location(s) of the local peak SAR value(s). The measurement grid within an Area Scan is defined by the grid extent, grid step size and grid offset. Next, in order to determine the EM field distribution in a three-dimensional spatial extension, Zoom Scan is required. The Zoom Scan measures 5x5x7 points with step size 8, 8 and 5 mm for 300 MHz to 3 GHz, and 8x8x8 points with step size 4, 4 and 2.5 mm for 3 GHz to 6 GHz. The Zoom Scan is performed around the highest E-field value to determine the averaged SAR-distribution over 10 g.

## 13.4 Volume Scan Procedures

The volume scan is used for assess overlapping SAR distributions for antennas transmitting in different frequency bands. It is equivalent to an oversized zoom scan used in standalone measurements. The measurement volume will be used to enclose all the simultaneous transmitting antennas. For antennas transmitting simultaneously in different frequency bands, the volume scan is measured separately in each frequency band. In order to sum correctly to compute the 1g aggregate SAR, the EUT remain in the same test position for all measurements and all volume scan use the same spatial resolution and grid spacing (step-size is 4, 4 and 2.5 mm). When all volume scan were completed, the software can combine and subsequently superpose these measurement data to calculating the multiband SAR.

## 13.5 SAR Averaged Methods

The local SAR inside the phantom is measured using small dipole sensing elements inside a probe body. The probe tip must not be in contact with the phantom surface in order to minimize measurements errors, but the highest local SAR will occur at the surface of the phantom.

An extrapolation is using to determinate this highest local SAR values. The extrapolation is based on a fourth-order least-square polynomial fit of measured data. The local SAR value is then extrapolated from the liquid surface with a 1mm step.

The measurements have to be performed over a limited time (due to the duration of the battery) so the step of measurement is high. It could vary between 5 and 8 mm. To obtain an accurate assessment of the maximum SAR averaged over 10g and 1 g requires a very fine resolution in the three dimensional scanned data array.

## 13.6 Power Drift Monitoring

All SAR testing is under the EUT install full charged battery and transmit maximum output power. In SATIMO measurement software, the power reference measurement and power drift measurement procedures are used for monitoring the power drift of EUT during SAR test. Both these procedures measure the field at a specified reference position before and after the SAR testing. The software will calculate the field difference in dB. If the power drift more than 5%, the SAR will be retested.

# 14. SAR Test Result

## 14.1 Conducted RF Output Power

According KDB 447498 D01 General RF Exposure Guidance v06 Section 4.1 2) states that “Unless it is specified differently in the published RF exposure KDB procedures, these requirements also apply to test reduction and test exclusion considerations. Time-averaged maximum conducted output power applies to SAR and, as required by § 2.1091(c), time-averaged ERP applies to MPE. When an antenna port is not available on the device to support conducted power measurement, such as FRS and certain Part 15 transmitters with built-in integral antennas, the maximum output power allowed for production units should be used to determine RF exposure test exclusion and compliance.”

| WLAN(2.4G) - Conducted Power | | | | |
|---|---|---|---|---|
| **Test Mode** | **Data Rate** | **Channel** | **Frequency (MHz)** | **Average Power (dBm)** |
| 802.11b | 1Mbps | CH 01 | 2412 | 15.98 |
| | | CH 06 | 2437 | 16.31 |
| | | CH 11 | 2462 | **16.34** |
| 802.11g | 6Mbps | CH 01 | 2412 | 15.07 |
| | | CH 06 | 2437 | 15.28 |
| | | CH 11 | 2462 | 15.23 |
| 802.11n (20MHz) | 6.5Mbps | CH 01 | 2412 | 14.17 |
| | | CH 06 | 2437 | 14.34 |
| | | CH 11 | 2462 | 14.33 |
| 802.11n (40MHz) | 13.5Mbps | CH 03 | 2422 | 12.89 |
| | | CH 06 | 2437 | 12.72 |
| | | CH 09 | 2452 | 12.74 |

Note: SAR is not required for the following 2.4 GHz OFDM conditions as the highest reported SAR for DSSS is adjusted by the ratio of OFDM to DSSS specified maximum output power and the adjusted SAR is ≤ 1.2 W/kg.

| WLAN(5.8G) - Conducted Power | | | | |
|---|---|---|---|---|
| **Test Mode** | **Data Rate** | **Channel** | **Frequency (MHz)** | **Average Power (dBm)** |
| 802.11a | 6Mbps | CH 149 | 5745 | **13.74** |
| | | CH 157 | 5785 | 12.91 |
| | | CH 165 | 5825 | 12.24 |
| 802.11n(HT20) | 6.5Mbps | CH 149 | 5745 | 12.13 |
| | | CH 157 | 5785 | 11.84 |
| | | CH 165 | 5825 | 11.22 |
| 802.11n(HT40) | 13.5Mbps | CH 151 | 5755 | 10.78 |
| | | / | / | / |
| | | CH 159 | 5795 | 10.62 |
| 802.11ac(HT20) | 6.5Mbps | CH 149 | 5745 | 12.16 |
| | | CH 157 | 5785 | 11.83 |
| | | CH 165 | 5825 | 11.20 |
| 802.11ac(HT40) | 13.5Mbps | CH 151 | 5755 | 10.77 |
| | | / | / | / |
| | | CH 159 | 5795 | 10.58 |
| 802.11ac(HT80) | 29.3Mbps | / | / | / |
| | | CH 155 | 5775 | 9.98 |
| | | / | / | / |

Per KDB 447498 D01v06, the 1-g and 10-g SAR test exclusion thresholds for 100 MHz to 6 GHz at test separation distances ≤ 50 mm are determined by:

[(max. power of channel, including tune-up tolerance, mW)/(min. test separation distance, mm)] ·[$\sqrt{f(GHz)}$]

≤ 3.0 for 1-g SAR and ≤ 7.5 for 10-g extremity SAR

f(GHz) is the RF channel transmit frequency in GHz

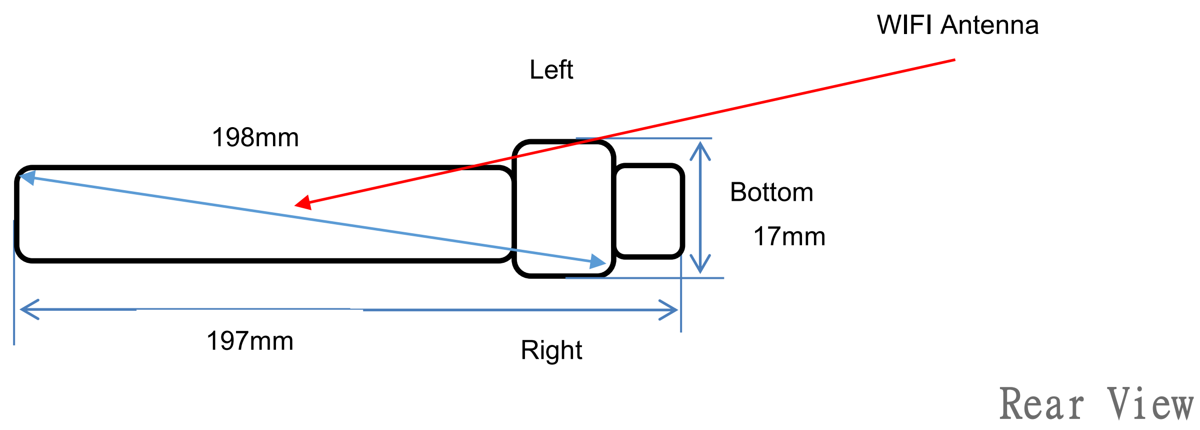
Power and distance are rounded to the nearest mW and mm before calculation

The result is rounded to one decimal place for comparison

| Bluetooth Turn up Power (dBm) | Separation Distance (mm) | Frequency (GHz) | Exclusion Thresholds |
|---|---|---|---|
| N/A | 5 | 2.45 | N/A |

Per KDB 447498 D01v06, when the minimum test separation distance is < 5 mm, a distance of 5 mm is applied to determine SAR test exclusion. The test exclusion threshold is N/A< 3.0, SAR testing is not required.

## 14.2 Transmit Antennas and SAR Measurement Position




Antenna information:

| | |
|---|---|
| WIFI Antenna | TX/RX |

Measured Position:

| | |
|---|---|
| Position 1 | Horizontal-Left |
| Position 2 | Horizontal-Right |
| Position 3 | Vertical-Front |
| Position 4 | Vertical-Back |

## 14.3 Standalone SAR Test Exclusion Considerations

SAR evaluation is required if the separation distance between the user and/or bystander and the antenna and/or radiating element of the device is less than or equal to 20 cm, except when the device operates at or below the applicable output power level (adjusted for tune-up tolerance) for the specified separation distance defined in the following table.

| Frequency (MHz) | Exemption Limits (mW) | | | | |
|---|---|---|---|---|---|
| | At separation distance of ≤5 mm | At separation distance of 10 mm | At separation distance of 15 mm | At separation distance of 20 mm | At separation distance of 25 mm |
| ≤300 | 71 mW | 101 mW | 132 mW | 162 mW | 193 mW |
| 450 | 52 mW | 70 mW | 88 mW | 106 mW | 123 mW |
| 835 | 17 mW | 30 mW | 42 mW | 55 mW | 67 mW |
| 1900 | 7 mW | 10 mW | 18 mW | 34 mW | 60 mW |
| 2450 | 4 mW | 7 mW | 15 mW | 30 mW | 52 mW |
| 3500 | 2 mW | 6 mW | 16 mW | 32 mW | 55 mW |
| 5800 | 1 mW | 6 mW | 15 mW | 27 mW | 41 mW |
| Frequency (MHz) | Exemption Limits (mW) | | | | |
| | At separation distance of 30 mm | At separation distance of 35 mm | At separation distance of 40 mm | At separation distance of 45 mm | At separation distance of ≥50 mm |
| ≤300 | 223 mW | 254 mW | 284 mW | 315 mW | 345 mW |
| 450 | 141 mW | 159 mW | 177 mW | 195 mW | 213 mW |
| 835 | 80 mW | 92 mW | 105 mW | 117 mW | 130 mW |
| 1900 | 99 mW | 153 mW | 225 mW | 316 mW | 431 mW |
| 2450 | 83 mW | 123 mW | 173 mW | 235 mW | 309 mW |
| 3500 | 86 mW | 124 mW | 170 mW | 225 mW | 290 mW |
| 5800 | 56 mW | 71 mW | 85 mW | 97 mW | 106 mW |

Note:
Output power level shall be the higher of the maximum conducted or equivalent isotropically radiated power (e.i.r.p.) source-based, time-averaged output power. For controlled use devices where the 8 W/kg for 1 gram of tissue applies, the exemption limits for routine evaluation in the above table are multiplied by a factor of 5. For limb-worn devices where the 10 gram value applies, the exemption limits for routine evaluation in the above table are multiplied by a factor of 2.5. If the operating frequency of the device is between two frequencies located in the above table linear interpolation shall be applied for the applicable separation distance. For test separation distance less than 5 mm, the exemption limits for a separation distance of 5 mm can be applied to determine if a routine evaluation is required.
For medical implants devices, the exemption limit for routine evaluation is set at 1 mW. The output power of a medical implants device is defined as the higher of the conducted or e.i.r.p to determine whether the device is exempt from the SAR evaluation.

## 14.4 Test Results for Standalone SAR Test

The calculated SAR is obtained by the following formula:

Reported SAR=Measured SAR*10(Ptarget-Pmeasured))/10
Scaling factor=10(Ptarget-Pmeasured))/10
Reported SAR= Measured SAR* Scaling factor

Where
Ptarget is the power of manufacturing upper limit;
Pmeasured is the measured power;
Measured SAR is measured SAR at measured power which including power drift)
Reported SAR which including Power Drift and Scaling factor

Duty Cycle

| Test Mode | Duty Cycle |
|---|---|
| WLAN2450 | 1:1 |
| WLAN5800 | 1:1 |

SAR Values [WIFI5.8G] 180 degrees

| Ch. | Freq. (MHz) | Service | Test Position | Conducted Power (dBm) | Maximum Allowed Power (dBm) | Power Drift (%) | Scaling Factor | SAR1-g results(W/kg) | | Graph Results |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Measured | Reported | |
| measured / reported SAR numbers - Body (hotspot open, distance 0mm) | | | | | | | | | | |
| 149 | 5745 | 802.11a | Position 3 | 13.74 | 14.00 | 0.54 | 1.062 | 0.106 | 0.113 | |
| 149 | 5745 | 802.11a | Position 4 | 13.74 | 14.00 | 4.41 | 1.062 | 0.126 | **0.134** | Plot 1 |
| 149 | 5745 | 802.11a | Position 1 | 13.74 | 14.00 | 0.32 | 1.062 | 0.087 | 0.092 | |
| 149 | 5745 | 802.11a | Position 2 | 13.74 | 14.00 | 2.14 | 1.062 | 0.072 | 0.076 | |

SAR Values [WIFI5.8G] 90 degrees

| Ch. | Freq. (MHz) | Service | Test Position | Conducted Power (dBm) | Maximum Allowed Power (dBm) | Power Drift (%) | Scaling Factor | SAR1-g results(W/kg) | | Graph Results |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Measured | Reported | |
| measured / reported SAR numbers - Body (hotspot open, distance 0mm) | | | | | | | | | | |
| 149 | 5745 | 802.11a | Position 3 | 13.74 | 14.00 | 0.01 | 1.062 | 0.068 | 0.072 | |
| 149 | 5745 | 802.11a | Position 4 | 13.74 | 14.00 | 1.12 | 1.062 | 0.079 | **0.084** | |
| 149 | 5745 | 802.11a | Position 1 | 13.74 | 14.00 | 2.54 | 1.062 | 0.052 | 0.055 | |
| 149 | 5745 | 802.11a | Position 2 | 13.74 | 14.00 | 0.50 | 1.062 | 0.047 | 0.050 | |

SAR Values [WIFI2.4G] 180 degrees

| Ch. | Freq. (MHz) | Service | Test Position | Conducted Power (dBm) | Maximum Allowed Power (dBm) | Power Drift (%) | Scaling Factor | SAR1-g results(W/kg) | | Graph Results |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Measured | Reported | |
| measured / reported SAR numbers - Body (hotspot open, distance 0mm) | | | | | | | | | | |
| 11 | 2462 | 802.11b | Position 3 | 16.34 | 16.50 | 1.12 | 1.038 | 0.902 | 0.936 | |
| 11 | 2462 | 802.11b | Position 4 | 16.34 | 16.50 | -0.68 | 1.038 | 1.331 | **1.381** | Plot 2 |
| 1 | 2412 | 802.11b | Position 4 | 15.98 | 16.00 | 2.36 | 1.005 | 1.030 | 1.035 | |
| 6 | 2437 | 802.11b | Position 4 | 16.31 | 16.50 | 4.14 | 1.045 | 1.005 | 1.050 | |
| 11 | 2462 | 802.11b | Position 1 | 16.34 | 16.50 | 0.41 | 1.038 | 0.823 | 0.854 | |
| 11 | 2462 | 802.11b | Position 2 | 16.34 | 16.50 | 1.63 | 1.038 | 0.780 | 0.809 | |

SAR Values [WIFI2.4G] 90 degrees

| Ch. | Freq. (MHz) | Service | Test Position | Conducted Power (dBm) | Maximum Allowed Power (dBm) | Power Drift (%) | Scaling Factor | SAR1-g results(W/kg) | | Graph Results |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Measured | Reported | |
| measured / reported SAR numbers - Body (hotspot open, distance 0mm) | | | | | | | | | | |
| 11 | 2462 | 802.11b | Position 3 | 16.34 | 16.50 | 2.23 | 1.038 | 0.541 | 0.561 | |
| 11 | 2462 | 802.11b | Position 4 | 16.34 | 16.50 | 1.54 | 1.038 | 0.745 | **0.773** | |
| 11 | 2462 | 802.11b | Position 1 | 16.34 | 16.50 | 3.84 | 1.038 | 0.503 | 0.522 | |
| 11 | 2462 | 802.11b | Position 2 | 16.34 | 16.50 | 4.12 | 1.038 | 0.487 | 0.505 | |

## 14.5 Standalone SAR Test Exclusion Considerations and Estimated SAR

Per KDB447498 requires when the standalone SAR test exclusion of section 4.3.1 is applied to an antenna that transmits simultaneously with other antennas, the standalone SAR must be estimated according to the following to determine simultaneous transmission SAR test exclusion;

● (max. power of channel, including tune-up tolerance, mW)/(min. test separation distance, mm)]·[$\sqrt{f(GHz)}/x$] W/kg for test separation distances ≤ 50 mm;

where x = 7.5 for 1-g SAR, and x = 18.75 for 10-g SAR.

● 0.4 W/kg for 1-g SAR and 1.0 W/kg for 10-g SAR, when the test separation distances is > 50 mm

Per FCC KD B447498 D01,simultaneous transmission SAR test exclusion may be applied when the sum of the 1-g SAR for all the transmitting antenna in a specific a physical test configuration is ≤1.6 W/Kg.When the sum is greater than the SAR limit,SAR test exclusion is determined by the SAR to peak location separation ratio.

$$\text{Ratio}=\frac{(SAR_1+SAR_2)^{1.5}}{(\text{peak location separation,mm})}<0.04$$

| Estimated stand alone SAR | | | | | |
|---|---|---|---|---|---|
| Communication system | Frequency (MHz) | Configuration | Maximum Power (dBm) | Separation Distance (mm) | Estimated SAR1-g (W/kg) |
| Bluetooth* | 2450 | Hotspot | N/A | 5 | N/A |
| Bluetooth* | 2450 | Body-worn | N/A | 5 | N/A |

Remark:

1. Bluetooth*- Including Lower power Bluetooth
2. Maximum average power including tune-up tolerance;
3. When the minimum test separation distance is < 5 mm, a distance of 5 mm is applied to determine SAR test exclusion
4. Body as body use distance is 5mm from manufacturer declaration of user manual

## 14.6 Simultaneous TX SAR Considerations

Simultaneous transmission SAR test exclusion is determined for each operating configuration and exposure condition according to the reported standalone SAR of each applicable simultaneous transmiting antenna.The device has 2 antennas, DFS antenna(RX only) and WiFi antennas supports 2.4Wi-Fi and 5GWi-Fi.The 2 TX antennas can always transmit simultaneously.The work mode combination is showed as below table.;

Application Simultaneous Transmission information:

| Combination No. | Mode |
|---|---|
| 1 | N/A |

## 14.7 SAR Measurement Variability

According to KDB865664, Repeated measurements are required only when the measured SAR is ≥ 0.80 W/kg. If the measured SAR value of the initial repeated measurement is < 1.45 W/kg with ≤ 20% variation, only one repeated measurement is required to reaffirm that the results are not expected to have substantial variations, which may introduce significant compliance concerns. A second repeated measurement is required only if the measured result for the initial repeated measurement is within 10% of the SAR limit and vary by more than 20%, which are often related to device and measurement setup difficulties. The following procedures are applied to determine if repeated measurements are required. The same procedures should be adapted for measurements according to extremity and occupational exposure limits by applying a factor of 2.5 for extremity exposure and a factor of 5 for occupational exposure to the corresponding SAR thresholds.19 The repeated measurement results must be clearly identified in the SAR report. All measured SAR, including the repeated results, must be considered to determine compliance and for reporting according to KDB 690783.Repeated measurement is not required when the original highest measured SAR is < 0.80 W/kg; steps 2) through 4) do not apply.

1) When the original highest measured SAR is ≥ 0.80 W/kg, repeat that measurement once.
2) Perform a second repeated measurement only if the ratio of largest to smallest SAR for the original and first repeated measurements is > 1.20 or when the original or repeated measurement is ≥ 1.45 W/kg (~ 10% from the 1-g SAR limit).
3) Perform a third repeated measurement only if the original, first or second repeated measurement is ≥ 1.5 W/kg and the ratio of largest to smallest SAR for the original, first and second repeated measurements is > 1.20.
4) Perform a third repeated measurement only if the original, first or second repeated measurement is ≥ 1.5 W/kg and the ratio of largest to smallest SAR for the original, first and second repeated measurements is > 1.20

| Frequency Band (MHz) | Air Interface | RF Exposure Configuration | Test Position | Repeated SAR (yes/no) | Highest Measured SAR1-g (Wkg) | First Repeated | |
|---|---|---|---|---|---|---|---|
| | | | | | | Measued SAR1-g (W/kg) | Largest to Smallest SAR Ratio |
| 2450 | 2.4GWLAN | Standalone | Body-Rear | no | 1.331 | 1.328 | 1.002 |
| 5800 | 5.8GWLAN | Standalone | Body-Rear | no | 0.126 | n/a | n/a |

Remark:

1. Second Repeated Measurement is not required since the ratio of the largest to smallest SAR for the orignal and first repeated measurement is not > 1.20 or 3 (1-g or 10-g respectively)

## 14.8 General description of test procedures

The DUT is tested using CMU 200 communications testers as controller unit to set test channels and maximum output power to the DUT, as well as for measuring the conducted peak power.

1. Test positions as described in the tables above are in accordance with the specified test standard.
2. Tests in body position were performed in that configuration, which generates the highest time based averaged output power (see conducted power results).
3. Tests in head position with GSM were performed in voice mode with 1 timeslot unless GPRS/EGPRS/DTM function allows parallel voice and data traffic on 2 or more timeslots.
4. UMTS was tested in RMC mode with 12.2 kbit/s and TPC bits set to 'all 1'.
5. WiFi was tested in 802.11b/g/n mode with 1 Mbit/s and 6 Mbit/s. According to KDB 248227 the SAR testing for 802.11g/n is not required since When the highest reported SAR for DSSS is adjusted by the ratio of OFDM to DSSS specified maximum output power and the adjusted SAR is ≤ 1.2 W/kg.
6. Required WiFi test channels were selected according to KDB 248227
7. According to FCC KDB pub 248227 D01, When there are multiple test channels with the same measured maximum output power, the channel closest to mid-band frequency is selected for SAR measurement and when there are multiple test channels with the same measured maximum output power and equal separation from mid-band frequency; for example, high and low channels or two mid-band channels, the higher frequency (number) channel is selected for SAR measurement.

8. According to FCC KDB pub 941225 D06 this device has been tested with 10 mm distance to the phantom for operation in WiFi hot spot mode.
9. Per FCC KDB pub 941225 D06 the edges with antennas within 2.5 cm are required to be evaluated for SAR to cover WiFi hot spot function.
10. According to IEEE 1528 the SAR test shall be performed at middle channel. Testing of top and bottom channel is optional.
11. According to KDB 447498 D01 testing of other required channels within the operating mode of a frequency band is not required when the reported 1-g or 10-g SAR for the mid-band or highest output power channel is:
    ● ≤ 0.8 W/kg or 2.0 W/kg, for 1-g or 10-g respectively, when the transmission band is ≤ 100 MHz
    ● ≤ 0.6 W/kg or 1.5 W/kg, for 1-g or 10-g respectively, when the transmission band is between 100 MHz and 200 MHz
    ● ≤ 0.4 W/kg or 1.0 W/kg, for 1-g or 10-g respectively, when the transmission band is ≥ 200 MHz
12. IEEE 1528-2003 require the middle channel to be tested first. This generally applies to wireless devices that are designed to operate in technologies with tight tolerances for maximum output power variations across channels in the band.
13. Per KDB648474 D04 require when the reported SAR for a body-worn accessory, measured without a headset connected to the handset, is < 1.2 W/kg.
14. Per KDB648474 D04 require when the separation distance required for body-worn accessory testing is larger than or equal to that tested for hotspot mode, using the same wireless mode test configuration for voice and data, such as UMTS, LTE and Wi-Fi, and for the same surface of the phone, the hotspot mode SAR data may be used to support body-worn accessory SAR compliance for that particular configuration (surface)
15. 10-g extremity SAR is required only for the surfaces and edges with hotspot mode 1-g SAR > 1.2 W/kg.
16. Per KDB648474 D04 require for phablet SAR test considerations，For Smart phones with a display diagonal dimension > 15.0 cm or an overall diagonal dimension > 16.0 cm, When hotspot mode applies, 10-g extremity SAR is required only for the surfaces and edges with hotspot mode 1-g reported SAR > 1.2 W/kg.
17. 10-g extremity SAR is required only for the surfaces and edges with hotspot mode 1-g SAR > 1.2 W/kg.

## 15. Test Plots

### 15.1 System Check Results

System check at 2450 MHz

A. Experimental conditions.

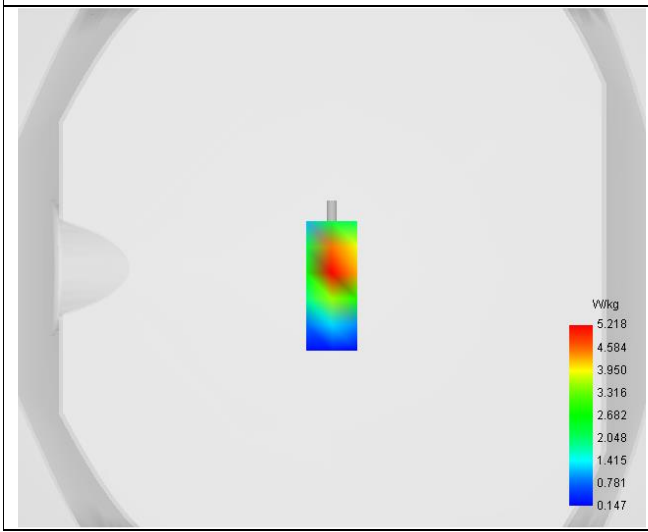
| | |
|---|---|
| Probe | SN EPGO362 |
| ConvF | 26.43 |
| Area Scan | dx=10mm dy=10mm, Adaptative 2 max |
| Zoom Scan | 5x5x7,dx=8mm dy=8mm dz=5mm,Very fast |
| Phantom | Validation plane |
| Device Position | Dipole |
| Band | CW2450 |
| Channels | Middle |
| Signal | CW (Crest factor: 1.0) |

B. Permitivity

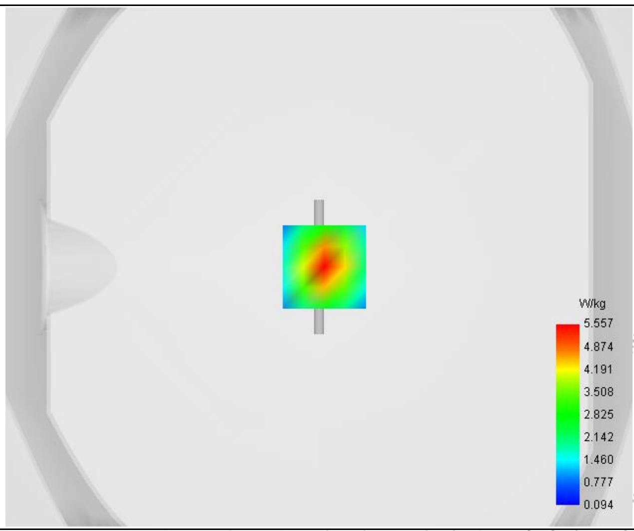
| | |
|---|---|
| Frequency (MHz) | 2450.000 |
| Relative permitivity (real part) | 52.700 |
| Relative permitivity (imaginary part) | 14.330 |
| Conductivity (S/m) | 1.950 |

C. SAR Surface and Volume

SURFACE SAR




VOLUME SAR



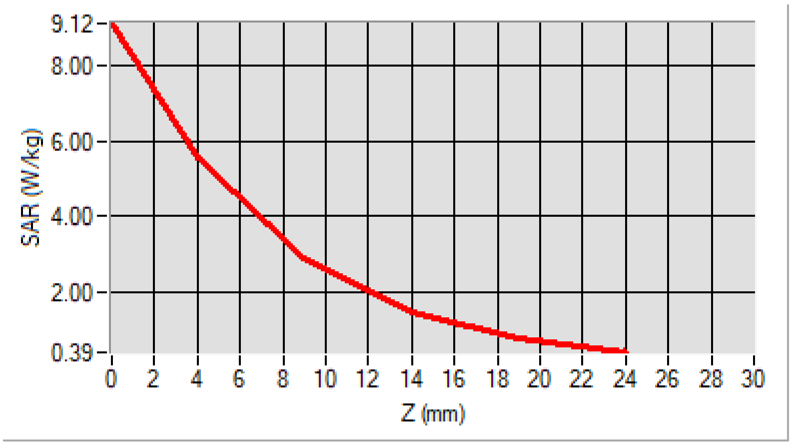

Maximum location: X=2.00, Y=0.00 ; SAR Peak: 9.11 W/kg

D. SAR 1g & 10g

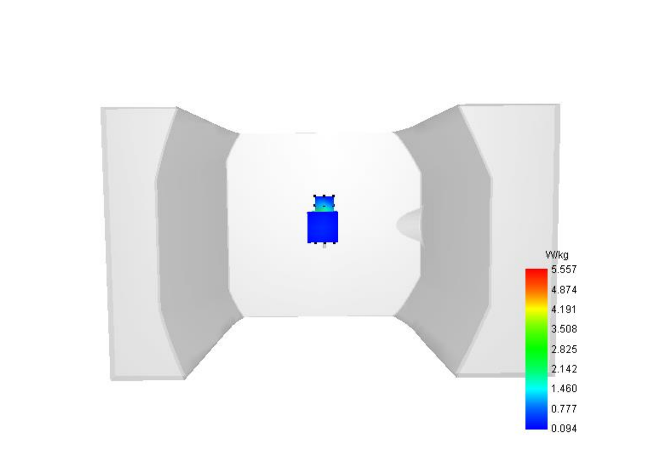
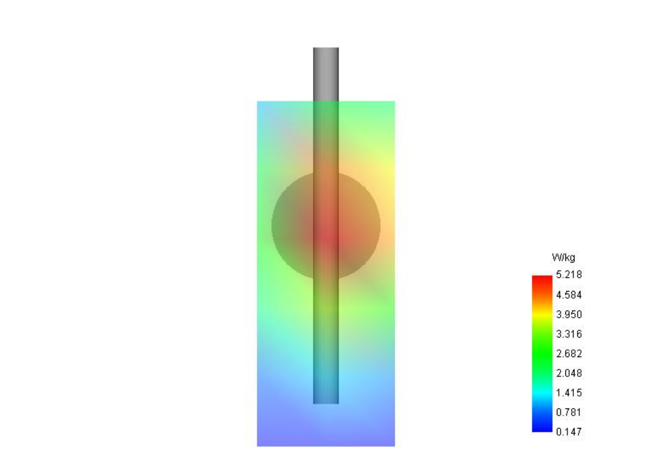
| | |
|---|---|
| SAR 10g (W/Kg) | 2.457 |
| SAR 1g (W/Kg) | 5.085 |
| Variation (%) | 0.360 |
| Horizontal validation criteria: minimum distance (mm) | 0.000000 |
| Vertical validation criteria: SAR ratio M2/M1 (%) | 0.000000 |

E. Z Axis Scan

| | | | | | |
|---|---|---|---|---|---|
| Z (mm) | 0.00 | 4.00 | 9.00 | 14.00 | 19.00 |
| SAR (W/Kg) | 9.121 | 5.557 | 2.866 | 1.459 | 0.770 |




F. 3D Image

| 3D screen shot | Hot spot position |
| --- | --- |
|  |  |

System check at 5800 MHz

A. Experimental conditions.

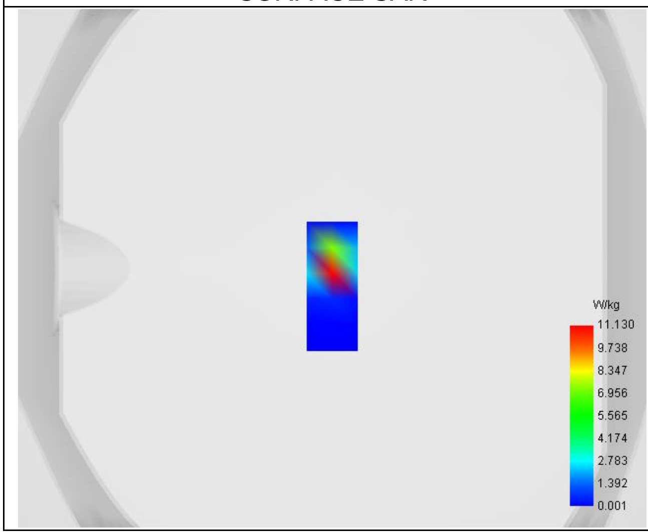
| | |
|---|---|
| Probe | SN EPGO362 |
| ConvF | 21.00 |
| Area Scan | dx=10mm dy=10mm, Adaptative 2 max |
| Zoom Scan | 5x5x7,dx=8mm dy=8mm dz=5mm,Very fast |
| Phantom | Validation plane |
| Device Position | Dipole |
| Band | CW5800 |
| Channels | Middle |
| Signal | CW (Crest factor: 1.0) |

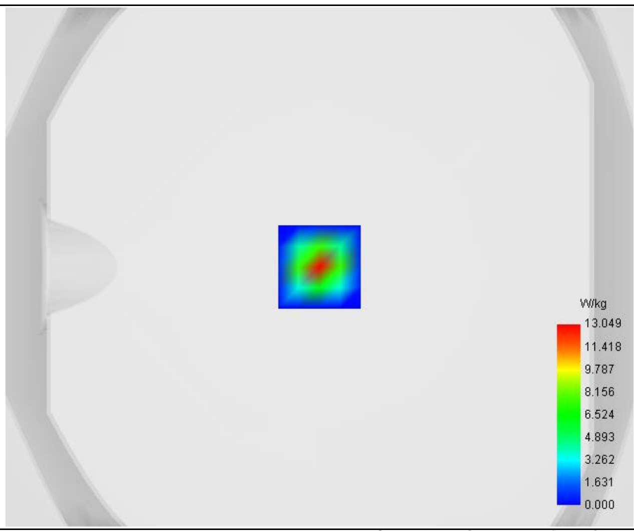
B. Permitivity

| | |
|---|---|
| Frequency (MHz) | 5800.000 |
| Relative permitivity (real part) | 48.200 |
| Relative permitivity (imaginary part) | 18.620 |
| Conductivity (S/m) | 6.000 |

C. SAR Surface and Volume

| SURFACE SAR | VOLUME SAR |
|---|---|
| SURFACE SAR image | VOLUME SAR image |



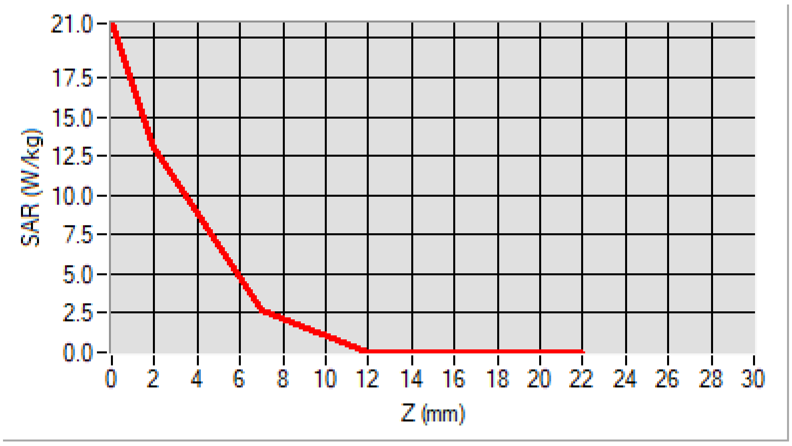

Maximum location: X=0.00, Y=0.00 ; SAR Peak: 22.11 W/kg

D. SAR 1g & 10g

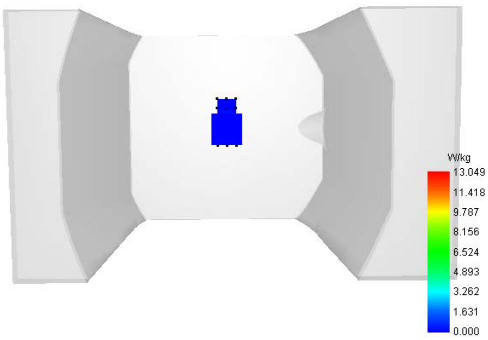
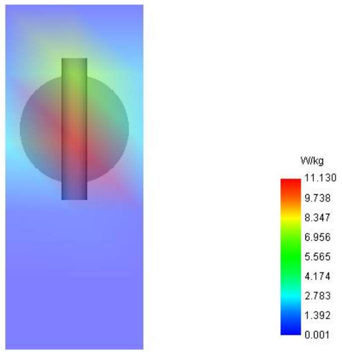
| | |
|---|---|
| SAR 10g (W/Kg) | 2.063 |
| SAR 1g (W/Kg) | 6.847 |
| Variation (%) | 0.430 |
| Horizontal validation criteria: minimum distance (mm) | 0.000000 |
| Vertical validation criteria: SAR ratio M2/M1 (%) | 0.000000 |

E. Z Axis Scan

| | | | | | |
|---|---|---|---|---|---|
| Z (mm) | 0.00 | 2.00 | 7.00 | 12.00 | 17.00 |
| SAR (W/Kg) | 20.951 | 13.049 | 2.674 | 0.012 | 0.003 |




F. 3D Image

| 3D screen shot | Hot spot position |
|---|---|
|  |  |

## 15.2 SAR Test Graph Results

SAR plots for the highest measured SAR in each exposure configuration, wireless mode and frequency band combination according to FCC KDB 865664 D02

# Plot 1

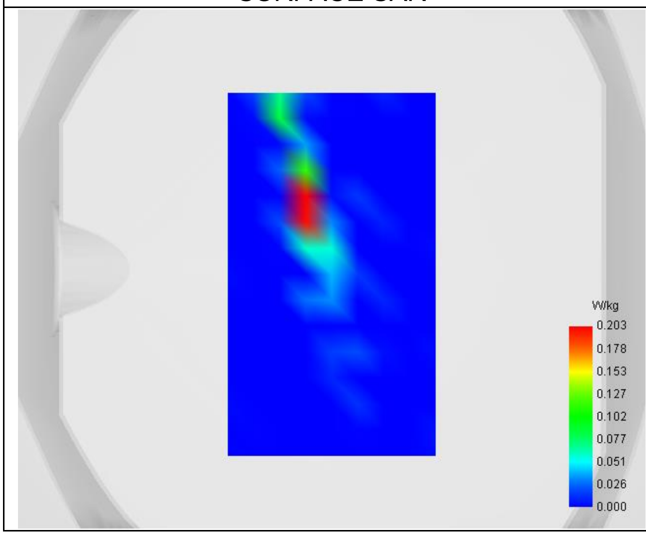
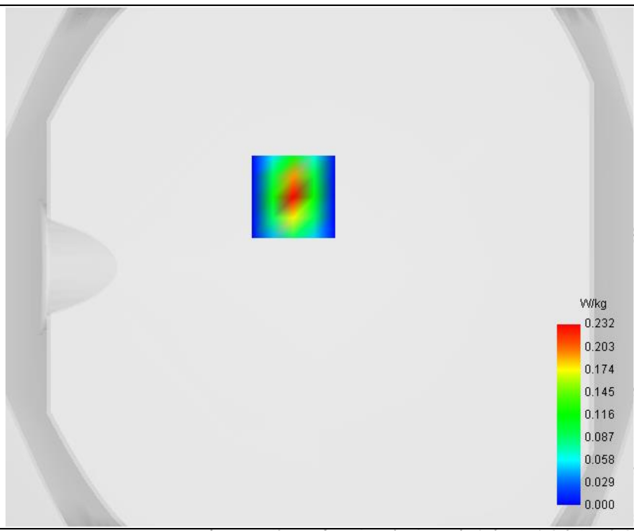
A. Experimental conditions.

| | |
|---|---|
| Probe | SN EPGO362 |
| ConvF | 23.63 |
| Area Scan | surf_sam_plan.txt |
| Zoom Scan | 5x5x7,dx=8mm dy=8mm dz=5mm,Very fast |
| Phantom | Validation plane |
| Device Position | Body |
| Band | IEEE 802.11a U-NII |
| Channels | Middle (149) |
| Signal | IEEE802.a (Crest factor: 1.0) |

B. Permitivity

| | |
|---|---|
| Frequency (MHz) | 5745.000 |
| Relative permitivity (real part) | 35.650 |
| Relative permitivity (imaginary part) | 16.250 |
| Conductivity (S/m) | 4.965 |

C. SAR Surface and Volume

| SURFACE SAR | VOLUME SAR |
|---|---|
|  |  |

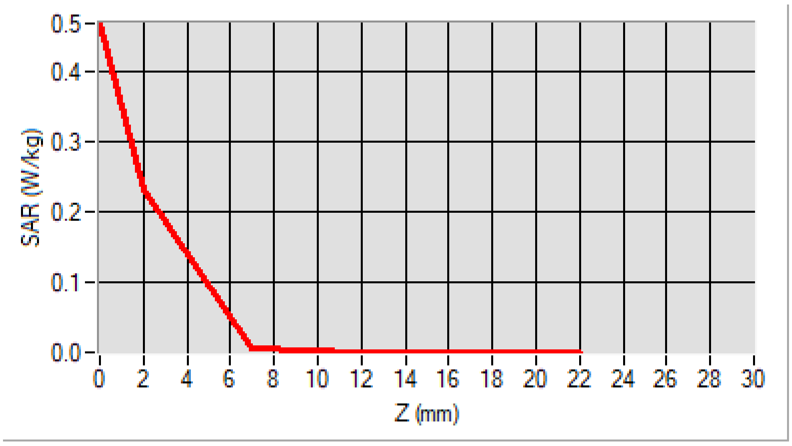
Maximum location: X=-10.00, Y=27.00 ; SAR Peak: 0.53 W/kg

D. SAR 1g & 10g

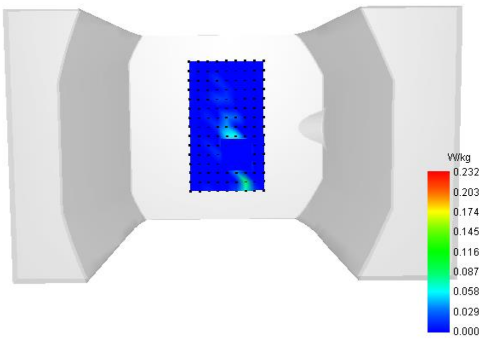
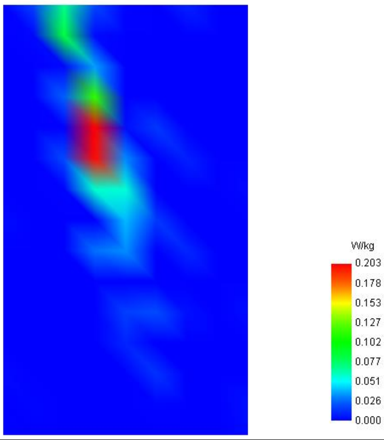
| | |
|---|---|
| SAR 10g (W/Kg) | 0.044 |
| SAR 1g (W/Kg) | 0.126 |
| Variation (%) | 4.410 |
| Horizontal validation criteria: minimum distance (mm) | 0.000000 |
| Vertical validation criteria: SAR ratio M2/M1 (%) | 0.000000 |

E. Z Axis Scan

| Z (mm) | 0.00 | 2.00 | 7.00 | 12.00 | 17.00 |
|---|---|---|---|---|---|
| SAR (W/Kg) | 0.470 | 0.232 | 0.006 | 0.000 | 0.000 |




F. 3D Image

| 3D screen shot | Hot spot position |
|---|---|
|  |  |

# Plot 2

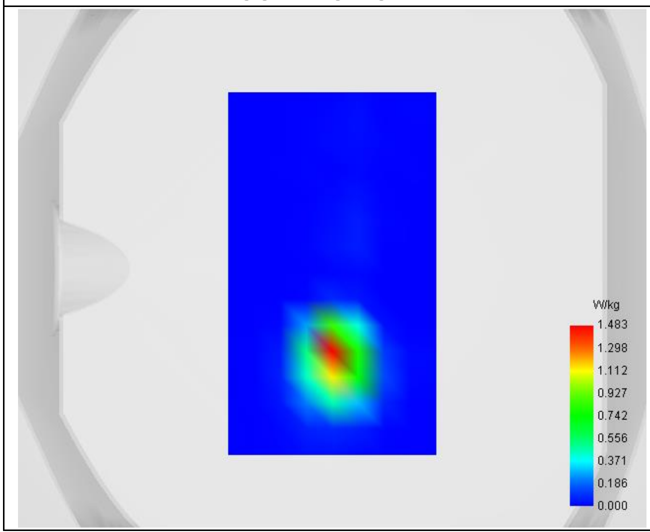
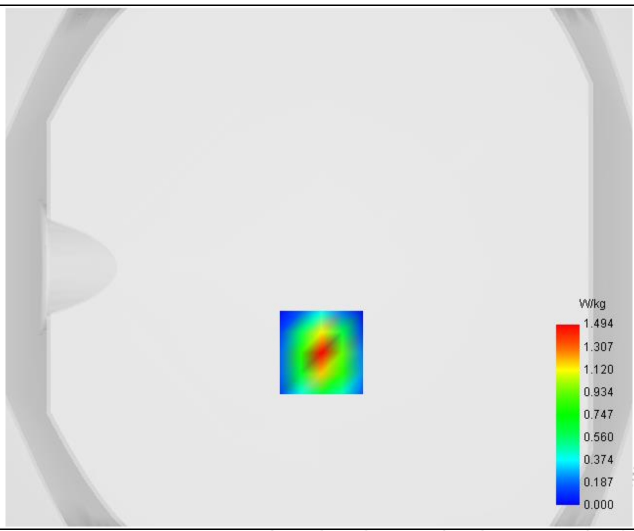
A. Experimental conditions.

| | |
|---|---|
| Probe | SN EPGO362 |
| ConvF | 25.73 |
| Area Scan | surf_sam_plan.txt |
| Zoom Scan | 5x5x7,dx=8mm dy=8mm dz=5mm,Complete |
| Phantom | Validation plane |
| Device Position | Body |
| Band | IEEE 802.11b ISM |
| Channels | High (11) |
| Signal | IEEE802.b (Crest factor: 1.0) |

B. Permitivity

| | |
|---|---|
| Frequency (MHz) | 2462.000 |
| Relative permitivity (real part) | 39.226 |
| Relative permitivity (imaginary part) | 13.207 |
| Conductivity (S/m) | 1.788 |

C. SAR Surface and Volume

| SURFACE SAR | VOLUME SAR |
|---|---|
|  |  |



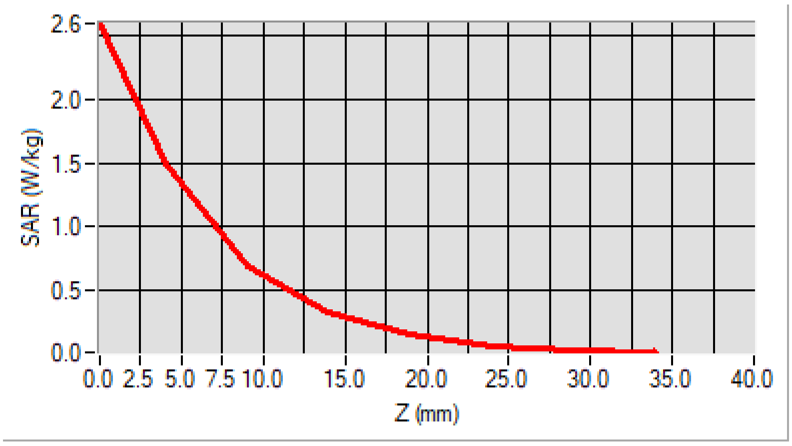
Maximum location: X=1.00, Y=-33.00 ; SAR Peak: 2.58 W/kg

D. SAR 1g & 10g

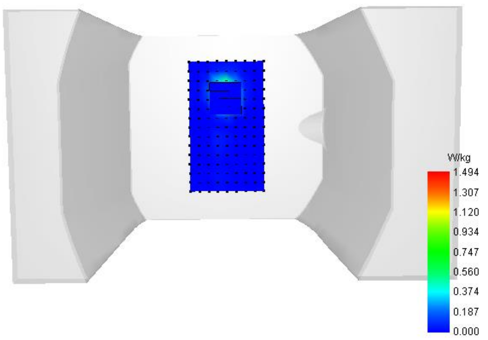
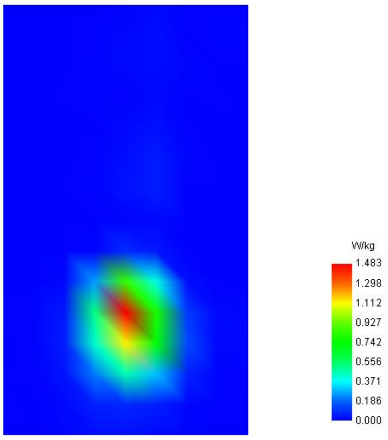
| | |
|---|---|
| SAR 10g (W/Kg) | 0.540 |
| SAR 1g (W/Kg) | 1.331 |
| Variation (%) | -0.680 |
| Horizontal validation criteria: minimum distance (mm) | 11.313708 |
| Vertical validation criteria: SAR ratio M2/M1 (%) | 46.469237 |

E. Z Axis Scan

| Z (mm) | 0.00 | 4.00 | 9.00 | 14.00 | 19.00 | 24.00 | 29.00 |
|---|---|---|---|---|---|---|---|
| SAR (W/Kg) | 2.601 | 1.494 | 0.694 | 0.319 | 0.150 | 0.060 | 0.023 |




F. 3D Image

| 3D screen shot | Hot spot position |
|---|---|
|  |  |

## 16. Calibration Certificates

**Probe-EPGO362 Calibration Certificate**
**SID2450Dipole Calibration Ceriticate**
**SID5000Dipole Calibration Ceriticate**

# COMOSAR E-Field Probe Calibration Report

Ref : ACR.329.6.21.BES.A

**SHENZHEN BCTC TECHNOLOGY CO., LTD.**
**1 ~2/ F, NO. B FACTORY BUILDING, PENGZHOU INDUSTRIAL PARK, FUYUAN 1ST ROAD, TANGWEI COMMUNITY, FUHAI STREET, BAO'AN DISTRICT, SHENZHEN, GUANGDONG,CHINA**
**MVG COMOSAR DOSIMETRIC E-FIELD PROBE**
**SERIAL NO.: SN 46/21 EPGO362**

**Calibrated at MVG**
**Z.I. de la pointe du diable**
**Technopôle Brest Iroise – 295 avenue Alexis de Rochon**
**29280 PLOUZANE - FRANCE**

**Calibration date: 11/25/2021**

Accreditations #2-6789
Scope available on www.cofrac.fr



*Summary:*

This document presents the method and results from an accredited COMOSAR E-Field Probe calibration performed at MVG, using the CALIPROBE test bench, for use with a MVG COMOSAR system only. The test results covered by accreditation are traceable to the International System of Units (SI).

| | *Name* | *Function* | *Date* | *Signature* |
|---|---|---|---|---|
| *Prepared by :* | Jérôme Luc | Technical Manager | 11/25/2021 | JES |
| *Checked by :* | Jérôme Luc | Technical Manager | 11/25/2021 | JES |
| *Approved by :* | Yann Toutain | Laboratory Director | 11/25/2021 | Yann TOUTAIN |

2021.11.25
11:50:23 +01'00'

| | *Customer Name* |
|---|---|
| *Distribution :* | Shenzhen BCTC Technology Co., Ltd. |

| *Issue* | *Name* | *Date* | *Modifications* |
|---|---|---|---|
| A | Jérôme Luc | 11/25/2021 | Initial release |
| | | | |
| | | | |
| | | | |

TABLE OF CONTENTS

## 1 DEVICE UNDER TEST

| Device Under Test | |
|---|---|
| Device Type | COMOSAR DOSIMETRIC E FIELD PROBE |
| Manufacturer | MVG |
| Model | SSE2 |
| Serial Number | SN 46/21 EPGO362 |
| Product Condition (new / used) | New |
| Frequency Range of Probe | 0.15 GHz-6GHz |
| Resistance of Three Dipoles at Connector | Dipole 1: R1=0.221 MΩ<br>Dipole 2: R2=0.231 MΩ<br>Dipole 3: R3=0.212 MΩ |

## 2 PRODUCT DESCRIPTION

### 2.1 GENERAL INFORMATION

MVG's COMOSAR E field Probes are built in accordance to the IEC/IEEE 62209-1528 and FCC KDB865664 D01 standards.

**Figure 1** – *MVG COMOSAR Dosimetric E field Probe*

| | |
|---|---|
| Probe Length | 330 mm |
| Length of Individual Dipoles | 2 mm |
| Maximum external diameter | 8 mm |
| Probe Tip External Diameter | 2.5 mm |
| Distance between dipoles / probe extremity | 1 mm |

## 3 MEASUREMENT METHOD

The IEC/IEEE 62209-1528 and FCC KDB865664 D01 standards provide recommended practices for the probe calibrations, including the performance characteristics of interest and methods by which to assess their affect. All calibrations / measurements performed meet the fore mentioned standards.

### 3.1 LINEARITY

The evaluation of the linearity was done in free space using the waveguide, performing a power sweep to cover the SAR range 0.01W/kg to 100W/kg.

### 3.2 SENSITIVITY

The sensitivity factors of the three dipoles were determined using a two step calibration method (air and tissue simulating liquid) using waveguides as outlined in the standards.

### 3.3 LOWER DETECTION LIMIT

The lower detection limit was assessed using the same measurement set up as used for the linearity measurement. The required lower detection limit is 10 mW/kg.

### 3.4 ISOTROPY

The axial isotropy was evaluated by exposing the probe to a reference wave from a standard dipole with the dipole mounted under the flat phantom in the test configuration suggested for system validations and checks. The probe was rotated along its main axis from 0 to 360 degrees in 15-degree steps. The hemispherical isotropy is determined by inserting the probe in a thin plastic box filled with tissue-equivalent liquid, with the plastic box illuminated with the fields from a half wave dipole. The dipole is rotated about its axis (0°–180°) in 15° increments. At each step the probe is rotated about its axis (0°–360°).

### 3.1 BOUNDARY EFFECT

The boundary effect is defined as the deviation between the SAR measured data and the expected exponential decay in the liquid when the probe is oriented normal to the interface. To evaluate this effect, the liquid filled flat phantom is exposed to fields from either a reference dipole or waveguide. With the probe normal to the phantom surface, the peak spatial average SAR is measured and compared to the analytical value at the surface.

The boundary effect uncertainty can be estimated according to the following uncertainty approximation formula based on linear and exponential extrapolations between the surface and $d_{be}$ + $d_{step}$ along lines that are approximately normal to the surface:

$$SAR_{uncertainty}[\%] = \delta SAR_{be}\frac{(d_{be}+d_{step})^2}{2d_{step}}\frac{(e^{-d_{be}/(\delta/2)})}{\delta/2} \quad \text{for } (d_{be}+d_{step}) < 10\text{ mm}$$

where

| | |
|---|---|
| $SAR_{uncertainty}$ | is the uncertainty in percent of the probe boundary effect |
| $d_{be}$ | is the distance between the surface and the closest *zoom-scan* measurement point, in millimetre |
| $\Delta_{step}$ | is the separation distance between the first and second measurement points that are closest to the phantom surface, in millimetre, assuming the boundary effect at the second location is negligible |
| $\delta$ | is the minimum penetration depth in millimetres of the head tissue-equivalent liquids defined in this standard, i.e., $\delta \approx$ 14 mm at 3 GHz; |
| $\Delta SAR_{be}$ | in percent of SAR is the deviation between the measured SAR value, at the distance $d_{be}$ from the boundary, and the analytical SAR value. |

The measured worst case boundary effect SARuncertainty[%] for scanning distances larger than 4mm is 1.0% Limit ,2%).

## 4 MEASUREMENT UNCERTAINTY

The guidelines outlined in the IEC/IEEE 62209-1528 and FCC KDB865664 D01 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 (%)** |
| **Expanded uncertainty**<br>95 % confidence level k = 2 | | | | | 14 % |

## 5 CALIBRATION MEASUREMENT RESULTS

| Calibration Parameters | |
|---|---|
| Liquid Temperature | 20 +/- 1 °C |
| Lab Temperature | 20 +/- 1 °C |
| Lab Humidity | 30-70 % |

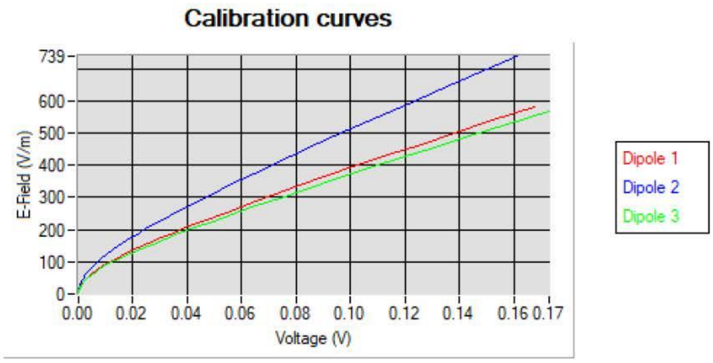
### 5.1 SENSITIVITY IN AIR

| Normx dipole 1 (µV/(V/m)$^2$) | Normy dipole 2 (µV/(V/m)$^2$) | Normz dipole 3 (µV/(V/m)$^2$) |
|---|---|---|
| 1.25 | 0.74 | 1.41 |

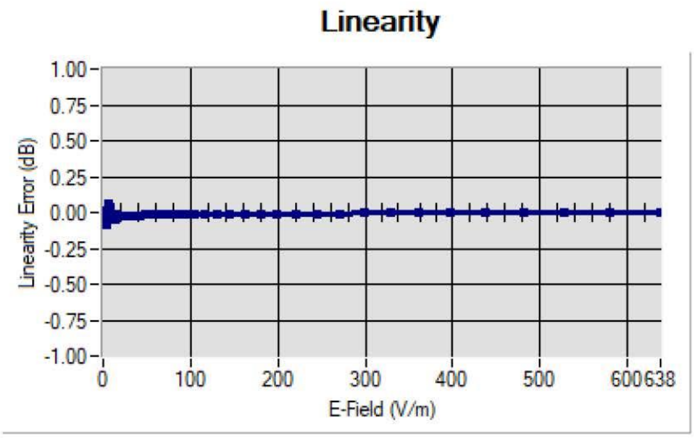
| DCP dipole 1 (mV) | DCP dipole 2 (mV) | DCP dipole 3 (mV) |
|---|---|---|
| 110 | 107 | 107 |

Calibration curves ei=f(V) (i=1,2,3) allow to obtain E-field value using the formula:

$$E = \sqrt{E_1^2 + E_2^2 + E_3^2}$$




5.2 LINEARITY




Linearity:+/-1.89% (+/-0.08dB)

## 5.3 SENSITIVITY IN LIQUID

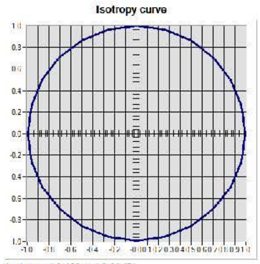
| Liquid | Frequency (MHz +/- 100MHz) | ConvF |
|---|---|---|
| HL450* | 450 | 2.13 |
| BL450* | 450 | 2.08 |
| HL750 | 750 | 2.04 |
| BL750 | 750 | 2.12 |
| HL850 | 835 | 2.08 |
| BL850 | 835 | 2.17 |
| HL900 | 900 | 2.13 |
| BL900 | 900 | 2.22 |
| HL1800 | 1800 | 2.35 |
| BL1800 | 1800 | 2.72 |
| HL1900 | 1900 | 2.50 |
| BL1900 | 1900 | 2.96 |
| HL2100 | 2100 | 2.63 |
| BL2100 | 2100 | 3.12 |
| HL2300 | 2300 | 2.95 |
| BL2300 | 2300 | 3.41 |
| HL2450 | 2450 | 2.99 |
| BL2450 | 2450 | 3.38 |
| HL2600 | 2600 | 2.87 |
| BL2600 | 2600 | 2.98 |
| HL5200 | 5200 | 2.78 |
| BL5200 | 5200 | 2.90 |
| HL5400 | 5400 | 2.63 |
| BL5400 | 5400 | 2.75 |
| HL5600 | 5600 | 2.59 |
| BL5600 | 5600 | 2.55 |
| HL5800 | 5800 | 2.59 |
| BL5800 | 5800 | 2.70 |

* Frequency not covered by COFRAC scope, calibration not accredited

LOWER DETECTION LIMIT: 8mW/kg

## 5.4 ISOTROPY

**HL1800 MHz**




Isotropy:+/-0.40% (+/-0.02dB)

## 6 LIST OF EQUIPMENT

| Equipment Summary Sheet | | | | |
|---|---|---|---|---|
| **Equipment Description** | **Manufacturer / Model** | **Identification No.** | **Current Calibration Date** | **Next Calibration Date** |
| CALIPROBE Test Bench | Version 2 | NA | Validated. No cal required. | Validated. No cal required. |
| Network Analyzer | Rohde & Schwarz ZVM | 100203 | 08/2021 | 08/2024 |
| Network Analyzer | Agilent 8753ES | MY40003210 | 10/2019 | 10/2022 |
| Network Analyzer – Calibration kit | Rohde & Schwarz ZV-Z235 | 101223 | 05/2019 | 05/2022 |
| Network Analyzer – Calibration kit | HP 85033D | 3423A08186 | 06/2021 | 06/2027 |
| Multimeter | Keithley 2000 | 1160271 | 02/2020 | 02/2023 |
| Signal Generator | Rohde & Schwarz SMB | 106589 | 04/2019 | 04/2022 |
| Amplifier | MVG | MODU-023-C-0002 | Characterized prior to test. No cal required. | Characterized prior to test. No cal required. |
| Power Meter | NI-USB 5680 | 170100013 | 06/2021 | 06/2024 |
| Power Meter | Rohde & Schwarz NRVD | 832839-056 | 11/2019 | 11/2022 |
| Directional Coupler | Krytar 158020 | 131467 | Characterized prior to test. No cal required. | Characterized prior to test. No cal required. |
| Waveguide | MVG | SN 32/16 WG4_1 | Validated. No cal required. | Validated. No cal required. |
| Liquid transition | MVG | SN 32/16 WGLIQ_0G900_1 | Validated. No cal required. | Validated. No cal required. |
| Waveguide | MVG | SN 32/16 WG6_1 | Validated. No cal required. | Validated. No cal required. |
| Liquid transition | MVG | SN 32/16 WGLIQ_1G500_1 | Validated. No cal required. | Validated. No cal required. |
| Waveguide | MVG | SN 32/16 WG8_1 | Validated. No cal required. | Validated. No cal required. |
| Liquid transition | MVG | SN 32/16 WGLIQ_1G800B_1 | Validated. No cal required. | Validated. No cal required. |
| Liquid transition | MVG | SN 32/16 WGLIQ_1G800H_1 | Validated. No cal required. | Validated. No cal required. |
| Waveguide | MVG | SN 32/16 WG10_1 | Validated. No cal required. | Validated. No cal required. |
| Liquid transition | MVG | SN 32/16 WGLIQ_3G500_1 | Validated. No cal required. | Validated. No cal required. |

| | | | | |
|---|---|---|---|---|
| Waveguide | MVG | SN 32/16 WG12_1 | Validated. No cal required. | Validated. No cal required. |
| Liquid transition | MVG | SN 32/16 WGLIQ_5G000_1 | Validated. No cal required. | Validated. No cal required. |
| Temperature / Humidity Sensor | Testo 184 H1 | 44225320 | 06/2021 | 06/2024 |

# SAR Reference Dipole Calibration Report

Ref : ACR.329.15.21.BES.A

**SHENZHEN BCTC TECHNOLOGY CO., LTD.**
**1 ~2/ F, NO. B FACTORY BUILDING, PENGZHOU INDUSTRIAL PARK, FUYUAN 1ST ROAD, TANGWEI COMMUNITY, FUHAI STREET, BAO'AN DISTRICT, SHENZHEN, GUANGDONG,CHINA**
**MVG COMOSAR REFERENCE DIPOLE**
**FREQUENCY: 2450 MHZ**
**SERIAL NO.: SN 47/21 DIP 2G450-627**

**Calibrated at MVG**
**Z.I. de la pointe du diable**
**Technopôle Brest Iroise – 295 avenue Alexis de Rochon**
**29280 PLOUZANE - FRANCE**

**Calibration date: 11/25/2021**

Accreditations #2-6789 and #2-6814
Scope available on www.cofrac.fr



*Summary:*

This document presents the method and results from an accredited SAR reference dipole calibration performed in MVG using the COMOSAR test bench. All calibration results are traceable to national metrology institutions.

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| | *Name* | *Function* | *Date* | *Signature* |
|---|---|---|---|---|
| *Prepared by :* | Jérôme Luc | Technical Manager | 11/25/2021 | JS |
| *Checked by :* | Jérôme Luc | Technical Manager | 11/25/2021 | JS |
| *Approved by :* | Yann Toutain | Laboratory Director | 11/25/2021 | Yann TOUTAIN |

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| | *Customer Name* |
|---|---|
| *Distribution :* | Shenzhen BCTC Technology Co., Ltd. |

| *Issue* | *Name* | *Date* | *Modifications* |
|---|---|---|---|
| A | Jérôme Luc | 11/25/2021 | Initial release |
| | | | |
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