SAR TEST REPORT

For

UHF Mobile RFID Reader

REPORT NO.: ES160830038E

ISSUE DATE: December 22, 2016

Prepared for

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Prepared by

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1 TEST RESULT CERTIFICATION

Applicant:	Megabyte Limited Unit 507, Building 12W, No. 12 Science Park West Avenue, Hong Kong Science Park, Shatin, N.T., Hong Kong
Manufacturer:	Megabyte Limited Unit 507, Building 12W, No. 12 Science Park West Avenue, Hong Kong Science Park, Shatin, N.T., Hong Kong
Product Description:	UHF Mobile RFID Reader
Model No.:	T8-01-MB, T8-01-39, T8-01-PH
File Number:	ES160830038E
Date of Test:	December 08, 2016 to January 18, 2016

Measurement Procedure Used:

APPLICABLE STANDARDS	
STANDARD	TEST RESULT
FCC 47 CFR Part 2 (2.1093) ANSI/IEEE C95.1-1992 IEEE 1528-2013	PASS

The above equipment was tested by EMTEK (SHENZHEN) CO., LTD. The test data, data evaluation, test procedures, and equipment configurations shown in this report were made in accordance with the procedures given in IEEE 1528-2013.This 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 C95.1-1992.

The test results of this report relate only to the tested sample identified in this report.

Date of Test : December 08, 2016 to January 18, 2016

Prepared by : Yaping Shen

Yaping Shen/Editor

Reviewer : Joe Xia

Joe Xia/Supervisor

Approve & Authorized Signer :

Lisa Wang/Manager

2 EUT TECHNICAL DESCRIPTION

Characteristics	Description
Device Type:	UHF Mobile RFID Reader
Exposure Category:	Uncontrolled Environment/General Population
Test Modulation:	RFID with DSB - ASK Bluetooth with GFSK/π/4 DQPSK/8DPSK NFC with ASK DSSS with DBPSK/DQPSK/CCK for 802.11b OFDM with BPSK/QPSK/16QAM/64QAM for 802.11a/g/n
Operating Frequency Range:	RFID: 917.4-927.2MHz; Bluetooth: 2402-2480MHz; WIFI2.4G: 2412-2462MHz for 802.11b/g/n; WIFI5G: 5180-5240MHz for 802.11a/n UNII Band 1; 5260-5320MHz for 802.11a/n UnII Band 2A; 5500-5700MHz for 802.11a/n UNII Band 2C; 5745-5825MHz for 802.11a/n UNII Band 3;
Number of Channels:	RFID: 50 channels NFC: 1 channels Bluetooth: 79 channels for Basic Rate+EDR 40 channels for BLE 3 channels for BLE beacon WIFI2.4G: 11 channels for 802.11b/g/n; WIFI5G: 4 channels for 802.11a/n UNII Band 1; 4 channels for 802.11a/n UNII Band 2A; 11 channels for 802.11a/n UNII Band 2C 5 channels for 802.11a/n UNII Band 3;
Antenna Type:	RFID: FR4 PCB Antenna NFC: N/A

	Bluetooth: Chip Antenna WIFI 2.4G: PCB Antenna WIFI 5G: PCB Antenna
Antenna Gain:	RFID: 0 dBi NFC: N/A Bluetooth: 1.9dBi WIFI 2.4G: 1.3dBi WIFI 5G: 2dBi
Power supply:	☒DC supply: DC 3.7V
Temperature Range:	0°C ~ +40°C
Product Software Version:	N/A
Product Hardware Version:	N/A
Radio Software Version:	N/A
Radio Hardware Version:	N/A
Test Channel:	802.11 a /b

Note:

1. *For more details, please refer to the User's manual of the EUT.*
2. *The sample under test was selected by the Client.*

Modified Information

Rev.	Summary	Date of Rev.	Report No.
Ver.1.0	Original Report	2016-12-22	ES160830038E

3 STATEMENT OF COMPLIANCE

Frequency Band	Operating Mode	Highest SAR Summary		
		Head 1g SAR (W/kg) (Gap 0cm)	Body 1g SAR (W/kg) (Gap 0cm)	Max Simultaneous Transmission SAR (W/kg)
Bluetooth	Data	N/A	0.333	1.582
BLE beacon	Data	N/A	0.02	
NFC	Data	N/A	0.04	
WLAN 2.4GHz	Data	N/A	0.464	
WLAN 5GHz	Data	N/A	0.390	
RFID	Data	N/A	0.765	

Note NFC is used for Bluetooth pairing only, NFC and RFID will not TX at the same time
Note RFID&BT&WIFI will TX at the same time.
Note BT&WIFI will TX at the same time.

4 AUXILIARY EQUIPMENT DETAILS

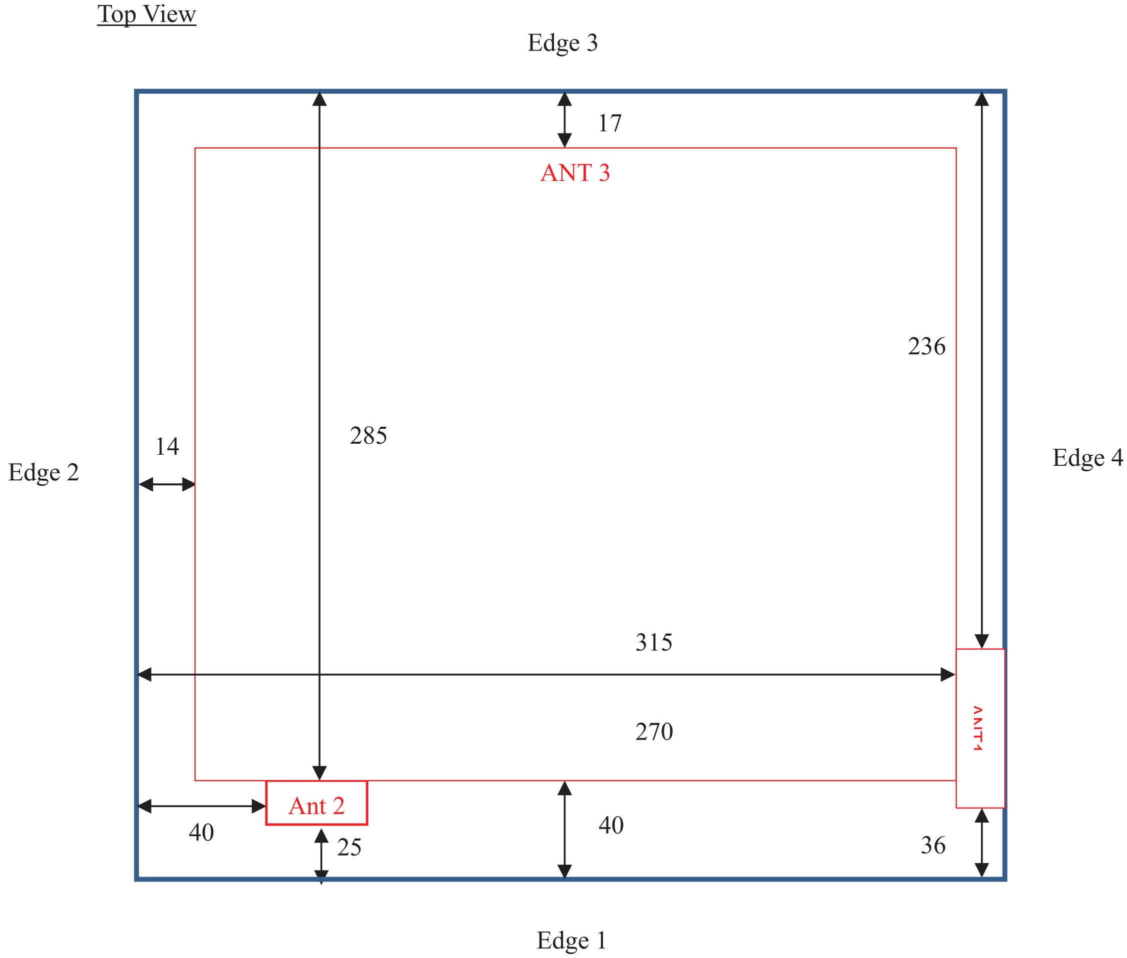
AE: Battery	Description
Manufacturer:	N/A
Model:	N/A
S/N:	N/A
capacity:	N/A
Voltage:	N/A

5 TEST FACILITY

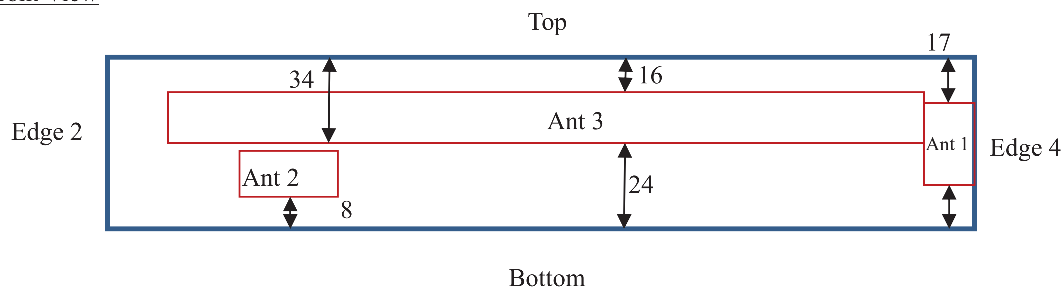
Site Description		
EMC Lab.	:	Accredited by CNAS, 2016.10.24 The certificate is valid until 2022.10.28 The Laboratory has been assessed and proved to be in compliance with CNAS-CL01:2006 (identical to ISO/IEC 17025:2005) The Certificate Registration Number is L2291
		Accredited by TUV Rheinland Shenzhen 2016.05.19 The Laboratory has been assessed according to the requirements ISO/IEC 17025.
		Accredited by FCC, Valid until 2017/07/12 The Certificate Registration Number is 709623.
		Accredited by Industry Canada, November 24, 2015 The Certificate Registration Number is 4480A.
Name of Firm	:	EMTEK (SHENZHEN) CO., LTD.
Site Location	:	Bldg 69, Majialong Industry Zone,Nanshan District, Shenzhen, Guangdong, China

6 ANTENNA LOCATIONS

Top View



Front View



Note:
Ant1: Small RFID antenna (size: 296*279*9.7mm)
Ant2: WIFI antenna (2.4/ 5GHz) (size: 16*7.6mm)
Ant3: Big RFID antenna (size: 50*15*4mm)
Unit: mm

Sides for SAR Testing:

Mode	Top Face	Bottom Face	Edge1	Edge2	Edge3	Edge4
WLAN 2.4GHz	NO	YES	NO	NO	NO	NO
WLAN 5GHz	NO	YES	NO	NO	NO	NO
Small RFID	YES	YES	YES	NO	NO	YES
Big RFID	YES	YES	YES	YES	YES	YES

SAR test reduction and exclusion guidance:
1) 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, where
- $f_{(GHz)}$ 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
- 3.0 and 7.5 are referred to as the numeric thresholds in the step 2 below

The test exclusions are applicable only when the minimum test separation distance is ≤ 50 mm and for transmission frequencies between 100 MHz and 6 GHz. When the minimum test separation distance is < 5 mm, a distance of 5 mm according to 5) in section 4.1 is applied to determine SAR test exclusion.
2) At 100 MHz to 6 GHz and for test separation distances > 50 mm, the SAR test exclusion threshold is determined according to the following, and as illustrated in Appendix B:
a) [Power allowed at numeric threshold for 50 mm in step 1) + (test separation distance - 50 mm)·($f_{(MHz)}$/150)] mW, at 100 MHz to 1500 MHz
b) [Power allowed at numeric threshold for 50 mm in step 1) + (test separation distance - 50 mm)·10] mW at > 1500 MHz and ≤ 6 GHz
The WIFI 2.4G SAR evaluation of Maximum power (, including tune-up tolerance)

Exposure Position	Wireless Interface	802.11b
	Calculated Frequency	2437MHz
	Maximum power (dBm)	15
	Maximum rated power(mW)	31.62
Top Face	Separation distance(mm)	34
	exclusion threshold	3
	Testing required?	No
Bottom Face	Separation distance(mm)	8
	exclusion threshold	3
	Testing required?	Yes
Edge 1	Separation distance(mm)	25
	exclusion threshold	3
	Testing required?	No
Edge 2	Separation distance(mm)	40
	exclusion threshold	3
	Testing required?	No
Edge 3	Separation distance(mm)	285
	exclusion threshold	3
	Testing required?	No

Edge 4	Separation distance(mm)	270
	exclusion threshold	3
	Testing required?	No

The WIFI 5G SAR evaluation of Maximum power (, including tune-up tolerance)

Exposure Position	Wireless Interface	802.11a
	Calculated Frequency	5200 MHz
	Maximum power (dBm)	13
	Maximum rated power(mW)	19.95
Top Face	Separation distance(mm)	34
	exclusion threshold	3
	Testing required?	No
Bottom Face	Separation distance(mm)	8
	exclusion threshold	3
	Testing required?	Yes
Edge 1	Separation distance(mm)	25
	exclusion threshold	3
	Testing required?	No
Edge 2	Separation distance(mm)	40
	exclusion threshold	3
	Testing required?	No
Edge 3	Separation distance(mm)	285
	exclusion threshold	3
	Testing required?	No
Edge 4	Separation distance(mm)	270
	exclusion threshold	3
	Testing required?	No

The small RFID SAR evaluation of Maximum power (, including tune-up tolerance1 dBm)

Exposure Position	Wireless Interface	RFID
	Calculated Frequency	922.2 MHz
	Maximum power (dBm)	23
	Maximum rated power(mW)	199.5
Top Face	Separation distance(mm)	17
	exclusion threshold	3
	Testing required?	Yes
Bottom Face	Separation distance(mm)	10
	exclusion threshold	3
	Testing required?	Yes
Edge 1	Separation distance(mm)	36
	exclusion threshold	3
	Testing required?	Yes
Edge 2	Separation distance(mm)	315
	exclusion threshold	3
	Testing required?	No
Edge 3	Separation distance(mm)	236
	exclusion threshold	3
	Testing required?	No
Edge 4	Separation distance(mm)	2
	exclusion threshold	3
	Testing required?	Yes

The big RFID SAR evaluation of Maximum power (, including tune-up tolerance1 dBm)

Exposure Position	Wireless Interface	RFID
	Calculated Frequency	922.2 MHz
	Maximum power (dBm)	24.5
	Maximum rated power(mW)	281.8
Top Face	Separation distance(mm)	16
	exclusion threshold	3
	Testing required?	Yes
Bottom Face	Separation distance(mm)	24
	exclusion threshold	3
	Testing required?	Yes
Edge 1	Separation distance(mm)	40
	exclusion threshold	3
	Testing required?	Yes
Edge 2	Separation distance(mm)	14
	exclusion threshold	3

	Testing required?	Yes
Edge 3	Separation distance(mm)	17
	exclusion threshold	3
	Testing required?	Yes
Edge 4	Separation distance(mm)	14
	exclusion threshold	3
	Testing required?	Yes

Bluetooth basic Rate and BLE (including tune-up tolerance)

Exposure Position	Wireless Interface	Bluetooth
	Calculated Frequency	2441 MHz
	Maximum power (dBm)	9
	Maximum rated power(mW)	7.9
All Face	Separation distance(mm)	5
	exclusion threshold	3
	Testing required?	No

BLE beacon (including tune-up tolerance)

Exposure Position	Wireless Interface	Bluetooth
	Calculated Frequency	2441 MHz
	Maximum power (dBm)	-3
	Maximum rated power(mW)	0.5
All Face	Separation distance(mm)	5
	exclusion threshold	3
	Testing required?	No

NFC (including tune-up tolerance)

Exposure Position	Wireless Interface	Bluetooth
	Calculated Frequency	13.56 MHz
	Maximum power (dBm)	10
	Maximum rated power(mW)	10
All Face	Separation distance(mm)	5
	exclusion threshold	3
	Testing required?	No

7 GUIDANCE STANDARD

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

FCC 47CFR §2.1093 Radiofrequency Radiation Exposure Evaluation: Portable Devices

ANSI C95.1, 1992: Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz.(IEEE Std C95.1-1991)

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.

KDB 865664 D01 SAR measurement 100 MHz to 6 GHz v01r04: SAR Measurement Requirements for 100 MHz to 6 GHz

☒**KDB 447498 D01** Mobile Portable RF Exposure v06: Mobile and Portable Device RF Exposure Procedures and Equipment Authorization Policies

☒ **KDB 248227 D01** 802.11 Wi-Fi SAR v02r02: SAR GUIDANCE FOR IEEE 802.11 (Wi-Fi) TRANSMITTERS.

Remark:
This portable wireless equipment has been measured in all cases requested by the relevant standards. Test results in Chapter 11 of this test report are below limits specified in the relevant standards for the tested bands only.

8 RF EXPOSURE

8.1 LIMITS

Uncontrolled Environment

Uncontrolled Environments are defined as locations where there is the exposure of individuals who have no knowledge or control of their exposure. The general population/uncontrolled exposure limits are applicable to situations in which the general public may be exposed or in which persons who are exposed as a consequence of their employment may not be made fully aware of the potential for exposure or cannot exercise control over their exposure. Members of the general public would come under this category when exposure is not employment-related; for example, in the case of a wireless transmitter that exposes persons in its vicinity.

Controlled Environment

Controlled Environments are defined as locations where there is exposure that may be incurred by persons who are aware of the potential for exposure, (i.e. as a result of employment or occupation). In general, occupational/controlled exposure limits are applicable to situations in which persons are exposed as a consequence of their employment, who have been made fully aware of the potential for exposure and can exercise control over their exposure. The exposure category is also applicable when the exposure is of a transient nature due to incidental passage through a location where the exposure levels may be higher than the general population/uncontrolled limits, but the exposed person is fully aware of the potential for exposure and can exercise control over his or her exposure by leaving the area or by some other appropriate means.

Limits for Occupational/Controlled Exposure (W/kg)

Whole-Body	Partial-Body	Hands, Wrists, Feet and ankles
0.4	8.0	20.0

Limits for General Population/Uncontrolled Exposure (W/kg)

Whole-Body	Partial-Body	Hands, Wrists, Feet and ankles
0.08	1.6	4.0

Whole-Body SAR is averaged over the entire body, partial-body SAR is averaged over any 1gram of tissue defined as a tissue volume in the shape of a cube. SAR for hands, wrists, feet and ankles is averaged over any 10 grams of tissue defined as a tissue volume in the shape of a cube.

8.2 EVALUATION

☒According to §15.247 (i) and §1.1307(b)(1), systems operating under the provisions of this section shall be operated in a manner that ensures that the public is not exposed to radio frequency energy level in excess of the Commission's guidelines.

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,[25] where

- $f_{(GHz)}$ is the RF channel transmit frequency in GHz
- Power and distance are rounded to the nearest mW and mm before calculation[26]
- The result is rounded to one decimal place for comparison
- 3.0 and 7.5 are referred to as the numeric thresholds in the step 2 below

The test exclusions are applicable only when the minimum *test separation distance* is ≤ 50 mm and for transmission frequencies between 100 MHz and 6 GHz. When the minimum *test separation distance* is < 5 mm, a distance of 5 mm according to 5) in section 4.1 is applied to determine SAR test exclusion.

Routine SAR evaluation refers to that specifically required by § 2.1093, using measurements or computer simulation. When routine SAR evaluation is not required, portable transmitters with output power greater than the applicable low threshold require SAR evaluation to qualify for TCB approval.

8.3 MAXIMUM TUNE-UP LIMIT

For Small antenna RFID:

Frequency (GHz)	Channel	Target power (dBm)	Tolerance (dBm)
917.4	Low	22	±1
922.2	Mid	22	±1
927.4	High	22	±1

For Big antenna RFID:

Frequency (GHz)	Channel	Target power (dBm)	Tolerance (dBm)
917.4	Low	24	±0.5
922.2	Mid	24	±0.5
927.4	High	24	±0.5

For 2.4G Wifi

Mode	Frequency (GHz)	Channel	Target power (dBm)	Tolerance (dBm)
11b	2.412	Low	14	±1
	2.437	Mid	14	±1
	2.462	High	14	±1
11g	2.412	Low	13	±1
	2.437	Mid	13	±1
	2.462	High	13	±1
11n (HT20)	2.412	Low	11	±1
	2.437	Mid	11	±1
	2.462	High	11	±1
11n (HT40)	2422	Low	11	±1
	2442	Mid	11	±1
	2462	High	11	±1

For Bluetooth Basic rate and BLE:

Mode	Channel	Target power (dBm)	Tolerance (dBm)
	Low	8	±1
	Mid	8	±1
	High	8	±1

For BLE beacon:

Mode	Channel	Target power (dBm)	Tolerance (dBm)
Bluetooth 4.0(BLE)	Low	-5	±2
	Mid	-5	±2
	High	-5	±2

For NFC

Frequency (GHz)	Target power (dBm)	Tolerance (dBm)
13.56	10	+0/-1

For 5G Wifi:

802.11. a	Frequency (GHz)	Channel	Target power (dBm)	Tolerance (dBm)
5G Band 1	5180	36	11.00	±1
	5200	40	12.00	±1
	5240	48	11.00	±1
5G Band 2	5260	52	12.00	±1
	5280	56	12.00	±1
	5320	64	10.00	±1
5G Band 3	5500	100	10.00	±1
	5600	120	10.00	±1
	5700	140	10.00	±1
5G Band 4	5745	149	10.00	±1
	5785	157	10.00	±1
	5825	165	10.00	±1

For 5G Wifi:

802.11n 20	Frequency (GHz)	Channel	Target power (dBm)	Tolerance (dBm)
5G Band 1	5180	36	11.00	±1
	5200	40	12.00	±1
	5240	48	11.00	±1
5G Band 2	5260	52	12.00	±1
	5280	56	12.00	±1
	5320	64	10.00	±1
5G Band 3	5500	100	10.00	±1
	5600	120	10.00	±1
	5700	140	10.00	±1
5G Band 4	5745	149	10.00	±1
	5785	157	10.00	±1

	5825	165	10.00	±1

For 5G Wifi:

802.11n 40	Frequency (GHz)	Channel	Target power (dBm)	Tolerance (dBm)
5G Band 1	5190	38	6.0	±1
	5230	46	11.00	±1
5G Band 2	5270	54	11.00	±1
	5310	62	6.00	±1
5G Band 3	5510	102	4.00	±1
	5590	118	11.00	±1
	5670	134	8.00	±1
5G Band 4	5755	151	10.00	±1
	5795	159	10.00	±1

9 SPECIFIC ABSORPTION RATE (SAR)

9.1 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 techniques 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.

9.2 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 (ρ). The equation description is as below:

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

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

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

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

Where: C is the specific head capacity, δT is the temperature rise and δt is the exposure duration, or related to the electrical field in the tissue by

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

Where: σ is the conductivity of the tissue ρ is the mass density of tissue and E is the RMS electrical field strength.

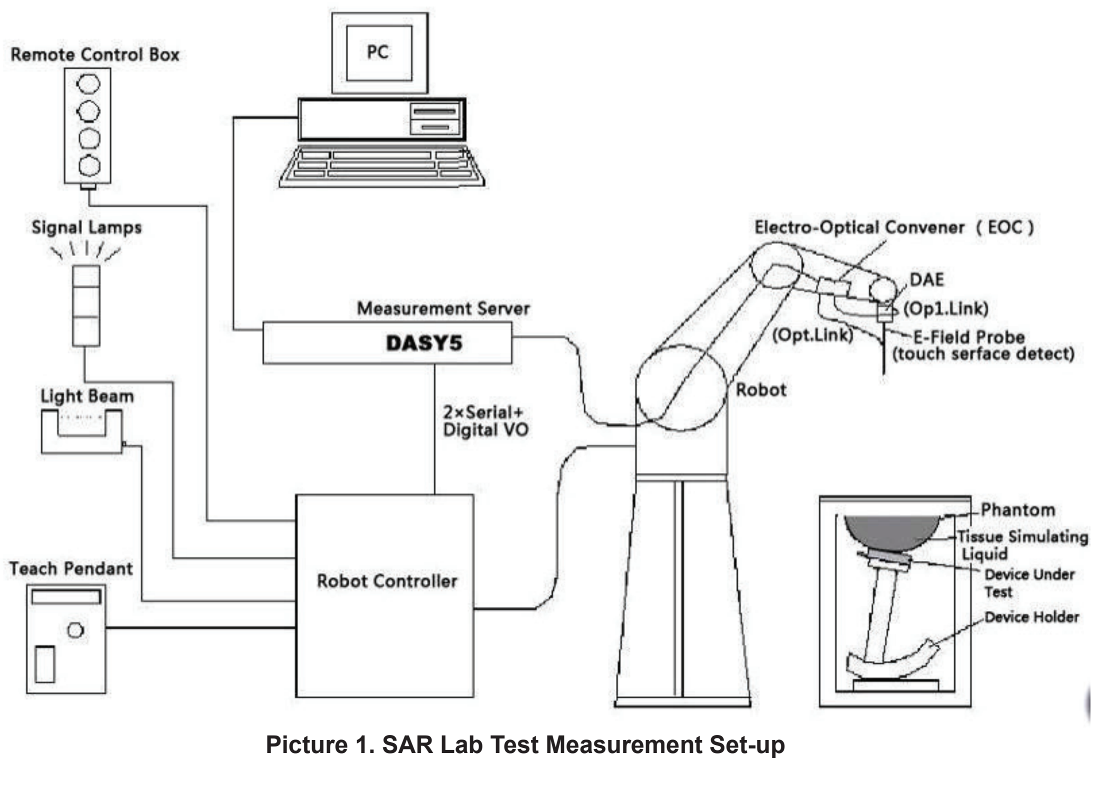
However for evaluating SAR of low power transmitter, electrical field measurement is typically applied.

10 SAR MEASUREMENTS SYSTEM CONFIGURATION

10.1 SAR MEASUREMENT SET-UP

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

- A standard high precision 6-axis robot (Stäubli TX=RX family) with controller, teach pendant and software. An arm extension for accommodating the data acquisition electronics (DAE).
- An isotropic field probe optimized and calibrated for the targeted measurement.
- A data acquisition electronics (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.
- The Electro-optical converter (EOC) performs the conversion from optical to electrical signals for the digital communication to the DAE. To use optical surface detection, a special version of the EOC is required. The EOC signal is transmitted to the measurement server.
- The function of the measurement server is to perform the time critical tasks such as signal filtering, control of the robot operation and fast movement interrupts.
- The Light Beam used is for probe alignment. This improves the (absolute) accuracy of the probe positioning.
- A computer running WinXP and the DASY5 software.
- Remote control and teach pendant as well as additional circuitry for robot safety such as warning lamps, etc.
- The generic twin phantom enabling the testing of left-hand and right-hand usage.
- The device holder for handheld mobile phones.
- Tissue simulating liquid mixed according to the given recipes.
- System validation dipoles allowing to validate the proper functioning of the system.



Picture 1. SAR Lab Test Measurement Set-up

10.2 DASY5 E-FIELD PROBE SYSTEM

The SAR measurements were conducted with the dosimetric probe designed in the classical triangular configuration and optimized for dosimetric evaluation. The probe is constructed using the thick film technique; with printed resistive lines on ceramic substrates. The probe is equipped with an optical multifiber line ending at the front of the probe tip. It is connected to the EOC box on the robot arm and provides an automatic detection of the phantom surface. Half of the fibers are connected to a pulsed infrared transmitter, the other half to a synchronized receiver. As the probe approaches the surface, the reflection from the surface produces a coupling from the transmitting to the receiving fibers. This reflection increases first during the approach, reaches maximum and then decreases. If the probe is flatly touching the surface, the coupling is zero. The distance of the coupling maximum to the surface is independent of the surface reflectivity and largely independent of the surface to probe angle. The DASY5 software reads the reflection turning a software approach and looks for the maximum using 2^{nd} ord curve fitting. The approach is stopped at reaching the maximum.

Probe Specifications:

Model: EX3DV4

Frequency Range: 10MHz — 6.0GHz (EX3DV4)

Calibration: In head and body simulating tissue at
Frequencies from 835 up to 5800MHz

Linearity: ± 0.2 dB (30 MHz to 6 GHz) for EX3DV4

Dynamic Range: 10 mW/kg — 100W/kg

Probe Length: 330 mm

Probe Tip Length: 20 mm

Body Diameter: 12 mm

Tip Diameter: 2.5 mm

Tip-Center: 1 mm

Application: SAR Dosimetry Testing
Compliance tests of mobile phones
Dosimetry in strong gradient fields

Picture 2 E-field Probe

10.3 E-FIELD PROBE CALIBRATION

Each E-Probe/Probe Amplifier combination has unique calibration parameters. A TEM cell 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/cm^2) using an RF Signal generator, TEM cell, and RF Power Meter.
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 inn 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 then rotated 360 degrees until the three channels show the maximum reading. The power density readings equates to 1 mw/ cm^2.
E-field temperature correlation calibration is performed in a flat phantom filled with the appropriate simulated brain 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.

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

Where:
Δt = Exposure time (30 seconds),
C = Heat capacity of tissue (brain or muscle),
ΔT = Temperature increase due to RF exposure.

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

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

10.4 OTHER TEST EQUIPMENT

10.4.1 Data Acquisition Electronics (DAE)

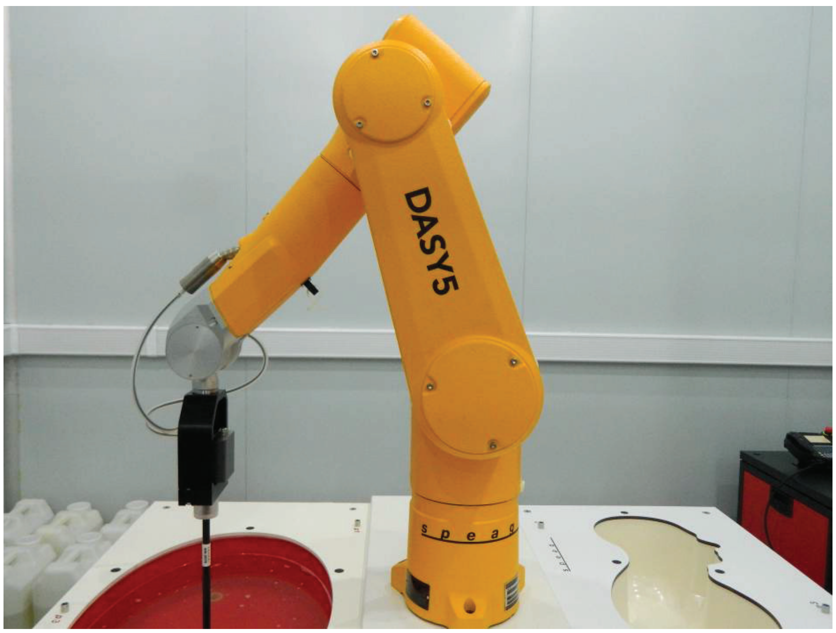
The data acquisition electronics consist of a highly sensitive electrometer-grade preamplifier with auto-zeroing, a channel and gain-switching multiplexer, a fast 16 bit AD-converter and a command decoder with a control logic unit. Transmission to the measurement server is accomplished through an optical downlink for data and status information, as well as an optical uplink for commands and the clock.
The mechanical probe mounting device includes two different sensor systems for frontal and sideways probe contacts. They are used for mechanical surface detection and probe collision detection.
The input impedance of the DAE is 200 MOhm; the inputs are symmetrical and floating. Common mode rejection is above 80 dB.

Picture 3: DAE

10.4.2 Robot

The SPEAG DASY system uses the high precision robots (DASY5: TX60XL) type from Stäubli SA (France). For the 6-axis controller system, the robot controller version from Stäubli is used. The Stäubli robot series have many features that are important for our application:

- High precision (repeatability 0.02mm)
- High reliability (industrial design)
- Low maintenance costs (virtually maintenance free due to direct drive gears; no belt drives)
- Jerk-free straight movements (brushless synchron motors; no stepper motors)
- Low ELF interference (motor control fields shielded via the closed metallic construction shields)



Picture 4 DASY 5

10.4.3 Measurement Server

The Measurement server is based on a PC/104 CPU broad with CPU (DASY5: 400 MHz, Intel Celeron), chip disk (DASY5: 128MB), RAM (DASY5: 128MB). The necessary circuits for communication with the DAE electronic box, as well as the 16 bit AD converter system for optical detection and digital I/O interface are contained on the DASY I/O broad, which is directly connected to the PC/104 bus of the CPU broad.

Picture 5 Server for DASY 5

The measurement server performs all real-time data evaluation of field measurements and surface detection, controls robot movements and handles safety operation. The PC operating system cannot interfere with these time critical processes. All connections are supervised by a watchdog, and disconnection of any of the cables to the measurement server will automatically disarm the robot and disable all program-controlled robot movements. Furthermore, the measurement server is equipped with an expansion port which is reserved for future applications. Please note that this expansion port does not have a standardized pinout, and therefore only devices provided by SPEAG can be connected. Devices from any other supplier could seriously damage the measurement server.

10.4.4 Device Holder for Phantom

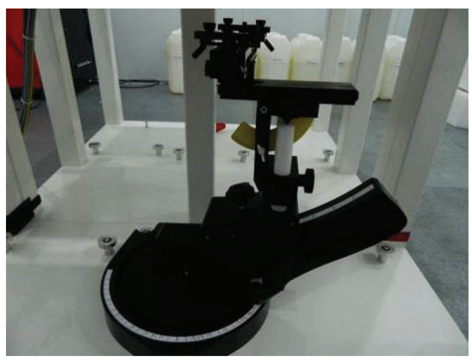
The SAR in the phantom is approximately inversely proportional to the square of the distance between the source and the liquid surface. For a source at 5mm distance, a positioning uncertainty of ±0.5mm would produce a SAR uncertainty of ±20%. Accurate device positioning is therefore crucial for accurate and repeatable measurements. The positions in which the devices must be measured are defined by the standards.

The DASY device holder is designed to cope with the different positions given in the standard. It has two scales for device rotation (with respect to the body axis) and device inclination (with respect to the line between the ear reference points). The rotation centers for both scales are the ear reference point (ERP). Thus the device needs no repositioning when changing the angles.

The DASY device holder is constructed of low-loss POM material having the following dielectric parameters: relative permittivity ε =3 and loss tangent δ =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.

<Laptop Extension Kit>

The extension is lightweight and made of POM, acrylic glass and foam. It fits easily on the upper part of the Mounting Device in place of the phone positioner. The extension is fully compatible with the Twin-SAM and ELI phantoms.



Picture 6: Device Holder

10.4.5 Phantom

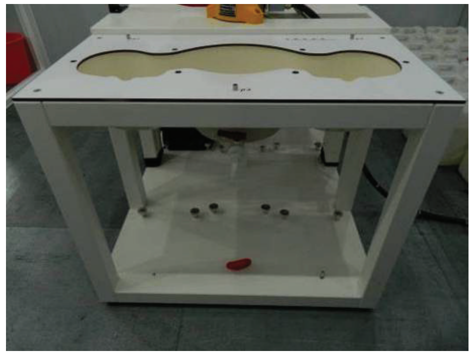
The SAM Twin Phantom V4.0 is constructed of a fiberglass shell integrated in a table. The shape of the shell is based on data from an anatomical study designed to Represent the 90th percentile of the population. The phantom enables the dissymmetric evaluation of SAR for both left and right handed handset usage, as well as body-worn usage using the flat phantom region. Reference markings on the Phantom allow the complete setup of all predefined phantom positions and measurement grids by manually teaching three points in the robot. The shell phantom has a 2mm shell thickness (except the ear region where shell thickness increases to 6 mm).

Shell Thickness: 2 ± 0. 2 mm

Filling Volume: Approx. 25 liters

Dimensions: 810 x l000 x 500 mm (H x L x W)

Available: Special



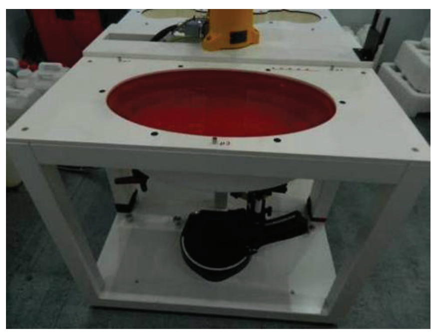
Picture 7: SAM Twin Phantom

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.

Shell Thickness 2±0.2 mm

Filling Volume Approx. 30 liters

Dimensions 190×600×0 mm (H x L x W)



Picture 8.ELI4 Phantom

10.5 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 DUT’s output power and should vary max. ± 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 ± 0.1mm). 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 ± 30°.)

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 is set according to FCC KDB Publication 865664. During 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

After the maximum interpolated values were calculated between the points in the cube, the SAR was averaged over the spatial volume (1g or 10g) using a 3D-Spline interpolation algorithm. The 3D-spline is composed of three one-dimensional splines with the “Not a knot” condition (in x, y, and z directions). The volume was then integrated with the trapezoidal algorithm.

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.

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

Table 1: Area and Zoom Scan Resolutions per FCC KDB Publication 865664 D01

Frequency	Maximum Area Scan Resolution (mm) (Δxarea, Δyarea)	Maximum Zoom Scan Resolution (mm) (Δxzoom, Δyzoom)	Maximum Zoom Scan Spatial Resolution (mm) Δzzoom(n)	Minimum Zoom Scan Volume (mm) (x,y,z)
≤2 GHz	≤15	≤8	≤5	≥ 30
2-3 GHz	≤12	≤5	≤5	≥30
3-4 GHz	≤12	≤5	≤4	≥28
4-5 GHz	≤10	≤4	≤3	≥25
5-6 GHz	≤10	≤4	≤2	≥22

10.6 DATA STORAGE AND EVALUATION

10.6.1 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 ".DAE4". 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 set up, 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 loss less media will always be zero. Raw data can also be exported to perform the evaluation with other software packages.

10.6.2 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	$Norm_i$, a_{i0}, a_{i1}, a_{i2}
- Conversion factor	$ConvF_i$
- Diode compression point	Dcp_i
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:

$$\mathbf{V_i = U_i + U_i^2 \cdot c\,f / dcp_i}$$

With $\mathbf{V_i}$ = compensated signal of channel i (i = x, y, z)

$\mathbf{U_i}$ = input signal of channel i (i = x, y, z)

cf = crest factor of exciting field (DASY parameter)

$\mathbf{dcp_i}$ = diode compression point (DASY parameter)

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

evaluated:

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

H-field probes: $\mathbf{H_i = (V_i)^{1/2} \cdot (a_{i0} + a_{i1} f + a_{i2} f^2) / f}$

With $\mathbf{V_i}$ = compensated signal of channel i (i = x, y, z)

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

[mV/(V/m)2] for E-field Probes

ConvF = sensitivity enhancement in solution

a_{ij} = 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 · σ / (ρ· 1000)

with **SAR** = local specific absorption rate in mW/g

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

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

= equivalent tissue density in g/cm^3

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.

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

with **P_{pwe}** = equivalent power density of a plane wave in mW/cm^2

E_{tot} = total electric field strength in V/m ; **H_{tot}** = total magnetic field strength in A/m

10.7 TISSUE-EQUIVALENT LIQUID

10.7.1 Tissue-equivalent Liquid Ingredients

The liquid is consisted of water, salt and Glycol. The liquid has previously been proven to be suited for worst-case. The Table 3 shows the detail solution. It's satisfying the latest tissue dielectric parameters requirements proposed by the KDB 865664 D01.

Table 3: Composition of the Body Tissue Equivalent Matter

MIXTURE%	FREQUENCY (Body) 2450MHz
Water	73.2
Glycol	26.7
Salt	0.1
Dielectric Parameters Target Value	f=2450MHz ε=52.7 σ=1.95

10.7.2 Tissue-equivalent Liquid Properties

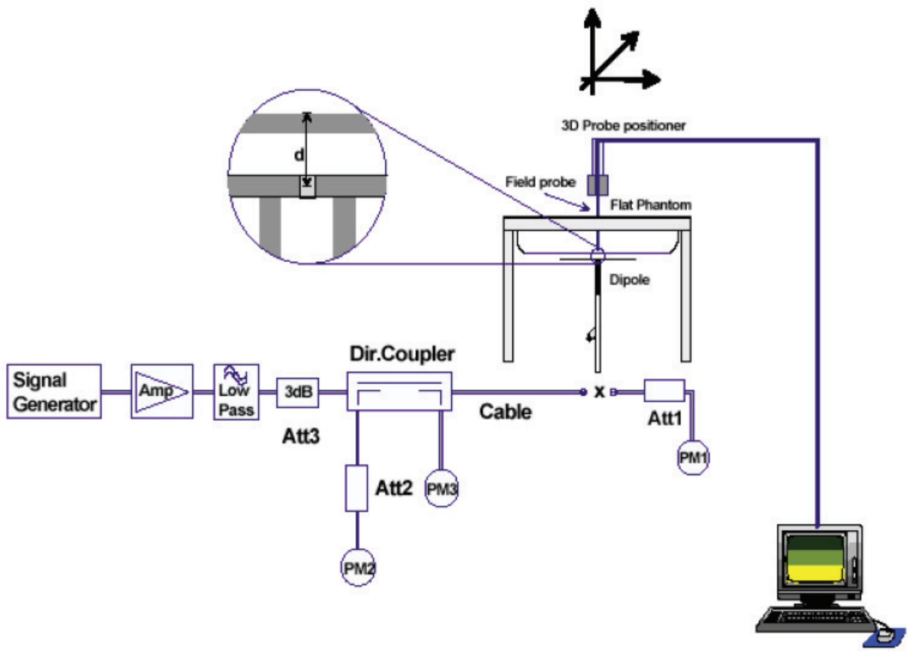
Table 4: Dielectric Performance of Tissue Simulating Liquid

Test Date	Frequency (MHz)	Tissue Type	Liquid Temp. (℃)	Conductivity (σ)	Permittivity (εr)	Conductivity Target (σ)	Permittivity Target (εr)	Delta (σ) (%)	Delta (εr) (%)	Limit (%)
2016.12.19	900	Body	22.5	1.063	55.128	1.05	55.00	1.24	0.23	±5
2016.12.20	2450	Body	22.6	2.010	52.980	1.95	52.70	3.08	0.53	±5
2016.12.14	5250	Body	22.7	5.310	50.859	5.44	49.32	-2.39	3.12	±5
2016.12.14	5600	Body	22.8	5.718	50.529	5.85	48.86	-2.26	3.42	±5
2016.12.15	5750	Body	22.6	6.092	50.014	6.02	48.72	1.20	2.66	±5
2017.1.17	900	Body	22.5	1.059	55.132	1.05	55.00	0.86	0.24	±5

10.8 SYSTEM CHECK

10.8.1 Description of System Check

The manufacturer calibrates the probes annually. Dielectric parameters of the tissue simulants 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 simulant, 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 table 6. System check results have to be equal or near the values determined during dipole calibration with the relevant liquids and test system (±10 %). System check is performed regularly on all frequency bands where tests are performed with the DASY5 system.



Picture 10. System Check Set-up

Justification for Extended SAR Dipole Calibrations
Usage of SAR dipoles calibrated less than 3 years ago but more than 1 year ago were confirmed in maintaining return loss (< - 20 dB, within 20% of prior calibration) and impedance (within 5 ohm from prior calibration) requirements per extended calibrations in KDB 865664 D01 v01r04:
Table 5: Antenna Parameters with Body Tissue Simulating Liquid

Dipole D900V2 SN: 1d162				
Body Liquid				
Date of Measurement	Return Loss(dB)	Δ %	Impedance (Ω)	ΔΩ
2014-01-14	-28.581	/	47.850	/
2015-01-11	-28.332	0.87	47.396	-0.454
2016-01-10	-28.688	-1.26	47.861	0.465
Head Liquid				
Date of Measurement	Return Loss(dB)	Δ %	Impedance (Ω)	ΔΩ
2014-01-14	-30.675	/	52.545	/
2015-01-11	-30.317	1.17	52.028	-0.517
2016-01-10	-30.692	-1.24	52.735	0.707

Dipole D2450V2 SN: 845				
Head Liquid				
Date of Measurement	Return Loss(dB)	Δ %	Impedance (Ω)	ΔΩ
2014-1-13	-24.935	/	55.234	/
2015-1-11	-24.769	0.67	54.383	-0.851
2016-12-25	-25.735	0.14	51.964	0.123
Body Liquid				
Date of Measurement	Return Loss(dB)	Δ %	Impedance (Ω)	ΔΩ
2014-1-13	-26.331	/	51.422	/
2015-1-11	-26.153	0.68	51.016	-0.406
2016-12-25	-23.386	-1.32	51.215	1.416

Dipole D5GHzV2 SN: 1180					
	Body Liquid				
	Date of Measurement	Return Loss(dB)	Δ %	Impedance (Ω)	ΔΩ
	2014-1-7	-22.524	/	49.590	/
	2015-1-11	-22.158	1.62	50.335	0.745
	2016-1-9	-25.865	0.25	47.786	0.180
	Head Liquid				
	Date of Measurement	Return Loss(dB)	Δ %	Impedance (Ω)	ΔΩ
	2014-1-7	-21.669	/	49.711	/
	2015-1-11	-21.083	2.70	50.130	0.419
5G	2016-1-9	-25.820	0.47	48.965	0.959
	Body Liquid				
	Date of Measurement	Return Loss(dB)	Δ %	Impedance (Ω)	ΔΩ
	2014-1-7	-24.125	/	55.896	/
	2015-1-11	-23.978	0.61	56.534	0.638
	2016-1-9	-25.248	-0.99	55.967	0.841
	Head Liquid				
	Date of Measurement	Return Loss(dB)	Δ %	Impedance (Ω)	ΔΩ
	2014-1-7	-23.351	/	55.691	/
	2015-1-11	-23.213	0.59	56.217	0.526
	2016-1-9	-27.054	-1.98	53.843	0.266

Dipole D900V2 SN: 043				
Body Liquid				
Date of Measurement	Return Loss(dB)	Δ %	Impedance (Ω)	ΔΩ
2016-06-27	-20.9	/	44.9	/
Head Liquid				
Date of Measurement	Return Loss(dB)	Δ %	Impedance (Ω)	ΔΩ
2016-06-27	-24.9	/	47.2	/

10.8.2 System Check Results

Table 6: System Check for Head /BodyTissue Simulating Liquid

Date	Frequency (MHz)2	Tissue Type2	Input Power (mW)	Dipole S/N	Probe S/N	DAE S/N	Measured 1g SAR (W/kg)	Targeted 1g SAR (W/kg)	Normalized 1g SAR (W/kg)	Deviation (%)
2016.12.19	900	Body	250	1d162	3970	1418	2.63	10.70	10.52	-1.68
2016.12.20	2450	Body	250	845	3970	1418	12.20	51.20	48.8	-4.69
2016.12.14	5250	Body	100	1180	3970	1418	7.49	75.40	74.9	-0.66
2016.12.14	5600	Body	100	1180	3970	1418	7.89	80.20	78.9	-1.62
2016.12.15	5750	Body	100	1180	3970	1418	7.35	74.60	73.5	-1.47
2017.1.17	900	Body	250	043	3970	1418	2.65	10.80	10.6	-1.85