

SAR TEST REPORT

for

Harman International Industries, Inc.

BLUETOOTH HEADSET

Model No.: TUNE125TWS

FCC ID: APITUNE125TWS

IC: 6132A-TUNE125TWS

| The MAX SAR(1g) | |
|-----------------|-------------|
| Head SAR | 0.23171W/Kg |

Prepared for : Harman International Industries, Inc.
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Date of Test : Jan.19, 2020

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ANNEX A: SYSTEM CHECK RESULTS

ANNEX B: TEST PLOTS

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ANNEX D: TEST SETUP PHOTOS

SAR TEST REPORT

Applicant : Harman International Industries, Inc.
Product : BLUETOOTH HEADSET
FCC ID : APITUNE125TWS
IC : 6132A-TUNE125TWS
(A) Model No. : TUNE125TWS
(B) Test Voltage : DC 3.7V (battery)

Measurement Standard Used:

- FCC 47 CFR Part 2 (2.1093)
- IEEE C95.1-1999
- IEEE 1528-2013
- IEC62209-2:2010
- FCC OET Bulletin 65 Supplement C (Edition 01-01)
- RSS-102 ISSUE 5: 2015
- FCC KDB 447498 D01 v06
- FCC KDB 865664 D01/D02

The device described above is tested by Audix Technology (Shenzhen) Co., Ltd. to determine the maximum emission levels emanating from the device and the severe levels of the device can endure and its performance criterion. The test results are contained in this test report and Audix Technology (Shenzhen) Co., Ltd. is assumed full responsibility for the accuracy and completeness of test. This report contains data that are not covered by the NVLAP accreditation. Also, this report shows that the EUT is technically compliant with the FCC and RSS-102 requirements.

This report applies to above tested sample only. This report shall not be reproduced in part without written approval of Audix Technology (Shenzhen) Co., Ltd.

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

Date of Test : Jan.19, 2020 Report of date: Feb.14, 2020

Prepared by : Monica Liu Reviewed by : Sunny Lu
Monica Liu/Assistant Sunny Lu / Deputy Manager



Approved & Authorized Signer: David Jin
David Jin / Deputy General Manager

1. GENERAL INFORMATION

1.1. Description of Equipment Under Test

| | |
|-----------------|---|
| Applicant | Harman International Industries, Inc. 8500 Balboa Boulevard, Northridge, CA 91329, UNITED STATES |
| Manufacturer | Harman International Industries, Inc. 8500 Balboa Boulevard, Northridge, CA 91329, UNITED STATES |
| Product | BLUETOOTH HEADSET |
| Model No. | TUNE125TWS |
| FCC ID | APITUNE125TWS |
| IC | 6132A-TUNE125TWS |
| Sample Type | Prototype production |
| Date of Receipt | Jan.17, 2020 |
| Date of Test | Jan.19, 2020 |

1.2. Feature of Equipment Under Test

| Product Feature & Specification | | |
|---------------------------------|---|---------------|
| Product | BLUETOOTH HEADSET | |
| Model No. | TUNE125TWS | |
| FCC ID | APITUNE125TWS | |
| IC | 6132A-TUNE125TWS | |
| Radio | Bluetooth BDR+EDR; BLE | |
| Power Source | <input type="checkbox"/> Commercial Power | AC V |
| | <input type="checkbox"/> External Power Source | DC V |
| | <input checked="" type="checkbox"/> Coin cell battery | DC 3.7V, 85mA |
| Bluetooth | | |
| Frequency Range | 2402-2480MHz | |
| Type of Modulation | GFSK, $\pi/4$ DQPSK, 8DPSK | |
| Data Rate | 1Mbps, 2Mbps, 3Mbps | |
| Quantity of Channels | 79/40 | |
| Channel Separation | 1MHz/2MHz | |

Antenna System

| Bluetooth | |
|-------------------|------------------------------------|
| Type of Antenna | LDS Antenna |
| Antenna number | 1 |
| Antenna Peak Gain | Left: -1.12dBi; Right: -0.45dBi |

2. GENERAL DESCRIPTION

2.1. Product Description For EUT [None]

2.2. Applied Standards

The Specific Absorption Rate (SAR) testing specification, method and procedure for this device is in accordance with the following standards:

- FCC 47 CFR Part 2 (2.1093)
- IEEE C95.1-1999
- IEEE 1528-2013
- IEC62209-2:2010
- FCC OET Bulletin 65 Supplement C (Edition 01-01)
- RSS-102 ISSUE 5: 2015
- FCC KDB 447498 D01 v06
- FCC KDB 865664 D01/D02

2.3. Device Category and SAR Limits

This device belongs to portable device category because its radiating structure is allowed to be used within 20 centimeters of the body of the user. Limit for General Population/Uncontrolled exposure should be applied for this device, it is 1.6 W/kg as averaged over any 1 gram of tissue.

2.4. Test Conditions

2.4.1. Ambient Condition

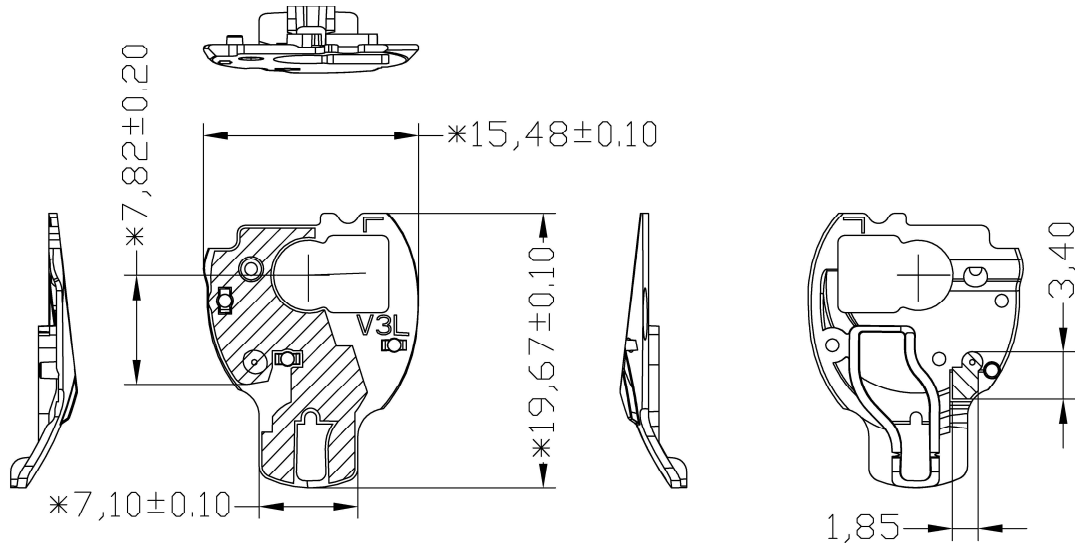
| | |
|---------------------|-------------|
| Ambient Temperature | 20 to 24 °C |
| Humidity | < 60 % |

2.4.2. Test Configuration

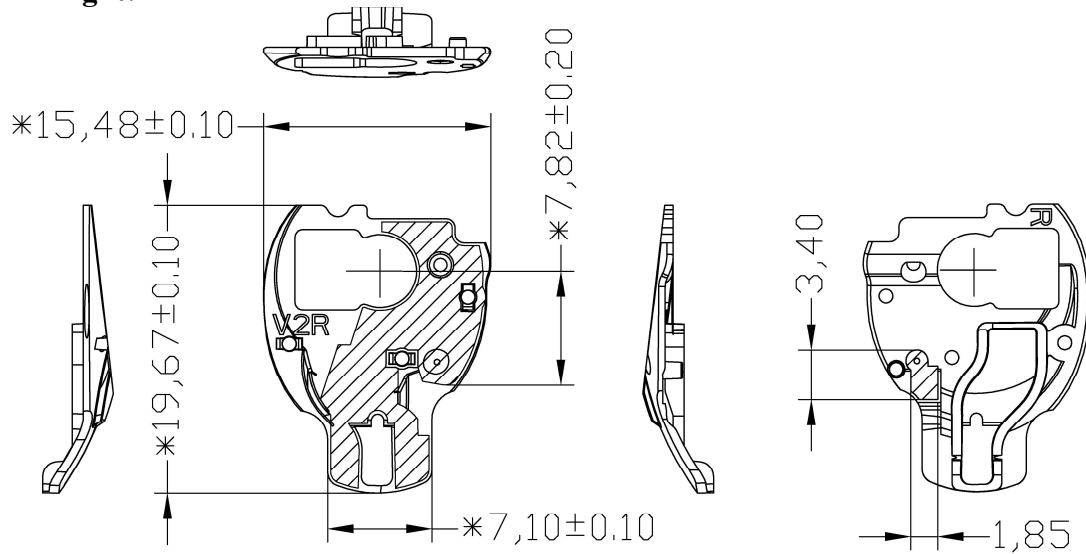
The distance between the EUT and the antenna of the emulator is larger than 50 cm and the output power radiated from the emulator antenna is at least 30dB smaller than the output power of EUT. The EUT was set from the emulator to radiate maximum output power during all tests.

2.5. Exposure Positions Consideration

Left:



Right:



| Antenna | Description |
|---------|------------------------|
| antenna | Bluetooth BDR+EDR; BLE |

| Sides for SAR tests | | | | | | |
|---------------------------|---------|-------|-----|--------|------|-------|
| Test distance: 0 mm(Head) | | | | | | |
| Band | Head | | | | | |
| | Cochlea | Front | Top | Bottom | Left | Right |
| Bluetooth | √ | √ | √ | √ | √ | √ |

Note:

The side which has a distance larger than 5cm from antenna can be excluded from SAR measurement.

2.6. Standalone SAR Test Exclusion Considerations

According to RSS-102 Table 1, the SAR test exclusion threshold for 2450MHz at 5mm test separation distances is 4mW.

| 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 |

Standalone 1-g head or body SAR evaluation by measurement or numerical simulation is not required when the corresponding SAR Exclusion Threshold condition, listed below, is satisfied. The 1-g SAR test exclusion threshold for 100 MHz to 6 GHz at test separation distances ≤ 50 mm are determined by:

$[(\text{max. power of channel, including tune-up tolerance, mW}) / (\text{min. test separation distance, mm})] \cdot [\sqrt{f(\text{GHz})}] \leq 3.0$ for 1-g SAR, where

- $f(\text{GHz})$ 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

According to the KDB447498 appendix A, the SAR test exclusion threshold for 2450MHz at 5mm test separation distances is 10 mW.

Appendix A

SAR Test Exclusion Thresholds for 100 MHz – 6 GHz and ≤ 50 mm

Approximate SAR Test Exclusion Power Thresholds at Selected Frequencies and Test Separation Distances are illustrated in the following Table.

| MHz | 5 | 10 | 15 | 20 | 25 | mm |
|------|----|----|-----|-----|-----|-----------------------------------|
| 150 | 39 | 77 | 116 | 155 | 194 | SAR Test Exclusion Threshold (mW) |
| 300 | 27 | 55 | 82 | 110 | 137 | |
| 450 | 22 | 45 | 67 | 89 | 112 | |
| 835 | 16 | 33 | 49 | 66 | 82 | |
| 900 | 16 | 32 | 47 | 63 | 79 | |
| 1500 | 12 | 24 | 37 | 49 | 61 | |
| 1900 | 11 | 22 | 33 | 44 | 54 | |
| 2450 | 10 | 19 | 29 | 38 | 48 | |
| 3600 | 8 | 16 | 24 | 32 | 40 | |
| 5200 | 7 | 13 | 20 | 26 | 33 | |
| 5400 | 6 | 13 | 19 | 26 | 32 | |
| 5800 | 6 | 12 | 19 | 25 | 31 | |

2.7. EUT Configuration and operation conditions for test.

EUT

(EUT: BLUETOOTH HEADSET)

2.8. Test Equipments

| Item | Equipment | Manufacturer | Model No. | Serial No. | Last Cal Date | Validity Date | Cal. Agency |
|------|---------------------------------|--------------------------------|--------------|--------------|---------------|---------------|-------------|
| 1. | DASY5 SAR Test System | Speag | TX60 L speag | F09/5B1H1/01 | NCR | NCR | N/A |
| 2. | Wireless Communication Test Set | Agilent | E5515C | GB443002433 | 2019.04.13 | 2020.04.13 | CCIC |
| 3. | Power Meter | Anritsu | ML2487A | 6K00003262 | 2019.04.13 | 2020.04.13 | CCIC |
| 4. | Power Sensor | Anritsu | MA2491A | 032516 | 2019.04.13 | 2020.04.13 | CCIC |
| 5. | Signal Generator | Rohde&Schwarz | SMB100A | 181375 | 2019.04.23 | 2020.04.23 | CCIC |
| 6. | Amplifier | Milmega | ZHL-42W | C620601316 | NCR | NCR | N/A |
| 7. | Dipole Validation Kits | Speag | D2450V2 | 862 | 2017.06.06 | 2020.06.06 | SPEAG |
| 8. | Attenuator | N/A | 1527 | 001 | 2019.10.13 | 2020.10.13 | CCIC |
| 9. | Date Acquisition Electronics | Speag | DAE4 | 899 | 2019.03.19 | 2020.03.19 | CCTL |
| 10. | E-Field Probe | Speag | EX3DV4 | 3767 | 2019.03.25 | 2020.03.25 | CCTL |
| 11. | ENA Series Analyzer | Agilent | E5071B | MY42403549 | 2019.04.13 | 2020.04.13 | CCIC |
| 12. | Test Software | Schmid&Partner Englinnering AG | DASY5 | 52.8.7.1137 | NCR | NCR | NCR |
| 13. | Radio Communication Analyzer | ANRITSU | MT8820C | 6201091003 | 2019.10.12 | 2020.10.12 | CCIC |
| 14. | Radio Communication Analyzer | R&S | CMW500 | 103249 | 2019.10.12 | 2020.10.12 | CCIC |

Note: Dipole antenna calibration interval is 3 year, annual check result to be follow (Refer to KDB 865664, Dipole calibration)

Dipole: 2450V2-SN862

Antenna Parameters with Body TSL

| Date | 2017.06.06 (Reference Value) | 2018.06.05 (Measured Value) | 2019.06.04 (Measured Value) |
|--|---------------------------------|--------------------------------|--------------------------------|
| Impedance, Transformed to Feed point | 50.7Ω+4.98jΩ | 50.3Ω+4.83jΩ | 50.8Ω+4.76jΩ |
| Return Loss | -26.0dB | -25.4dB | -26.4dB |

Antenna Parameters with Head TSL

| Date | 2017.06.06 (Reference Value) | 2018.06.05 (Measured Value) | 2019.06.04 (Measured Value) |
|--|---------------------------------|--------------------------------|--------------------------------|
| Impedance, Transformed to Feed point | 48.6Ω+5.14jΩ | 47.5Ω+5.04jΩ | 48.3Ω+5.18jΩ |
| Return Loss | -25.4dB | -24.7dB | -24.5dB |

Note: The impedance of the measured value, deviates by less than 5 Ω form the reference Value; the return loss of the measured value, deviates by less than 20% form the reference value. According to KDB 865664 D01 instead of the typical annual calibration recommended by measurement standards, longer calibration intervals of up to three years may be considered

2.9. Laboratory Environment

| | |
|--|------------------------|
| Temperature | Min:20°C,Max.25°C |
| Relative humidity | Min. = 30%, Max. = 70% |
| Note: Ambient noise is checked and found very low and in compliance with requirement of standards. | |

2.10. Measurement Uncertainty

| Test Item | Uncertainty |
|--|-------------|
| Uncertainty for SAR test | 1g: 21.14 |
| | 10g: 20.64 |
| Uncertainty for test site temperature and humidity | 0.6°C |

| Source | Type | Uncertainty Value (%) | Probability Distribution | K | C1(1g) | C1(10g) | Standard uncertainty u _i (%)1g | Standard uncertainty u _i (%)10g | Degree of freedom V _{eff} or V _i |
|--|--|-----------------------|--------------------------|----------|------------|---------|---|--|--|
| Measurement system repeatability | A | 0.5 | N | 1 | | 1 | 0.5 | 0.5 | 9 |
| Probe calibration | B | 5.9 | N | 1 | 1 | 1 | 5.9 | 5.9 | ∞ |
| Isotropy | B | 4.7 | R | √3 | 1 | 1 | 2.7 | 2.7 | ∞ |
| Linearity | B | 4.7 | R | √3 | 1 | 1 | 2.7 | 2.7 | ∞ |
| Probe modulation response | B | 0 | R | √3 | 1 | 1 | 0 | 0 | ∞ |
| Detection limits | B | 1.0 | R | √3 | 1 | 1 | 0.6 | 0.6 | ∞ |
| Boundary effect | B | 1.9 | R | √3 | 1 | 1 | 1.1 | 1.1 | ∞ |
| Readout electronics | B | 1.0 | N | 1 | 1 | 1 | 1.0 | 1.0 | ∞ |
| Response time | B | 0 | R | √3 | 1 | 1 | 0 | 0 | ∞ |
| Integration time | B | 4.32 | R | √3 | 1 | 1 | 2.5 | 2.5 | ∞ |
| RF ambient conditions – noise | B | 0 | R | √3 | 1 | 1 | 0 | 0 | ∞ |
| RF ambient conditions – reflections | B | 3 | R | √3 | 1 | 1 | 1.73 | 1.73 | ∞ |
| Probe positioner mech. restrictions | B | 0.4 | R | √3 | 1 | 1 | 0.2 | 0.2 | ∞ |
| Probe positioning with respect to phantom shell | B | 2.9 | R | √3 | 1 | 1 | 1.7 | 1.7 | ∞ |
| Post-processing | B | 0 | R | √3 | 1 | 1 | 0 | 0 | ∞ |
| Test sample related | | | | | | | | | |
| Device holder uncertainty | A | 2.94 | N | 1 | 1 | 1 | 2.94 | 2.94 | M-1 |
| Test sample positioning | A | 4.1 | N | 1 | 1 | 1 | 4.1 | 4.1 | M-1 |
| Power scaling | B | 5.0 | R | √3 | 1 | 1 | 2.9 | 2.9 | ∞ |
| Drift of output power (measured SAR drift) | B | 5.0 | R | √3 | 1 | 1 | 2.9 | 2.9 | ∞ |
| Phantom and set-up | | | | | | | | | |
| Phantom uncertainty (shape and thickness tolerances) | B | 4.0 | R | √3 | 1 | 1 | 2.3 | 2.1 | ∞ |
| Algorithm for correcting SAR for deviations in permittivity and conductivity | B | 1.9 | N | 1 | 1 | 0,84 | 1,9 | 1,6 | ∞ |
| Liquid conductivity (meas.) | A | 0.55 | N | 1 | 0.78 | 0.71 | 0.24 | 0.21 | M-1 |
| Liquid permittivity (meas.) | A | 0.19 | N | 1 | 0.23 | 0.26 | 0.09 | 0.06 | M |
| Liquid permittivity – temperature uncertainty | A | 5.0 | R | √3 | 0,78 | 0,71 | 1.4 | 1.1 | ∞ |
| Liquid conductivity – temperature uncertainty | A | 5.0 | R | √3 | 0.23 | 0,26 | 1.2 | 0.8 | ∞ |
| Combined standard uncertainty | $u_c = \sqrt{\sum_{i=1}^{23} c_i^2 u_i^2}$ | | | | | | 10.57 | 10.32 | |
| Expanded uncertainty (95 % conf. interval) | $u_e = 2u_c$ | | | N | K=2 | | 21.14 | 20.64 | |

The following tissue formulations are provided for reference only as some of the parameters have not been thoroughly verified. The composition of ingredients may be modified accordingly to achieve the desired target tissue parameters required for routine SAR evaluation.

| Ingredients (% by weight) | Frequency (MHz) | | | | | | | | | |
|------------------------------|-----------------|-------|-------|------|-------|-------|-------|------|------|------|
| | 450 | | 835 | | 915 | | 1900 | | 2450 | |
| Tissue Type | Head | Body | Head | Body | Head | Body | Head | Body | Head | Body |
| Water | 38.56 | 51.16 | 41.45 | 52.4 | 41.05 | 56.0 | 54.9 | 40.4 | 62.7 | 73.2 |
| Salt (NaCl) | 3.95 | 1.49 | 1.45 | 1.4 | 1.35 | 0.76 | 0.18 | 0.5 | 0.5 | 0.04 |
| Sugar | 56.32 | 46.78 | 56.0 | 45.0 | 56.5 | 41.76 | 0.0 | 58.0 | 0.0 | 0.0 |
| HEC | 0.98 | 0.52 | 1.0 | 1.0 | 1.0 | 1.21 | 0.0 | 1.0 | 0.0 | 0.0 |
| Bactericide | 0.19 | 0.05 | 0.1 | 0.1 | 0.1 | 0.27 | 0.0 | 0.1 | 0.0 | 0.0 |
| Triton X-100 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 36.8 | 0.0 |
| DGBE | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 44.92 | 0.0 | 0.0 | 26.7 |
| Dielectric Constant | 43.42 | 58.0 | 42.54 | 56.1 | 42.0 | 56.8 | 39.9 | 54.0 | 39.8 | 52.5 |
| Conductivity (S/m) | 0.85 | 0.83 | 0.91 | 0.95 | 1.0 | 1.07 | 1.42 | 1.45 | 1.88 | 1.78 |

Salt: 99+% Pure Sodium Chloride

Sugar: 98+% Pure Sucrose

Water: De-ionized, 16 MΩ+ resistivity

HEC: Hydroxyethyl Cellulose

DGBE: 99+% Di(ethylene glycol) butyl ether, [2-(2-butoxyethoxy)ethanol]

Triton X-100 (ultra pure): Polyethylene glycol mono [4-(1,1, 3, 3-tetramethylbutyl)phenyl]ether

Simulating Liquids for 5 GHz, Manufactured by SPEAG

| Ingredients | (% by weight) |
|--------------------|---------------|
| Water | 78 |
| Mineral oil | 11 |
| Emulsifiers | 9 |
| Additives and Salt | 2 |

3. MEASURE PROCEDURES

3.1. General description of test procedures

This is a Bluetooth Headset and it is appropriate for head SAR test, each side of the EUT should be tested. Choose the channel which has the maximum power as the priority test channel, if the test result less than 0.8W/Kg, then other channel can be excluded, otherwise, the channel which has a secondary highest power should be tested instead.

Please apply the following guidance for SAR testing:

1. Please use a 0 mm (touching) test separation distance on the flat phantom during SAR testing of this device. This separation distance is based on the guidance found in FCC KDB Publication 447498 D01, Section 5.2.3 3)
2. Please utilize a head tissue simulating liquid (TSL) of the appropriate frequency during SAR testing.
3. Please use the guidance found in FCC KDB Publication 447498 D01 to determine which sides of the device need to be tested for SAR.

4. SAR MEASUREMENTS SYSTEM

4.1. SAR Measurement Set-up

DASY5 system for performing compliance tests consists of the following items:

- (1) A standard high precision 6-axis robot (Stäubli RX family) with controller and software. An arm extension for accommodating the data acquisition electronics (DAE).
- (2) A dosimetric probe, i.e. an isotropic E-field probe optimized and calibrated for usage. It issues simulating liquid. The probe is equipped with an optical surface detector system.
- (3) A data acquisition electronic (DAE) which performs the signal amplification, signal multiplexing, AD-conversion, offset measurements, mechanical surface detection, collision detection, etc. The unit is battery powered with standard or rechargeable batteries. The signal is optically transmitted to the EOC.
- (4) A unit to operate the optical surface detector which is connected to the EOC.
- (5) The Electro-Optical Coupler (EOC) performs the conversion from the optical into a digital electric signal of the DAE. The EOC is connected to the DASY5 measurement server.
- (6) The DASY5 measurement server, which performs all real-time data evaluation for field measurements and surface detection, controls robot movements and handles safety operation. A computer operating Windows 2003.
- (7) DASY5 software and SEMCAD data evaluation software.
- (8) Remote control with teach panel and additional circuitry for robot safety such as warning lamps, etc.
- (9) The generic twin phantom enabling the testing of left-hand and right-hand usage.
- (10) The device holder for handheld mobile phones.
- (11) Tissue simulating liquid mixed according to the given recipes.
- (12) System validation dipoles allowing to validate the proper functioning of the system.

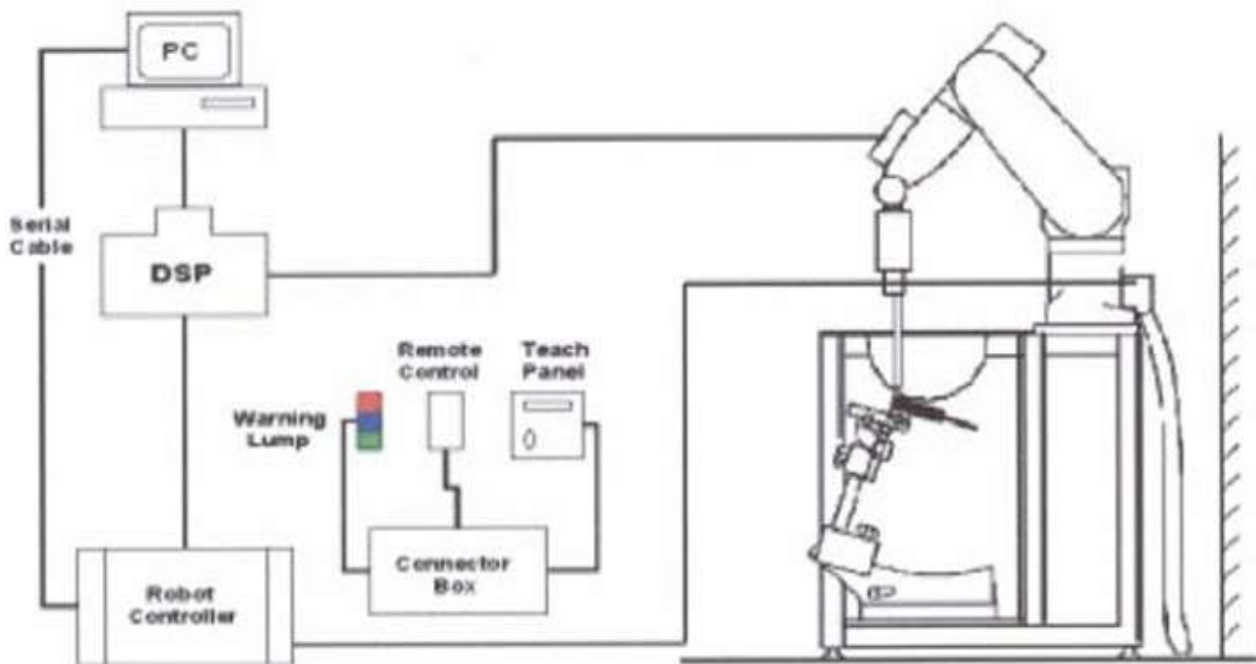
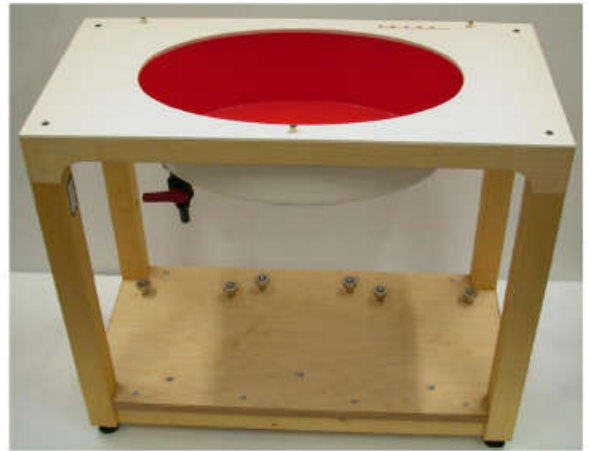


Figure 4.1 SAR Lab Test Measurement Set-up

4.2. ELI Phantom

Phantom for compliance testing of handheld and body-mounted wireless devices in the frequency range of 30 MHz to 6 GHz. ELI is fully compatible with the IEC 62209-2 standard and all known tissue simulating liquids. ELI has been optimized regarding its performance and can be integrated into our standard phantom tables. A cover prevents evaporation of the liquid. Reference markings on the phantom allow installation of the complete setup, including all predefined phantom positions and measurement grids, by teaching three points. The phantom is compatible with all SPEAG dosimetric probes and dipoles.



| | |
|----------------------|---|
| Material | Vynylester, glass fiber reinforced (VE-GF) |
| Liquid Compatibility | Compatible with all SPEAG tissue simulating liquids (incl. DGBE type) |
| Shell Thickness | 2.0 ± 0.2 mm (bottom plate) |
| Dimensions | Major axis: 600 mm Minor axis: 400 mm |
| Filling Volume | approx. 30 liters |
| Wooden Support | SPEAG standard phantom table |

The bottom plate contains three pair of bolts for locking the device holder. The device holder positions are adjusted to the standard measurement positions in the three sections.

Figure 6.2 Top View of Twin Phantom

A white cover is provided to tap the phantom during off-periods to prevent water evaporation and changes in the liquid parameters.

On the phantom top, three reference markers are provided to identify the phantom position with respect to the robot.

The phantom can be used with the following tissue simulating liquids:

- *Water-sugar based liquid
- *Glycol based liquids

4.3. Device Holder for SAM Twin Phantom

The SAR in the Phantom is approximately inversely proportional to the square of the distance between the source and the liquid surface. For a source in 5 mm distance, a positioning uncertainty of $\pm 0.5\text{mm}$ would produce a SAR uncertainty of $\pm 20\%$. An accurate device position is therefore crucial for accurate and repeatable measurement. The position in which the devices must be measured, are defined by the standards.

The DASY5 device holder is designed to cope with different positions given in the standard. It has two scales for the device rotation (with respect to the body axis) and the device inclination (with respect to the line between the ear reference points). The rotation centers for both scales is the ear reference point (EPR).

Thus the device needs no repositioning when changing the angles.

The DASY5 device holder has been made out of low-loss POM material having the following dielectric parameters: relative permittivity $\epsilon_r = 3$ and loss tangent $\tan \delta = 0.02$. The amount of dielectric material has been reduced in the closest vicinity of the device, since measurements have suggested that the influence of the clamp on the test results could thus be lowered.



Figure 4.3 Device Holder

4.4. DASY5 E-field Probe System

The SAR measurements were conducted with the dosimetric probe EX3DV4 (manufactured by SPEAG), designed in the classical triangular configuration and optimized for dosimetric evaluation.



Figure 4.4 EX3DV4 E-field Probe

4.4.1. EX3DV4 Probe Specification

| | |
|---------------|--|
| Construction | Symmetrical design with triangular core Built-in shielding against static charges PEEK enclosure material (resistant to organic solvents, e.g., DGBE) |
| Calibration | ISO/IEC 17025 calibration service available |
| Frequency | 10 MHz to > 6 GHz Linearity: ± 0.2 dB (30 MHz to 6 GHz) |
| Directivity | ± 0.3 dB in HSL (rotation around probe axis) ± 0.5 dB in tissue material (rotation normal to probe axis) |
| Dynamic Range | 10 μ W/g to > 100 mW/g Linearity: ± 0.2 dB (noise: typically < 1 μ W/g) |
| Dimensions | Overall length: PRS-T2 mm (Tip: 20 mm) Tip diameter: 2.5 mm (Body: 12 mm) Typical distance from probe tip to dipole centers: 1 mm |
| Application | High precision dosimetric measurements in any exposure scenario (e.g., very strong gradient fields). Only probe which enables compliance testing for frequencies up to 6 GHz with precision of better 30%. |

4.5. E-field Probe Calibration

Each probe is calibrated according to a dosimetric assessment procedure with accuracy better than $\pm 10\%$. The spherical isotropy was evaluated and found to be better than $\pm 0.25\text{dB}$. The sensitivity parameters (NormX, NormY, NormZ), the diode compression parameter (DCP) and the conversion factor (ConvF) of the probe are tested.

The free space E-field from amplified probe outputs is determined in a test chamber. This is performed in a TEM cell for frequencies below 1 GHz, and in a wave guide 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 then rotated 360 degrees.

E-field temperature correlation calibration is performed in a flat phantom filled with the appropriate simulated brain tissue. The measured free space E-field in the medium correlates to temperature rise in a 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: Δt = Exposure time (30 seconds),
 C = Heat capacity of tissue (brain or muscle),
 ΔT = Temperature increase due to RF exposure.
Or

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

Where:
 σ = Simulated tissue conductivity,
 ρ = Tissue density (kg/m^3).

4.6. Scanning procedure

The DASY5 installation includes predefined files with recommended procedures for measurements and validation. They are read-only document files and destined as fully defined but unmeasured masks. All test positions (head or body-worn) are tested with the same configuration of test steps differing only in the grid definition for the different test positions.

The "reference" and "drift" measurements are located at the beginning and end of the batch process. They measure the field drift at one single point in the liquid over the complete procedure. The indicated drift is mainly the variation of the EUT's output power and should vary max. $\pm 5\%$.

The "surface check" measurement tests the optical surface detection system of the DASY5 system by repeatedly detecting the surface with the optical and mechanical surface detector and comparing the results. The output gives the detecting heights of both systems, the difference between the two systems and the standard deviation of the detection repeatability. Air bubbles or refraction in the liquid due to separation of the sugar-water mixture gives poor repeatability (above $\pm 0.1\text{mm}$). To prevent wrong results tests are only executed when the liquid is free of air bubbles.

The difference between the optical surface detection and the actual surface depends on the Probe and is specified with each probe. (It does not depend on the surface reflectivity or the probe angle to the surface within $\pm 30^\circ$.)

Area Scan

The Area Scan is used as a fast scan in two dimensions to find the area of high field values before running a detailed measurement around the hot spot. Before starting the area scan a grid spacing of 15 mm x 15 mm is set. During the scan the distance of the probe to the phantom remains unchanged.

After finishing area scan, the field maxima within a range of 2 dB will be ascertained.

Zoom Scan

Zoom Scans are used to estimate the peak spatial SAR values within a cubic averaging volume containing 1 g and 10 g of simulated tissue. The default Zoom Scan is done by 7x7x7 points within a cube whose base is centered around the maxima found in the preceding area scan.

Spatial Peak Detection

The procedure for spatial peak SAR evaluation has been implemented and can determine values of masses of 1g and 10g, as well as for user-specific masses. The DASY5 system allows evaluations that combine measured data and robot positions, such as:

- maximum search
- extrapolation
- boundary correction
- peak search for averaged SAR

During a maximum search, global and local maxima searches are automatically performed in 2-D after each Area Scan measurement with at least 6 measurement points. It is based on the evaluation of the local SAR gradient calculated by the Quadratic Shepard's method. The algorithm will find the global maximum and all local maxima within -2 dB of the global maxima for all SAR distributions.

Extrapolation routines are used to obtain SAR values between the lowest measurement points and the inner phantom surface. The extrapolation distance is determined by the surface detection distance and the probe sensor offset. Several measurements at different distances are necessary for the extrapolation. Extrapolation routines require at least 10 measurement points in 3-D space. They are used in the Zoom Scan to obtain SAR values between the lowest measurement points and the inner phantom surface. The routine uses the modified Quadratic Shepard's method for extrapolation. For a grid using 7x7x7 measurement points with 5mm resolution amounting to 343 measurement points, the uncertainty of the extrapolation routines is less than 1% for 1g and 10g cubes.

A Z-axis scan measures the total SAR value at the x-and y-position of the maximum SAR value found during the cube 7x7x7 scan. The probe is moved away in z-direction from the bottom of the SAM phantom in 5mm steps.

5. DATA STORAGE AND EVALUATION

5.1. Data Storage

The DASY5 software stores the acquired data from the data acquisition electronics as raw data (in microvolt readings from the probe sensors), together with all necessary software parameters for the data evaluation (probe calibration data, liquid parameters and device frequency and modulation data) in measurement files with the extension ".DA4". The software evaluates the desired unit and format for output each time the data is visualized or exported. This allows verification of the complete software setup even after the measurement and allows correction of incorrect parameter settings. For example, if a measurement has been performed with a wrong crest factor parameter in the device setup, the parameter can be corrected afterwards and the data can be re-evaluated.

The measured data can be visualized or exported in different units or formats, depending on the selected probe type ([V/m], [A/m], [°C], [mW/g], [mW/cm²], [dBrel], etc.). Some of these units are not available in certain situations or show meaningless results, e.g., a SAR output in a lossless media will always be zero. Raw data can also be exported to perform the evaluation with other software packages.

5.2. Data Evaluation by SEMCAD

The SEMCAD software automatically executes the following procedures to calculate the field units from the microvolt readings at the probe connector. The parameters used in the evaluation are stored in the configuration modules of the software:

| | | |
|-------------------|---------------------------|----------------------|
| Probe parameters: | - Sensitivity | Normi, ai0, ai1, ai2 |
| | - Conversion factor | ConvFi |
| | - Diode compression point | Dcpi |

| | | |
|--------------------|----------------|----|
| Device parameters: | - Frequency | f |
| | - Crest factor | cf |

| | |
|-------------------|----------------|
| Media parameters: | - Conductivity |
| | - Density |

These parameters must be set correctly in the software. They can be found in the component documents or they can be imported into the software from the configuration files issued for the DASY5 components. In the direct measuring mode of the multimeter option, the parameters of the actual system setup are used. In the scan visualization and export modes, the parameters stored in the corresponding document files are used.

The first step of the evaluation is a linearization of the filtered input signal to account for the compression characteristics of the detector diode. The compensation depends on the input signal, the diode type and the DC-transmission factor from the diode to the evaluation electronics.

If the exciting field is pulsed, the crest factor of the signal must be known to correctly compensate for peak power. The formula for each channel can be given as:

$$Vi = Ui + Ui^2 \cdot cf / dcpi$$

With V_i = compensated signal of channel i ($i = x, y, z$)

U_i = input signal of channel i ($i = x, y, z$)

cf = crest factor of exciting field (DASY parameter)

dcp_i = diode compression point (DASY parameter)

From the compensated input signals the primary field data for each channel can be evaluated:

E-field probes: $E_i = (V_i / Norm_i \cdot ConvF)^{1/2}$

H-field probes: $H_i = (V_i)^{1/2} \cdot (ai_0 + ai_1 f + ai_2 f^2) / f$

With V_i = compensated signal of channel i ($i = x, y, z$)

$Norm_i$ = sensor sensitivity of channel i ($i = x, y, z$)

$ConvF$ = sensitivity enhancement in solution

ai_j = sensor sensitivity factors for H-field probes

f = carrier frequency [GHz]

E_i = electric field strength of channel i in V/m

H_i = magnetic field strength of channel i in A/m

The RSS value of the field components gives the total field strength (Hermitian magnitude):

$$E_{tot} = (E_x^2 + E_y^2 + E_z^2)^{1/2}$$

The primary field data are used to calculate the derived field units.

$$SAR = (E_{tot}^2 \cdot \sigma) / (\rho \cdot 1000)$$

with

SAR = local specific absorption rate in mW/g

E_{tot} = total field strength in V/m

σ = conductivity in [mho/m] or [Siemens/m]

ρ = equivalent tissue density in g/cm³

Note that the density is normally set to 1 (or 1.06), to account for actual brain density rather than the density of the simulation liquid. The power flow density is calculated assuming the excitation field to be a free space field.

$$P_{pwe} = E_{tot}^2 / 3770 \quad \text{or} \quad P_{pwe} = H_{tot}^2 \cdot 37.7$$

with P_{pwe} = equivalent power density of a plane wave in mW/cm²

E_{tot} = total electric field strength in V/m

H_{tot} = total magnetic field strength in A/m

6. SYSTEM CHECK

The manufacturer calibrates the probes annually. Dielectric parameters of the tissue simulates were measured every day using the dielectric probe kit and the network analyzer. A system check measurement was made following the determination of the dielectric parameters of the simulates, using the dipole validation kit. A power level of 250 mW was supplied to the dipole antenna, which was placed under the flat section of the twin SAM phantom. The system check results (dielectric parameters and SAR values) are given in the ANNEX A.

System check results have to be equal or near the values determined during dipole calibration with the relevant liquids and test system ($\pm 10\%$).

System check is performed regularly on all frequency bands where tests are performed with the DASY5 system.

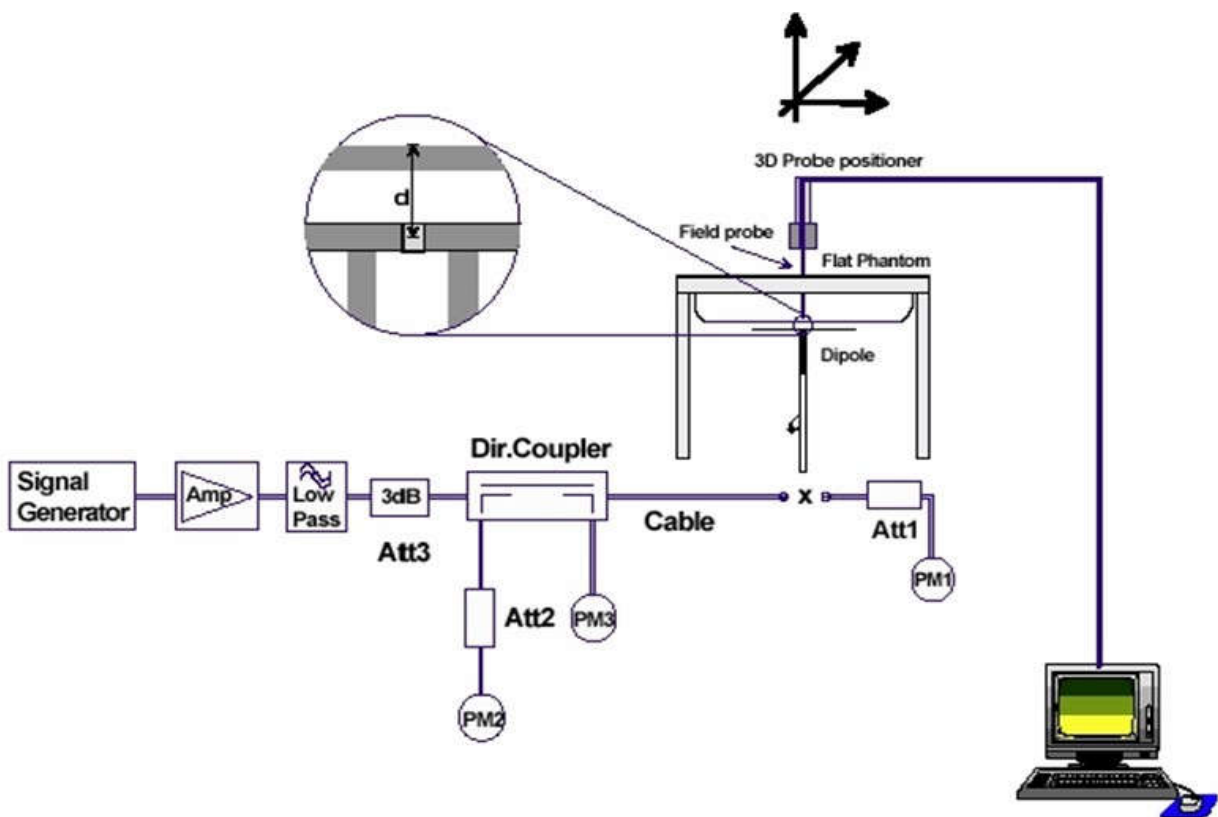


Figure 6.1: System Check Set-up

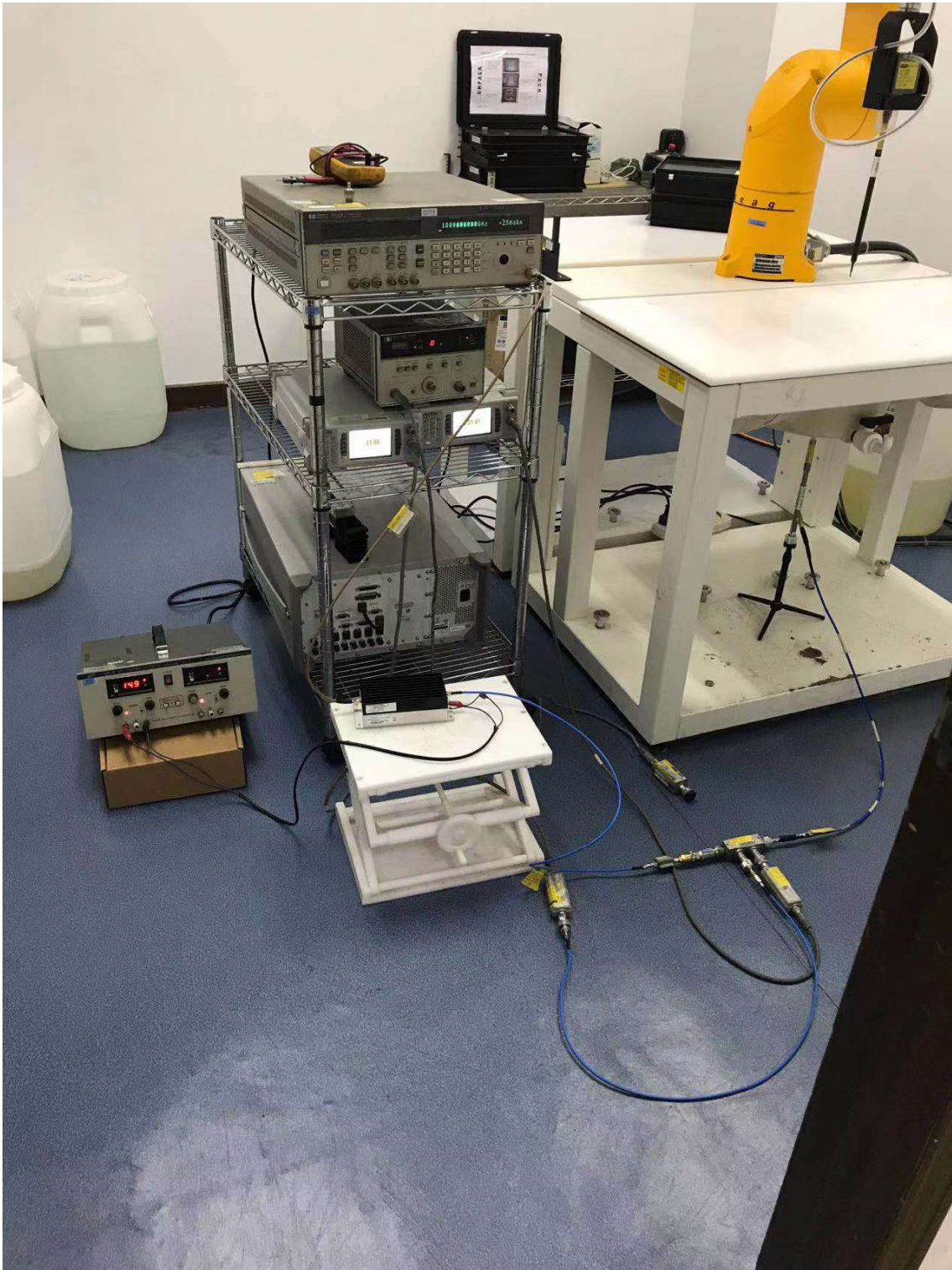


Figure 6.3: photos of system

7. TEST RESULTS

7.1. Output power

Left:

(Bluetooth BDR+EDR)

| Test Mode | Frequency (MHz) | Output power (dBm) | Maximum Tune-up Power (dBm) |
|-----------|-----------------|--------------------|-----------------------------|
| DH5 | 2402 | 9.95 | 10.00 |
| DH5 | 2441 | 9.12 | 9.50 |
| DH5 | 2480 | 8.35 | 8.50 |
| 2DH5 | 2402 | 10.06 | 10.50 |
| 2DH5 | 2441 | 9.04 | 9.50 |
| 2DH5 | 2480 | 7.95 | 8.00 |
| 3DH5 | 2402 | 9.91 | 10.00 |
| 3DH5 | 2441 | 9.03 | 9.50 |
| 3DH5 | 2480 | 7.66 | 8.00 |

(BLE)

| Test Mode | Frequency (MHz) | Output power (dBm) | Maximum Tune-up Power (dBm) |
|-----------|-----------------|--------------------|-----------------------------|
| GFSK | 2402 | 9.85 | 10.00 |
| | 2440 | 9.42 | 9.50 |
| | 2480 | 9.16 | 9.50 |

Note:

Use the data rate with the maximum output level for the SAR test.

Right:

(Bluetooth BDR+EDR)

| Test Mode | Frequency (MHz) | Output power (dBm) | Maximum Tune-up Power (dBm) |
|-----------|-----------------|--------------------|-----------------------------|
| DH5 | 2402 | 9.85 | 10.00 |
| DH5 | 2441 | 10.05 | 10.50 |
| DH5 | 2480 | 9.22 | 9.50 |
| 2DH5 | 2402 | 9.76 | 10.00 |
| 2DH5 | 2441 | 10.00 | 10.50 |
| 2DH5 | 2480 | 9.31 | 9.50 |
| 3DH5 | 2402 | 9.67 | 10.00 |
| 3DH5 | 2441 | 10.05 | 10.50 |
| 3DH5 | 2480 | 9.26 | 9.50 |

(BLE)

| Test Mode | Frequency (MHz) | Output power (dBm) | Maximum Tune-up Power (dBm) |
|-----------|-----------------|--------------------|-----------------------------|
| GFSK | 2402 | 9.11 | 9.50 |
| | 2440 | 8.71 | 9.00 |
| | 2480 | 8.41 | 8.50 |

Note:

Use the data rate with the maximum output level for the SAR test.

7.2. System Check for Head Tissue simulating liquid

| Frequency | Description | SAR(W/kg) (1g±18.8% window; 10g±18.7% window) | | Dielectric Parameters (±5% window) | | Temp |
|-----------|---------------------------------|---|----------------------------|---------------------------------------|---------------------|-------|
| | | 1g | 10g | εr | σ(s/m) | °C |
| 2450MHz | Recommended value | 52.80 42.8736 – 62.7264 | 24.50 19.9185 – 29.0815 | 39.20 37.24 – 41.16 | 1.80 1.71 – 1.89 | / |
| | Measurement value 2020-01-19 | 50.20 | 22.44 | 39.440 | 1.818 | 22.01 |

Note: Recommended Values used derive from the calibration certificate and 250 mW is used as feeding power to the calibrated dipole.

7.3. Test Results

| Frequency | | Dielectric Parameters (±5% window) | | | |
|-----------|---------|---------------------------------------|-------------------|-------------------|-------------------|
| | | ϵ_r | | σ (s/m) | |
| | | Measurement value | Recommended value | Measurement value | Recommended value |
| 2450MHz | 2402MHz | 38.913 -0.73% | 39.20 | 1.828 1.56% | 1.80 |
| | 2441MHz | 38.734 -1.19% | | 1.878 4.33% | |
| | 2480MHz | 38.579 -1.58% | | 1.887 4.83% | |



Figure 4.4: Liquid depth in the Flat Phantom

Left:

| Band | CH | Test Position | Output Power | | Measured Results | | Scaled-1 | | Scaled-Final | | Power Drift (dBm) |
|--------------|----|---------------|----------------------------|-------------------------|------------------|---------------|--------------|---------------|----------------|---------------|-------------------|
| | | | Max. Scaled AV Power (dBm) | Measured AV Power (dBm) | SAR1g (W/kg) | SAR10g (W/kg) | SAR1g (W/kg) | SAR10g (W/kg) | SAR1g (W/kg) | SAR10g (W/kg) | |
| BT (BDR+EDR) | 0 | Top | 10.50 | 10.06 | 0.037 | 0.014 | 0.04095 | 0.01549 | 0.07059 | 0.02671 | 0.16 |
| | | Right | | | 0.057 | 0.020 | 0.06308 | 0.02213 | 0.10875 | 0.03816 | 0.13 |
| | | Left | | | 0.058 | 0.022 | 0.06418 | 0.02435 | 0.11066 | 0.04198 | 0.05 |
| | | Front | | | 0.061 | 0.023 | 0.06750 | 0.02545 | 0.11639 | 0.04388 | 0.06 |
| | | Cochlea | | | 0.015 | 0.00671 | 0.01660 | 0.00743 | 0.02862 | 0.01280 | 0.08 |
| | | Bottom | | | 0.018 | 0.00694 | 0.01992 | 0.00768 | 0.03434 | 0.01324 | 0.01 |
| | 39 | Front | 9.50 | 9.04 | 0.055 | 0.020 | 0.06115 | 0.02223 | 0.10542 | 0.03834 | 0.16 |
| | 78 | Front | 8.00 | 7.95 | 0.058 | 0.022 | 0.05867 | 0.02225 | 0.10116 | 0.03837 | -0.05 |
| BLE | 0 | Front | 10.00 | 9.85 | 0.144 | 0.050 | 0.14906 | 0.05176 | 0.15057 | 0.05228 | 0.07 |
| | 39 | Front | 9.50 | 9.42 | 0.149 | 0.052 | 0.15177 | 0.05297 | 0.15330 | 0.05350 | 0.13 |
| | 78 | Front | 9.50 | 9.16 | 0.153 | 0.053 | 0.16546 | 0.05732 | 0.16713 | 0.05789 | 0.12 |

Conclusion: PASS

Note :

Factor= Max. Scaled AV Power(W)/Measured Power(W)

Scaled SAR-1= Measured SAR*Factor

Scaled-Final= Scaled SAR-1*(1/Duty Cycle)

The Max. Reported SAR : 0.16713W/kg for 1g SAR

Note: The Bluetooth (BDR+EDR) duty cycle is 0.58.

The BLE duty cycle is 0.99.

Right:

| Band | CH | Test Position | Output Power | | Measured Results | | Scaled-1 | | Scaled-Final | | Power Drift (dBm) |
|--------------|----|---------------|----------------------------|-------------------------|------------------|---------------|--------------|---------------|----------------|---------------|-------------------|
| | | | Max. Scaled AV Power (dBm) | Measured AV Power (dBm) | SAR1g (W/kg) | SAR10g (W/kg) | SAR1g (W/kg) | SAR10g (W/kg) | SAR1g (W/kg) | SAR10g (W/kg) | |
| BT (BDR+EDR) | 0 | Front | 10.00 | 9.85 | 0.118 | 0.038 | 0.12215 | 0.03934 | 0.21060 | 0.06782 | 0.06 |
| | 39 | Top | 10.50 | 10.05 | 0.102 | 0.037 | 0.11314 | 0.04104 | 0.19506 | 0.07076 | 0.16 |
| | | Right | | | 0.035 | 0.014 | 0.03882 | 0.01553 | 0.06693 | 0.02677 | 0.06 |
| | | Left | | | 0.044 | 0.016 | 0.04880 | 0.01775 | 0.08414 | 0.03060 | 0.09 |
| | | Front | | | 0.114 | 0.036 | 0.12645 | 0.03993 | 0.21801 | 0.06885 | 0.16 |
| | | Cochlea | | | 0.012 | 0.00553 | 0.01331 | 0.00613 | 0.02295 | 0.01058 | -0.11 |
| | | Bottom | | | 0.016 | 0.00639 | 0.01775 | 0.00709 | 0.03060 | 0.01222 | 0.15 |
| | 78 | Front | 9.50 | 9.22 | 0.126 | 0.041 | 0.13439 | 0.04373 | 0.23171 | 0.07540 | -0.03 |
| BLE | 0 | Front | 9.50 | 9.11 | 0.133 | 0.042 | 0.14550 | 0.04595 | 0.14697 | 0.04641 | 0.13 |
| | 39 | Front | 9.00 | 8.71 | 0.134 | 0.043 | 0.14325 | 0.04597 | 0.14470 | 0.04643 | 0.14 |
| | 78 | Front | 8.50 | 8.41 | 0.143 | 0.046 | 0.14599 | 0.04696 | 0.14747 | 0.04744 | -0.06 |

Conclusion: PASS

Note :

Factor= Max. Scaled AV Power(W)/Measured Power(W)

Scaled SAR-1= Measured SAR*Factor

Scaled-Final= Scaled SAR-1*(1/Duty Cycle)

The Max. Reported SAR : **0.23171W/kg for 1g SAR**

Note: The Bluetooth (BDR+EDR) duty cycle is 0.58.

The BLE duty cycle is 0.99.