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TEST REPORT

SCOPE OF WORK
FCC TESTING–QCM1212

REPORT NUMBER
191216047SZN-004

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1 February 2020

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SAR TEST REPORT

For

KanDao Technology Co.Ltd

QooCam 8K 360 Camera

Model No.: QCM1212

FCC ID: 2ATPV-KDUC

Report No.: 191216047SZN-004

Issue Date: 1 February 2020

Prepared by

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Table of Contents

1 GENERAL INFORMATION

Applicant:	KanDao Technology Co.Ltd 5th Floor, M7 Steel Building, the second way in Technology Road, Nanshan District, Shenzhen, China
Product Description:	QooCam 8K 360 Camera
Model Number:	QCM1212
FCC ID	2ATPV-KDUC
File Number:	191216047SZN-004
Date of Test:	24 January 2020

The above equipment was tested by Intertek Testing Services Shenzhen Ltd. Longhua Branch. 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 and KDB 865664. This device is in compliance with Specific Absorption Rate (SAR) for general population/uncontrolled exposure limits (1.6 W/kg) specified in ANSI/IEEE C95.1-1992.

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

Prepared and Checked by:

Winkey Wang
Senior Project Engineer

Approved by:

Kidd Yang
Technical Supervisor
Date: 1 February 2020

2 STATEMENT OF COMPLIANCE

Max. Reported SAR (1g)

Test Position		Mode	Channel / Frequency (MHz)	Limit of SAR_{1g}: 1.6 W/kg	
				Measured SAR_{1g} (W/kg)	Reported SAR_{1g} (W/kg)
Body	Rear Side	802.11ac20	48/5240	0.751	0.766

The SAR values found for the QooCam 8K 360 Camera are below the maximum recommended levels of 1.6 W/kg as averaged over any 1g tissue according to the ANSI C95.1-1992.

The maximum reported SAR value is: 0.766W/kg (1g).

Modified Information

Rev.	Summary	Date of Rev.	Report No.
Ver.1.0	Original Report	25 January 2020	191216047SZN-004

3 EQUIPMENT UNDER TEST (EUT) TECHNICAL DESCRIPTION

Characteristics	Description
Description:	QooCam 8K 360 Camera
Model name:	QCM1212
Exposure Category:	Uncontrolled Environment/General Population
Test Mode(s):	802.11 b/g/n20/n40, 802.11a/n20/ac20/n40/ac40/ac80
Operating Frequency Range:	802.11b/g/n20/n40: 2412MHz- 2462MHz 802.11a/n20/ac20/n40/ac40/ac80: 5150MHz~5250 MHz
Modulation:	BPSK, QPSK, 16QAM, 64QAM, 256QAM, CCK, DQPSK, DBPSK
Power Level:	802.11 b/g/n20/n40: 16.5dBm (max.) 802.11a/n20/ac20/n40/ac40/ac80: 20dBm (max.)
Antenna Type:	Integral Antenna
Antenna Gain:	2.4G WIFI: 3dBi 5G WIFI: 2dBi
Dimensions:	14.7cmX5.7cmX3.3cm
Rating:	Input 5Vdc, 3A max; Battery inside 3.8Vdc, 3000mAh
Product Software Version:	V58
Product Hardware Version:	UNICORN_MB_V03

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.***

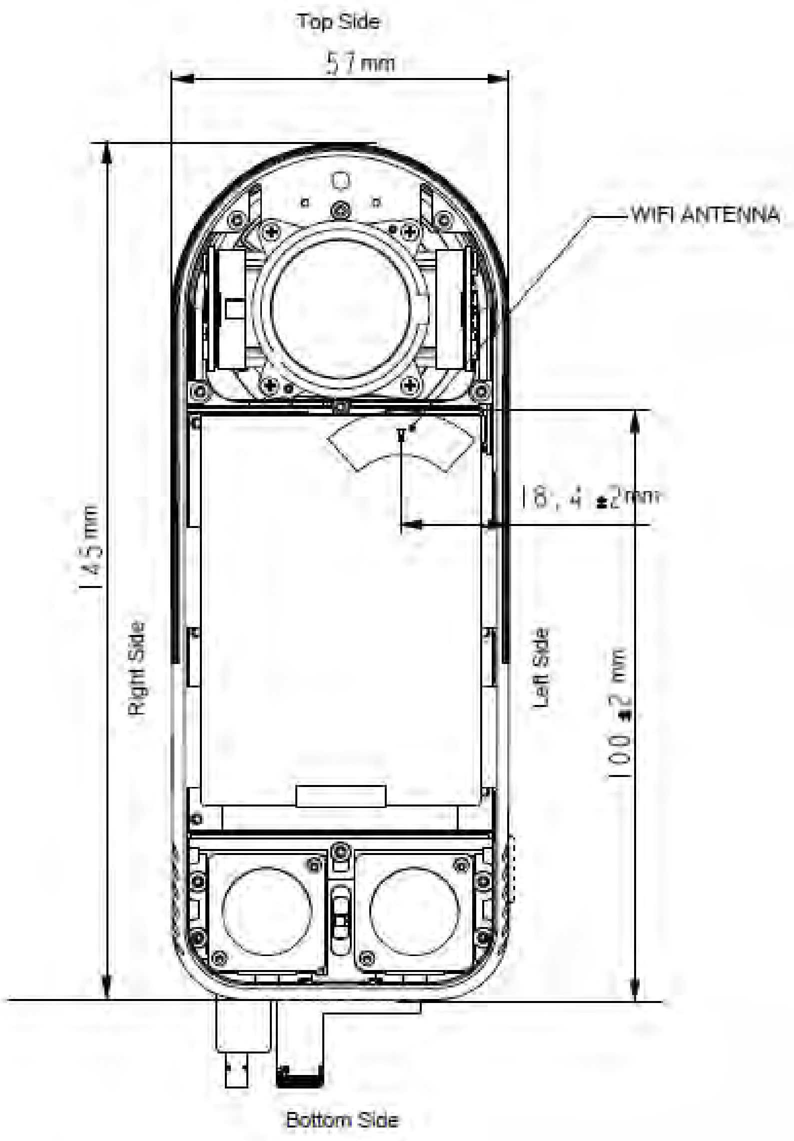
4 AUXILIARY EQUIPMENT DETAILS

AE: Battery	Description
Manufacturer:	/
Model:	/
S/N:	/
capacity:	3000mAh
Voltage:	3.8V

5 TEST FACILITY

Site Description	
EMC Lab.	Intertek Testing Services Shenzhen Ltd. Longhua Branch was accredited by China National Accreditation Service for Conformity Assessment (CNAS) with registration no.: L0327 according to ISO/IEC 17025: 2005.
	Accredited by FCC The Certificate Registration Number is CN1188 Accredited by Industry Canada The Certificate Registration Number is 2055C
Name of Firm	Intertek Testing Services Shenzhen Ltd.
Site Location	101, 201, Building B, No. 308 Wuhe Avenue, Zhangkengjing Community, GuanHu Subdistrict, LongHua District, ShenZhen, China

6 EUT ANTENNA LOCATIONS



Dorsal view

WIFI Antenna Location	
Distance from WIFI ANT to Front Side	23mm
Distance from WIFI ANT to Rear Side	1mm
Distance from WIFI ANT to Top Side	45mm
Distance from WIFI ANT to Bottom Side	85mm
Distance from WIFI ANT to Left Side	5mm
Distance from WIFI ANT to Right Side	27mm

All Sides for SAR Testing Evaluation:

Mode	Location	Distance from ANT (mm)	Max. tune-up Power(mW)	Exemption with Max. Allowed Power (mW)	SAR Test
2.4G	Front Side	23	44.668	43.975	YES
	Rear Side	1		9.560	YES
	Top Side	45		86.038	N/A
	Bottom Side	85		445.597	N/A
	Left Side	5		9.560	YES
	Right Side	27		51.622	N/A
5G	Front Side	23	100.0	30.114	YES
	Rear Side	1		6.546	YES
	Top Side	45		58.918	YES
	Bottom Side	85		415.465	N/A
	Left Side	5		6.546	YES
	Right Side	27		35.351	YES

Note: SAR testing exemption according to KDB 447498 D01 Clause 4.3.1 with the following ormula.

0) For 100 MHz to 6 GHz and test separation distances ≤ 50 mm, the 1-g SAR test exclusion thresholds are determined by the following:

[(max. power of channel, including tune-up tolerance, mW) / (min. test separation distance mm)] · [√f(GHz)] ≤ 3.0 for 1-g SAR,
*where f(GHz) is the RF channel transmit frequency in GHz
*When the minimum test separation distance is < 5 mm, a distance of 5 mm is applied to determine SAR test exclusion.

b) For 100 MHz to 6 GHz and test separation distances > 50 mm, the 1-g SAR test exclusion thresholds are determined by the following
{[Power allowed at numeric threshold for 50 mm in step a]] + [(test separation distance – 50 mm)·10]} mW, for > 1500 MHz and ≤ 6 GHz

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 865664 D02 RF Exposure Reporting v01r02**: RF Exposure Compliance Reporting and Documentation Considerations

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

☒**KDB 248227 D01 802.11 Wi-Fi SAR v02r02**: SAR Guidance for IEEE 802.11 (Wi-Fi) Transmotters

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.

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 FCC KDB447498 D01 and §1.1310, 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.

Routine SAR evaluation refers to that specifically required by § 2.1093, using measurements or computer simulation. Portable transmitters with output power greater than the applicable low threshold require SAR testing to qualify for TCB approval.

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.

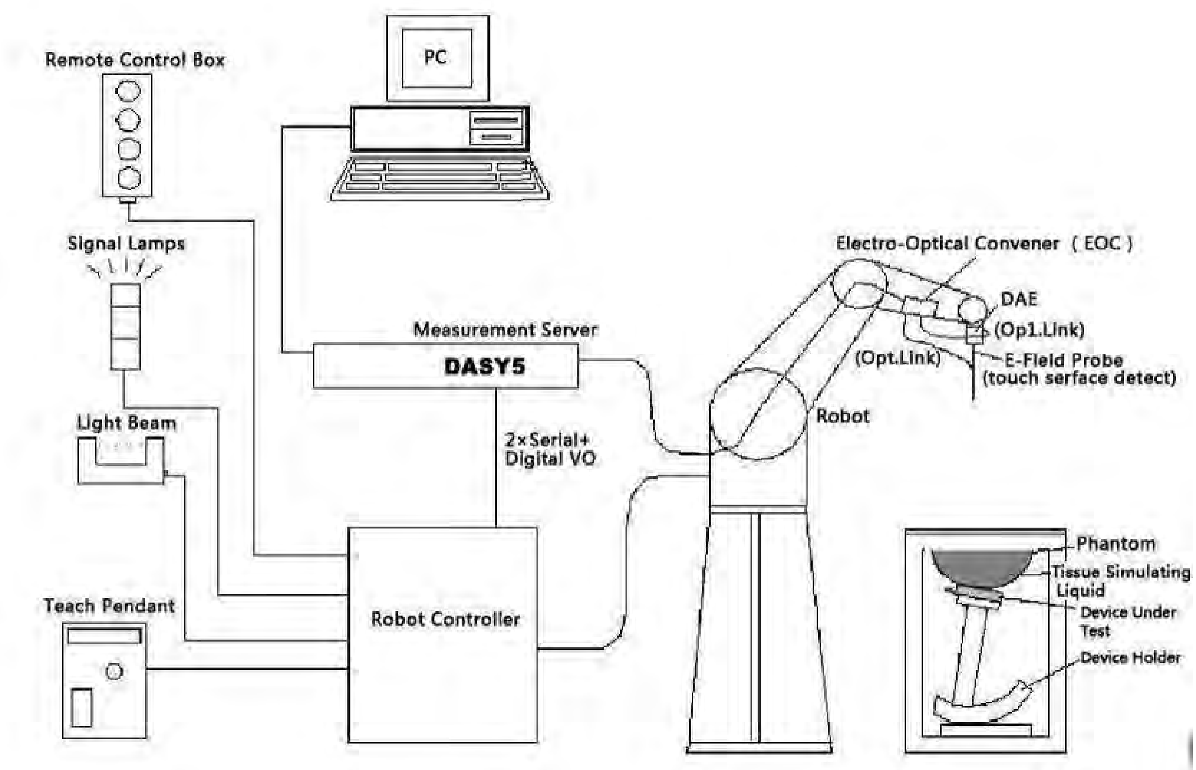
However for evaluating SAR of low power transmitter, electrical field measurement is typically applied.

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 Win 7 profesional operating system and the DASY5 software.
- Remote control and teach pendant as well as additional circuitry for robot safety such as warning lamps, etc.
- The phantom, the device holder and other accessories according to the targeted measurement.



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 2nd ord curve fitting. The approach is stopped at reaching the maximum.

Probe Specifications:

Frequency	10 MHz – >6 GHz Linearity: ±0.2 dB (30 MHz – 6 GHz)
Directivity	±0.3 dB in TSL (rotation around probe axis) ±0.5 dB in TSL (rotation normal to probe axis)
Dynamic Range	10 µW/g – >100 mW/g Linearity: ±0.2 dB (noise: typically <1 µW/g)
Dimensions	Overall length: 337 mm (tip: 20 mm) Tip diameter: 2.5 mm (body: 10 mm) Typical distance from probe tip to dipole centers: 1 mm
Applications	High precision dosimetric measurements in any exposure scenario (e.g., very strong gradient fields); the only probe that enables compliance testing for frequencies up to 6 GHz with precision of better than 30%

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: TX90XL) 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.. 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

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)

$\mathbf{Norm_i}$ = sensor sensitivity of channel i (i = x, y, z)

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

ConvF = sensitivity enhancement in solution

$\mathbf{a_{ij}}$ **=** sensor sensitivity factors for H-field probes

f = carrier frequency [GHz]

$\mathbf{E_i}$ = electric field strength of channel i in V/m

$\mathbf{H_i}$ = 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

= 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 2 shows the detail solution. It's satisfying the latest tissue dielectric parameters requirements proposed by the KDB 865664 D01.

Table 2: 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

MIXTURE%	FREQUENCY (Body) 5200MHz
Water	78.6
Glycol	10.7
Triton X-100	10.7
Dielectric Parameters Target Value	f=5200MHz ε=49.0 σ=5.30

10.7.2 Tissue-equivalent Liquid Properties

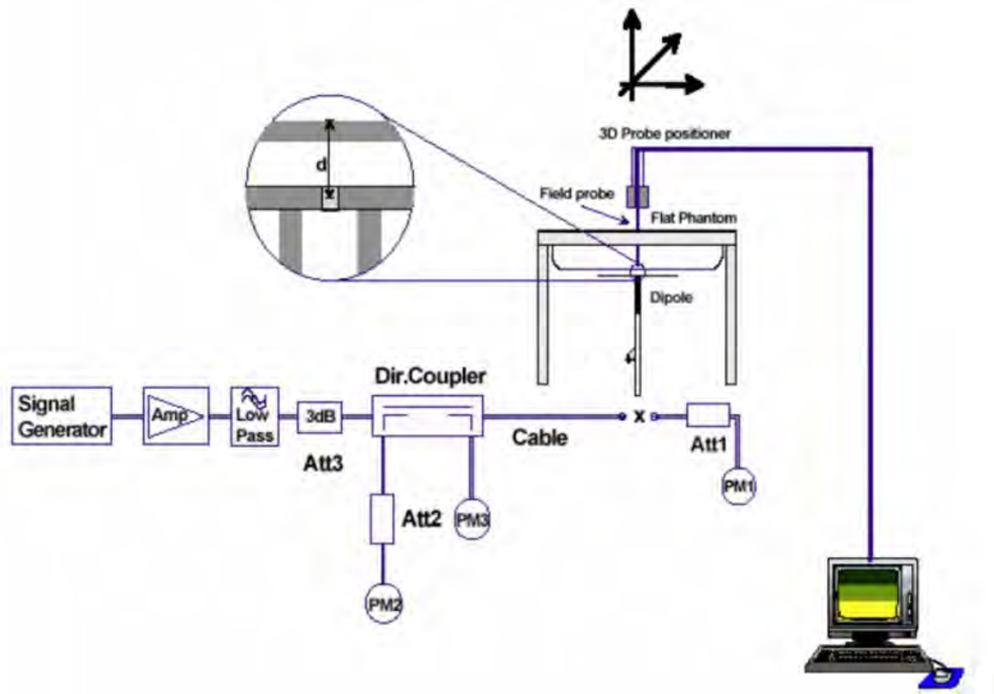
Table 3: Dielectric Performance of Tissue Simulating Liquid

Test Date	Frequency (MHz)	Tissue Type	Liquid Temp. (℃)	Conductivity (σ)	Permittivity (εr)	Conductivity Target (σ)	Permittivity Target (εr)	Delta (σ) (%)	Delta (εr) (%)	Limit (%)
2020-1-24	2450	Body	21.5	2.013	52.442	1.95	52.7	3.23	-0.49	±5
2020-1-24	5200	Body	21.5	5.256	49.589	5.30	49.0	-0.83	1.20	±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 4. 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 9. System Check Set-up

10.8.2 System Check Results

Table 4: System Check for Body Tissue Simulating Liquid

Frequency	Test Date	Dielectric Parameters		250mW Measured SAR1g	1W Normalized SAR1g	1W Target SAR1g	Limit(±10% Deviation)
		εr	σ (s/m)	(W/kg)			
2450MHz	2020-1-24	52.442	2.013	12.8	51.2	50.7	1.0
Note: 1. The graph results see ANNEX B. 2. Target Values used derive from the calibration certificate.							

Frequency	Test Date	Dielectric Parameters		100mW Measured SAR1g	1W Normalized SAR1g	1W Target SAR1g	Limit(±10% Deviation)
		εr	σ (s/m)	(W/kg)			
5200MHz	2020-1-24	49.589	5.256	7.5	75.0	71.3	5.2
Note: 1. The graph results see ANNEX B. 2. Target Values used derive from the calibration certificate.							

11 MEASUREMENT PROCEDURES

11.1 GENERAL DESCRIPTION OF TEST PROCEDURES

For WLAN SAR testing, WLAN engineering testing software installed on the DUT can provide continuous transmitting RF signal. This RF signal utilized in SAR measurement has almost 100% duty cycle and its crest factor is 1.

For the 802.11a/b/g/n/ac SAR tests, a communication link is set up with the test mode software for WIFImode test. During the test, at the each test frequency channel, the EUT is operated at the RF continuous emission mode. Provided higher maximum output power is not specified for the other channels, channels 1, 6, 11, 36, 40, 48, 46, 42 are used to configure 22 MHz DSSS and 20/40/80MHz OFDM channels for SAR measurements; otherwise, the closest adjacent channel with the highest maximum output power specified for production units should be tested instead of channels 1, 6, 11,40, 48, 46 or 42. In addition, SAR test reduction with respect to reported SAR and transmission band width according to 4.3.3 of KDB Publication 447498 D01 may also be applied

802.11a/b/g/n/ac operating modes are tested independently according to the service requirements in each frequency band. 802.11a/b/g/n/ac modes are tested on the maximum average output channel.

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 (see 3.1) for the exposure configuration is ≤ 0.8W/kg, no further SAR testing is required for 802.11b DSSS in that exposure configuration.
b) When the reported SAR is > 0.8W/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.

When SAR measurement is required for 2.4 GHz 802.11g/n OFDM configurations, the measurement and test reduction procedures for OFDM are applied (see 5.3, including subclauses). SAR is not required for the following 2.4 GHz OFDM conditions.

a) When KDB Publication 447498 D01 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.

11.2 MEASUREMENT VARIABILITY

Per FCC KDB Publication 865664 D01, SAR measurement variability was assessed for each frequency band, which was determined by the SAR probe calibration point and tissue-equivalent medium used for the device measurements. When both head and body tissue-equivalent media were required for SAR measurements in a frequency band, the variability measurement procedures were applied to the tissue medium with the highest measured SAR, using the highest measured SAR configuration for that tissue-equivalent medium. These additional measurements were repeated after the completion of all measurements requiring the same head or body tissue-equivalent medium in a frequency band. The test device was returned to ambient conditions (normal room temperature) with the battery fully charged before it was re-mounted on the device holder for the repeated measurement(s) to minimize any unexpected variations in the repeated results.
SAR Measurement Variability was assessed using the following procedures for each frequency band:

1) Repeated measurement is not required when the original highest measured SAR is < 0.8W/kg; steps 2) through 4) do not apply.

2) When the original highest measured SAR is ⩾ 0.8 W/kg, repeat that measurement once.

3) Perform a second repeated measurement only if the ratio of largest to smallest SAR for the original and first repeated measurements is > 1.2 or when the original or repeated measurement is ⩾ 1.45 W/kg (~ 10% from the 1-g SAR limit).

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 > 1.45.

11.3 TEST RESULTS

11.3.1 Conducted Power Result

WIFI Mode (2.4G)

Mode	Channel number	Frequency (MHz)	Data rate(Mbps)	Average Output Power(dBm)	Average Tune up limited(dBm)
802.11b	1	2412	1	16.22	15.5±1
	6	2437	1	16.10	15.5±1
	11	2462	1	15.98	15.5±1
802.11g	1	2412	6	15.73	15.5±1
	6	2437	6	15.53	15.5±1
	11	2462	6	15.69	15.5±1
802.11n(HT20)	1	2412	MCS0	14.35	13.5±1
	6	2437	MCS0	14.12	13.5±1
	11	2462	MCS0	13.93	13.5±1

WIFI Mode (5G)

Mode	Channel number	Frequency (MHz)	Data rate(Mbps)	Average Output Power(dBm)	Average Tune up limited(dBm)
802.11a	36	5180	6	19.07	19±1
	40	5200	6	19.46	
	48	5240	6	19.68	
802.11n20	36	5180	MCS0	17.35	18.0±1
	40	5200	MCS0	17.92	
	48	5240	MCS0	18.16	
802.11n40	38	5190	MCS0	19.04	19±1
	46	5230	MCS0	19.40	
802.11ac20	36	5180	MCS0	18.85	19±1
	40	5200	MCS0	19.45	
	48	5240	MCS0	19.92	
802.11ac40	38	5190	MCS0	18.08	19±1
	46	5230	MCS0	18.35	
802.11ac80	42	5210	MCS0	18.70	19±1

11.3.2 SAR TEST RESULTS

Test Position	Channel / Frequency (MHz)	Mode	Maximum Allowed Power (dBm)	Conducted Power (dBm)	Drift ±0.21 dB	Limit SAR_{1g} 1.6 W/kg		
					Drift (dB)	Measured SAR_{1g} (W/kg)	Scaling Factor	Reported SAR_{1g} (W/kg)
Test Position of extremity (Distance Between EUT and Flat Phatom:0mm)								
Rear Side	1 / 2412	DSSS	16.5	16.22	0.04	0.290	1.07	0.310
Front side	1 / 2412	DSSS	16.5	16.22	0.06	0.094	1.07	0.101
Left Side	1 / 2412	DSSS	16.5	16.22	0.12	0.102	1.07	0.109
Front Side	48 / 5240	OFDM	20.0	19.92	0.01	0.274	1.02	0.279
Rear Side	48 / 5240	OFDM	20.0	19.92	0.08	0.751	1.02	0.766
Left Side	48 / 5240	OFDM	20.0	19.92	-0.07	0.359	1.02	0.366
Right Side	48 / 5240	OFDM	20.0	19.92	-0.14	0.157	1.02	0.160
Top Side	48 / 5240	OFDM	20.0	19.92	0.13	0.092	1.02	0.094

Note:
1. The value with blue color is the maximum SAR Value of each test band.
2. When the reported SAR of the highest measured maximum output power channel for the exposure configuration is ≤ 0.8 W/kg, no further SAR testing is required for 802.11b DSSS in that exposure configuration.
3. 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.
4. The EUT exercise program (provided by client) used during SAR testing was designed to exercise the various system components in a manner similar to a typical use. During the test, Channel and test mode software provided by the applicant was used to control the operating channel as well as the test mode. The worst case configuration is used in all specified testing.

2.4 GHz 802.11g/n-HT20 OFDM SAR Test Exclusion Requirements

Test Position	Channel/ Frequency (MHz)	802.11b Max. Allowed Power (dBm)	802.11g/n Max. Allowed Power (dBm)	Limit SAR1g: 1.6W/kg		
				802.11b Report SAR1g (W/kg)	Scaling Factor	Adjusted SAR1g (W/kg)
Rear Side	1/2412	16.5	16.5	0.310	1.0	0.310

Note: SAR is not required for the 2.4 GHz OFDM conditions if 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.

11.3.3 Simultaneous Transmission SAR Analysis.

Not applicable. 2.4G WIFI and 5G WiFi can not transmit simultaneous.

11.3.4 MAXIMUM GRAPH RESULTS

The graph results see ANNEX C.

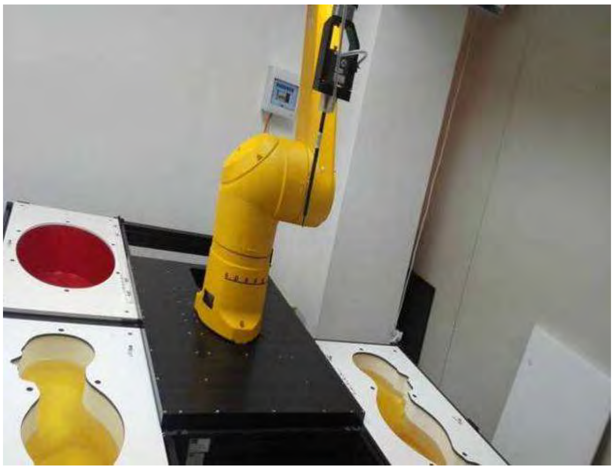
12 MEASUREMENT UNCERTAINTY

The measured SAR were <1.5 W/kg for all frequency bands, therefore per KDB Publication 865664 D01 v01r04, the extensive SAR measurement uncertainty analysis described in IEEE Std 1528-2013 is not required in SAR reports.

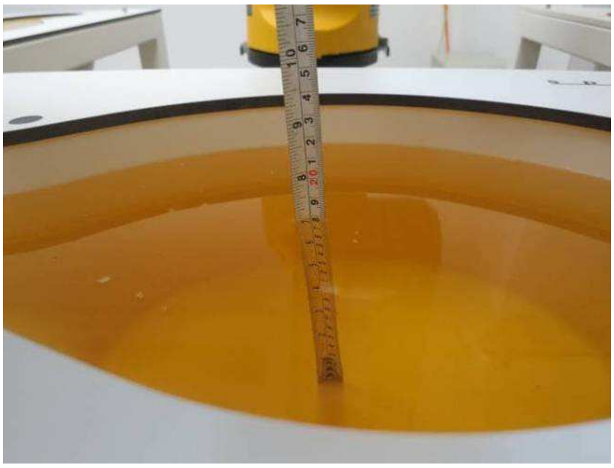
13 MAIN TEST INSTRUMENT

	Equipment No.	Equipment	Manufacturer	Model No.	Serial No.	Last Cal.	Cal. Interval
☒	SZ060-01	SAR Test System	SPEAG	DASY52 SAR TX90XL	F14/5YJ0B1/A/01	10/22/2019	1 year
☒	SZ060-01-01	E-Field Probe	SPEAG	EX3DV4	7322	10/22/2019	1 year
☒	SZ060-01-10	System Validation Dipole	SPEAG	D2450V2	966	8/31/2018	3 year
☒	SZ060-01-12	System Validation Dipole	SPEAG	D5GHzV2	1218	8/31/2018	3 year
☒	SZ060-01-13	Data Acquisition Unit	SPEAG	DAE4	1473	9/24/2019	1 year
☒	SZ060-01-14	Dielectric Assessment Kit	SPEAG	DAKS 3.5	1056	N/A	N/A
☒	SZ060-01-15	Vector Reflectometer	Copper Mountain Technologies	Planar R140	0090614	N/A	N/A
☒	SZ060-01-16	Thermometer	LKM electronics GmbH	DTM3000	3477	8/7/2019	1 year
☒	SZ060-01-17	Power Amplifier	Mini Circuits	ZHL-42W+	QA1449003	N/A	N/A
☒	SZ060-01-18	Power Amplifier	Mini Circuits	ZVE-8G+	111701437	N/A	N/A
☒	SZ060-01-20	SAM Twin Phantom	SPEAG	SAM Twin Phantom V5.0	1891	N/A	N/A
☒	SZ180-15	Signal Generator	R&S	SMB100A	113589	10/29/2019	1 year
☒	SZ070-04	Directional Bridge	Agilent	86205A	MY31402141	12/24/2019	1 year
☒	SZ182-02	RF Power Meter	Anritsu	ML2496A	1302005	5/28/2019	1 year
☒	SZ182-03	Average power sensor	R&S	NRP-Z22	101689	5/28/2019	1 year
☒	SZ070-01	Attenuator	Huber Suhner	10dB	N/A	N/A	N/A
☒	SZ070-02	Attenuator	Huber Suhner	30dB	N/A	N/A	N/A
☒	N/A	Device Holder	SPEAG	N/A	N/A	N/A	N/A
☒	SZ060-01-22	SAR Test System Software	SPEAG	DASY5.2 SW: 52.10.1 (1476)	N/A	N/A	N/A

ANNEX A: TEST LAYOUT



Specific Absorption Rate Test Layout



Liquid Depth in the flat phantom (18.2cm)

Front Side (distance 0mm with Flat Phantom)

Rear Side (distance 0mm with Flat Phantom)

Left Side (distance 0mm with Flat Phantom)

Right Side (distance 0mm with Flat Phantom)


Top Side (distance 0mm with Flat Phantom)

ANNEX B: SYSTEM CHECK RESULTS

Date: 1/24/2020

Test Laboratory: Intertek Service

System Check 2450

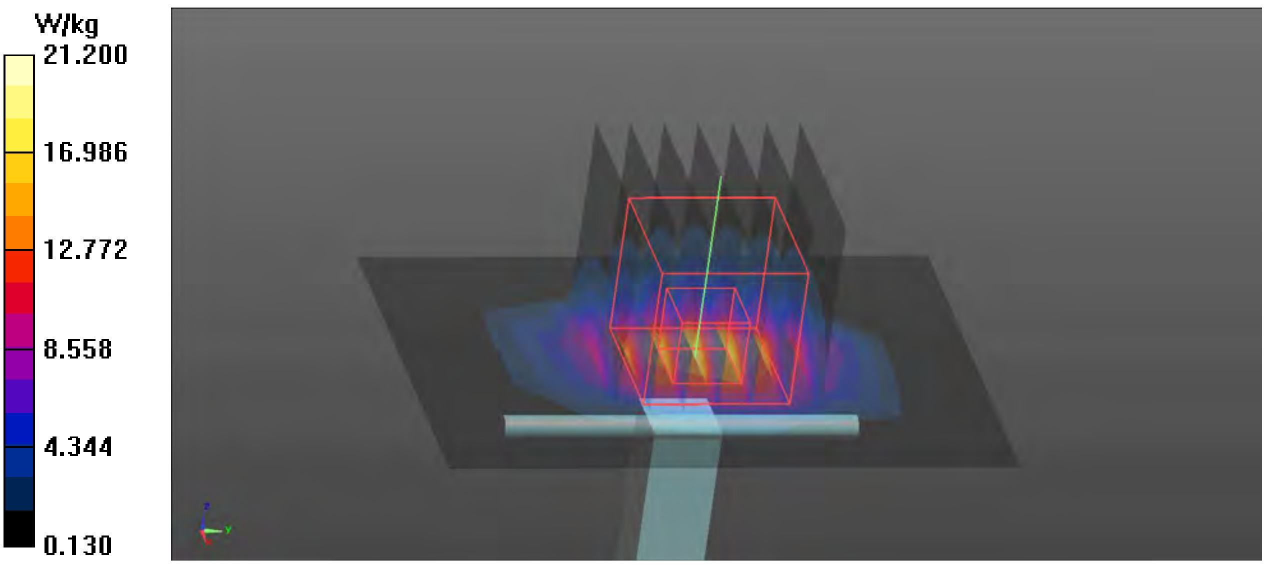
Communication System: UID 0, _CW (0); Frequency: 2450 MHz;Duty Cycle: 1:1
Medium: 2450 Body Medium parameters used: f = 2450 MHz; σ = 2.013 S/m; ε_r = 52.442; ρ = 1000 kg/m^3
Phantom section: Flat Section

Ambient Temperature: 22.0 ℃; Liquid Temperature: 21.5 ℃

DASY Configuration:

- Probe: EX3DV4 - SN7322; ConvF(7.46, 7.46, 7.46) @ 2450 MHz; Calibrated: 10/22/2019
- Sensor-Surface: 1.4mm (Mechanical Surface Detection)
- Electronics: DAE4 Sn1473; Calibrated: 9/24/2019
- Phantom: SAM 1 V5.0 (30deg); Type: QD 000 P40 CD; Serial: 1891
- DASY52 52.10.1(1476); SEMCAD X 14.6.11(7439)

Area Scan (6x8x1): Measurement grid: dx=12mm, dy=12mm
Maximum value of SAR (measured) = 16.5 W/kg
Zoom Scan (7x7x7)/Cube 0: Measurement grid: dx=5mm, dy=5mm, dz=5mm
Reference Value = 107.0 V/m; Power Drift = 0.05 dB
Peak SAR (extrapolated) = 25.9 W/kg
SAR(1 g) = 12.8 W/kg; SAR(10 g) = 5.91 W/kg
Maximum value of SAR (measured) = 21.2 W/kg



Test Laboratory: Intertek Service

System Check 5200

Communication System: UID 0, _CW (0); Frequency: 5200 MHz; Duty Cycle: 1:1
Medium: 5G Body Medium parameters used: f = 5200 MHz; σ = 5.256 S/m; ε_r = 49.589;
ρ = 1000 kg/m^3
Phantom section: Flat Section

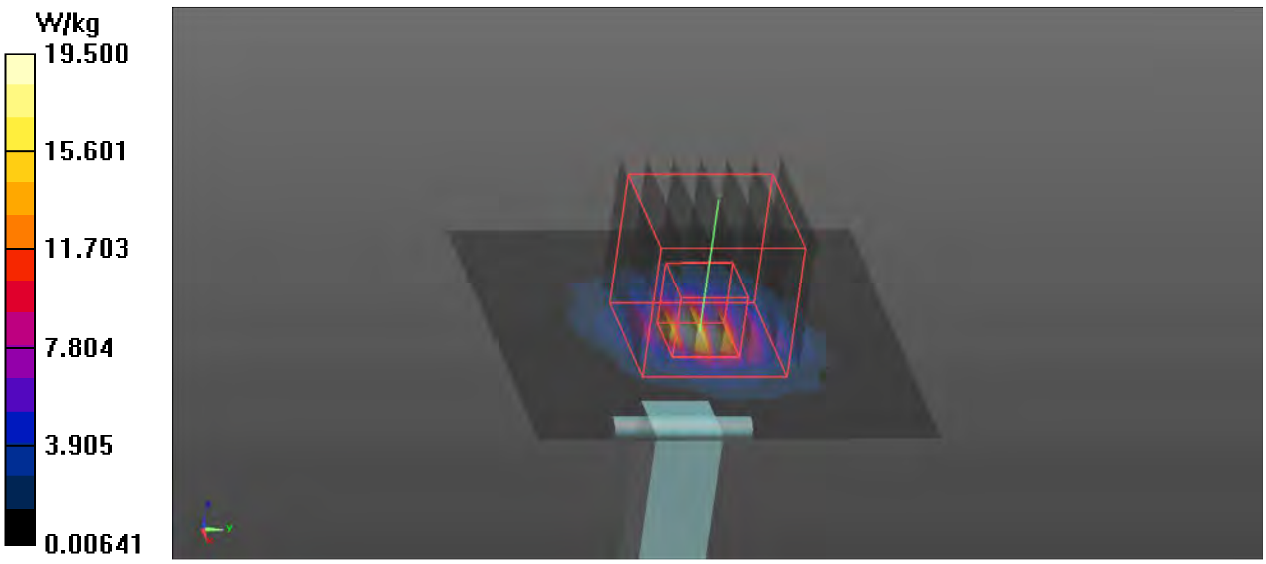
Ambient Temperature: 22.0 ℃; Liquid Temperature: 21.5 ℃

DASY Configuration:

- Probe: EX3DV4 - SN7322; ConvF(4.74, 4.74, 4.74) @ 5200 MHz; Calibrated: 10/22/2019
- Sensor-Surface: 1.4mm (Mechanical Surface Detection)
- Electronics: DAE4 Sn1473; Calibrated: 9/24/2019
- Phantom: SAM 1 V5.0 (30deg); Type: QD 000 P40 CD; Serial: 1891
- DASY52 52.10.1(1476); SEMCAD X 14.6.11(7439)

Area Scan (7x7x1): Measurement grid: dx=10mm, dy=10mm
Maximum value of SAR (measured) = 18.7 W/kg

Zoom Scan (7x7x12)/Cube 0: Measurement grid: dx=4mm, dy=4mm, dz=2mm
Reference Value = 66.90 V/m; Power Drift = 0.01 dB
Peak SAR (extrapolated) = 29.9 W/kg
SAR(1 g) = 7.5 W/kg; SAR(10 g) = 2.13 W/kg
Maximum value of SAR (measured) = 19.5 W/kg



ANNEX C: MAXIMUM GRAPH RESULTS

Date: 1/24/2020

Test Laboratory: Intertek Service

802.11b-Rear Side-1

Communication System: UID 0, WiFi 802.11 b (0); Frequency: 2412 MHz; Duty Cycle: 1:1
Medium: 2450 Body Medium parameters used: f = 2412 MHz; σ = 1.968 S/m; εr = 52.51; ρ = 1000 kg/m3
Phantom section: Flat Section

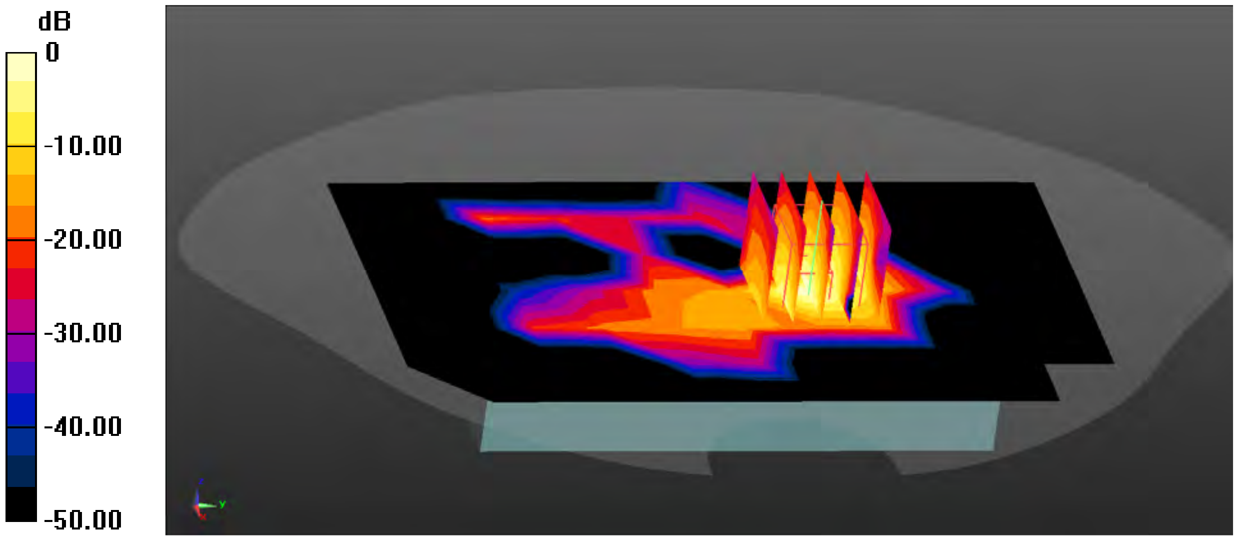
Ambient Temperature: 22.0 ℃; Liquid Temperature: 21.5 ℃

DASY Configuration:

- Probe: EX3DV4 - SN7322; ConvF(7.46, 7.46, 7.46) @ 2412 MHz; Calibrated: 10/22/2019
- Sensor-Surface: 1.4mm (Mechanical Surface Detection)
- Electronics: DAE4 Sn1473; Calibrated: 9/24/2019
- Phantom: SAM 1 V5.0 (30deg); Type: QD 000 P40 CD; Serial: 1891
- DASY52 52.10.1(1476); SEMCAD X 14.6.11(7439)

Area Scan (7x14x1): Measurement grid: dx=12mm, dy=12mm
Maximum value of SAR (measured) = 0.547 W/kg

Zoom Scan (7x7x7)/Cube 0: Measurement grid: dx=5mm, dy=5mm, dz=5mm
Reference Value = 3.640 V/m; Power Drift = 0.04 dB
Peak SAR (extrapolated) = 0.799 W/kg
SAR(1 g) = 0.290 W/kg; SAR(10 g) = 0.105 W/kg



Test Laboratory: Intertek Service

802.11ac20-Rear Side-48

Communication System: UID 0, 802.11ac20; Frequency: 5240 MHz; Duty Cycle: 1:1
Medium: 5G Head Medium parameters used: f = 5240 MHz; σ = 4.608 S/m; ε_r = 34.721; ρ = 1000 kg/m^3
Phantom section: Flat Section

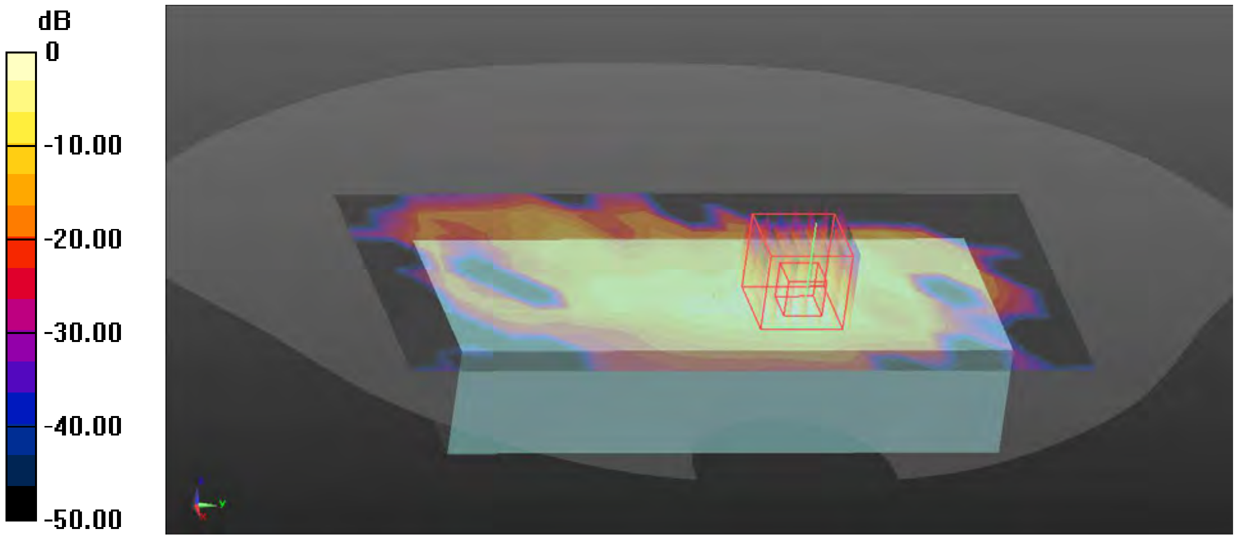
Ambient Temperature: 22.0 ℃; Liquid Temperature: 21.5 ℃

DASY Configuration:

- Probe: EX3DV4 - SN7322; ConvF(4.74, 4.74, 4.74) @ 5240 MHz; Calibrated: 10/22/2019
- Sensor-Surface: 1.4mm (Mechanical Surface Detection)
- Electronics: DAE4 Sn1473; Calibrated: 9/24/2019
- Phantom: SAM 1 V5.0 (30deg); Type: QD 000 P40 CD; Serial: 1891
- DASY52 52.10.1(1476); SEMCAD X 14.6.11(7439)

Area Scan (10x19x1): Measurement grid: dx=10mm, dy=10mm
Maximum value of SAR (measured) = 1.50 W/kg

Zoom Scan (7x7x12)/Cube 0: Measurement grid: dx=4mm, dy=4mm, dz=2mm
Reference Value = 7.800 V/m; Power Drift = 0.08 dB
Peak SAR (extrapolated) = 2.90 W/kg
SAR(1 g) = 0.751 W/kg; SAR(10 g) = 0.235 W/kg



ANNEX D: SYSTEM VALIDATION

The SAR system must be validated against its performance specifications before it is deployed. When SAR probes, system components or software are changed, upgraded or recalibrated, these must be validated with the SAR system(s) that operates with such components.

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:

Table D.1: Antenna Parameters with Body Tissue Simulating Liquid

Table D.1: System Validation Part 1

Body Liquid					
Dipole	Date of Measurement	Return Loss(dB)	Δ %	Impedance (Ω)	ΔΩ
D2450V2 SN: 966	2019-11-3	-25.7	5.2%	49.3+5.09j	1.2Ω
D5GHzV2 SN: 1218	2019-11-3	-22.5	3.6%	53.6-6.87j	4.7Ω

Table D.2: System Validation Part 2

Temperature: 21°C

Probe SN: 7322					
Liquid name	Measured Date	Description	Dielectric Parameters		Verdict
			εr	σ(s/m)	
2450MHz (Body)	2019-11-3	Target Value ±5% window	52.70 50.07 - 55.34	1.95 1.85 - 2.05	PASS
		Measurement Value	51.245	2.03	
5200MHz (Body)	2019-11-3	Target Value ±5% window	49.00 46.55 – 51.45	5.30 5.04 – 5.56	PASS
		Measurement Value	49.67	5.42	

Table D.3: System Validation Part 3

CW Validation	**Sensitivity**	**PASS**	**PASS**
	Probe linearity	PASS	PASS
	Probe Isotropy	PASS	PASS
Mod Validation	**MOD.type**	QPSK	QPSK
	Duty factor	PASS	PASS
	PAR	PASS	PASS

ANNEX E: PROBE, DAE AND DIPOLE CALIBRATION CERTIFICATE

TTL In Collaboration with speag CALIBRATION LABORATORY
Add: No.51 Xueyuan Road, Haidian District, Beijing, 100191, China
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E-mail: cttl@chinattl.com Http://www.chinattl.cn
ilac-MRA CNAS 中国认可 国际互认 校准 CALIBRATION CNAS L0570

Client Intertek Certificate No: Z19-60328

CALIBRATION CERTIFICATE

Object	EX3DV4 - SN:7322
Calibration Procedure(s)	FF-Z11-004-01 Calibration Procedures for Dosimetric E-field Probes
Calibration date:	October 22, 2019

This calibration Certificate documents the traceability to national standards, which realize the physical units of measurements(SI). The measurements and the uncertainties with confidence probability are given on the following pages and are part of the certificate.

All calibrations have been conducted in the closed laboratory facility: environment temperature(22±3)℃ and humidity<70%.

Calibration Equipment used (M&TE critical for calibration)

Primary Standards	ID #	Cal Date(Calibrated by, Certificate No.)	Scheduled Calibration
Power Meter NRP2	101919	18-Jun-19 (CTTL, No.J19X05125)	Jun-20
Power sensor NRP-Z91	101547	18-Jun-19 (CTTL, No.J19X05125)	Jun-20
Power sensor NRP-Z91	101548	18-Jun-19 (CTTL, No.J19X05125)	Jun-20
Reference10dBAttenuator	18N50W-10dB	09-Feb-18(CTTL, No.J18X01133)	Feb-20
Reference20dBAttenuator	18N50W-20dB	09-Feb-18(CTTL, No.J18X01132)	Feb-20
Reference Probe EX3DV4	SN 7307	24-May-19(SPEAG,No.EX3-7307_May19/2)	May-20
DAE4	SN 1525	26-Aug-19(SPEAG, No.DAE4-1525_Aug19)	Aug -20
Secondary Standards	ID #	Cal Date(Calibrated by, Certificate No.)	Scheduled Calibration
SignalGeneratorMG3700A	6201052605	18-Jun-19 (CTTL, No.J19X05127)	Jun-20
Network Analyzer E5071C	MY46110673	24-Jan-19 (CTTL, No.J19X00547)	Jan -20

	Name	Function	Signature
Calibrated by:	Yu Zongying	SAR Test Engineer	
Reviewed by:	Lin Hao	SAR Test Engineer	
Approved by:	Qi Dianyuan	SAR Project Leader	

Issued: October 24, 2019

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

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E-mail: cttl@chinattl.com Http://www.chinattl.cn

Glossary:

TSL	tissue simulating liquid
NORMx,y,z	sensitivity in free space
ConvF	sensitivity in TSL / NORMx,y,z
DCP	diode compression point
CF	crest factor (1/duty_cycle) of the RF signal
A,B,C,D	modulation dependent linearization parameters
Polarization Φ	Φ rotation around probe axis
Polarization θ	θ rotation around an axis that is in the plane normal to probe axis (at measurement center), i θ=0 is normal to probe axis
Connector Angle	information used in DASY system to align probe sensor X to the robot coordinate system

Calibration is Performed According to the Following Standards:

a) IEEE Std 1528-2013, "IEEE Recommended Practice for Determining the Peak Spatial-Averaged Specific Absorption Rate (SAR) in the Human Head from Wireless Communications Devices: Measurement Techniques", June 2013

b) IEC 62209-1, "Measurement procedure for the assessment of Specific Absorption Rate (SAR) from hand-held and body-mounted devices used next to the ear (frequency range of 300 MHz to 6 GHz)", July 2016

c) IEC 62209-2, "Procedure to determine the Specific Absorption Rate (SAR) for wireless communication devices used in close proximity to the human body (frequency range of 30 MHz to 6 GHz)", March 2010

d) KDB 865664, "SAR Measurement Requirements for 100 MHz to 6 GHz"

Methods Applied and Interpretation of Parameters:

- *NORMx,y,z:* Assessed for E-field polarization θ=0 (f≤900MHz in TEM-cell; f>1800MHz: waveguide). NORMx,y,z are only intermediate values, i.e., the uncertainties of NORMx,y,z does not effect the E^2-field uncertainty inside TSL (see below ConvF).
- *NORM(f)x,y,z = NORMx,y,z* frequency_response* (see Frequency Response Chart). This linearization is implemented in DASY4 software versions later than 4.2. The uncertainty of the frequency response is included in the stated uncertainty of ConvF.
- *DCPx,y,z:* DCP are numerical linearization parameters assessed based on the data of power sweep (no uncertainty required). DCP does not depend on frequency nor media.
- PAR: PAR is the Peak to Average Ratio that is not calibrated but determined based on the signal characteristics.
- *Ax,y,z; Bx,y,z; Cx,y,z;VRx,y,z:*A,B,C are numerical linearization parameters assessed based on the data of power sweep for specific modulation signal. The parameters do not depend on frequency nor media. VR is the maximum calibration range expressed in RMS voltage across the diode.
- *ConvF and Boundary Effect Parameters:* Assessed in flat phantom using E-field (or Temperature Transfer Standard for f≤800MHz) and inside waveguide using analytical field distributions based on power measurements for f >800MHz. The same setups are used for assessment of the parameters applied for boundary compensation (alpha, depth) of which typical uncertainty valued are given. These parameters are used in DASY4 software to improve probe accuracy close to the boundary. The sensitivity in TSL corresponds to NORMx,y,z* ConvF whereby the uncertainty corresponds to that given for ConvF. A frequency dependent ConvF is used in DASY version 4.4 and higher which allows extending the validity from±50MHz to±100MHz.
- *Spherical isotropy (3D deviation from isotropy):* in a field of low gradients realized using a flat phantom exposed by a patch antenna.
- *Sensor Offset:* The sensor offset corresponds to the offset of virtual measurement center from the probe tip (on probe axis). No tolerance required.
- *Connector Angle:* The angle is assessed using the information gained by determining the *NORMx* (no uncertainty required).

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Probe EX3DV4

SN: 7322

Calibrated: October 22, 2019

Calibrated for DASY/EASY Systems

(Note: non-compatible with DASY2 system!)

Certificate No: Z19-60328 Page 3 of 11

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DASY/EASY – Parameters of Probe: EX3DV4 – SN: 7322

Basic Calibration Parameters

	Sensor X	Sensor Y	Sensor Z	Unc (k=2)
Norm(μV/(V/m)^2)[A]	0.45	0.56	0.52	±10.0%
DCP(mV)[B]	97.8	98.5	98.9	

Modulation Calibration Parameters

UID	Communication System Name		A dB	B dB√μV	C	D dB	VR mV	Unc[E] (k=2)
0	CW	X	0.0	0.0	1.0	0.00	155.3	±2.2%
		Y	0.0	0.0	1.0		176.3	
		Z	0.0	0.0	1.0		171.6	

The reported uncertainty of measurement is stated as the standard uncertainty of Measurement multiplied by the coverage factor k=2, which for a normal distribution Corresponds to a coverage probability of approximately 95%.

[A] The uncertainties of Norm X, Y, Z do not affect the E^2-field uncertainty inside TSL (see Page 5 and Page 6).
[B] Numerical linearization parameter: uncertainty not required.
[E] Uncertainly is determined using the max. deviation from linear response applying rectangular distribution and is expressed for the square of the field value.

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DASY/EASY – Parameters of Probe: EX3DV4 – SN: 7322

Calibration Parameter Determined in Head Tissue Simulating Media

f [MHz][C]	Relative Permittivity [F]	Conductivity (S/m) [F]	ConvF X	ConvF Y	ConvF Z	Alpha[G]	Depth[G] (mm)	Unct. (k=2)
750	41.9	0.89	9.92	9.92	9.92	0.40	0.80	±12.1%
835	41.5	0.90	9.63	9.63	9.63	0.14	1.44	±12.1%
1750	40.1	1.37	8.33	8.33	8.33	0.22	1.10	±12.1%
1900	40.0	1.40	8.06	8.06	8.06	0.24	1.02	±12.1%
2300	39.5	1.67	7.73	7.73	7.73	0.48	0.75	±12.1%
2450	39.2	1.80	7.49	7.49	7.49	0.54	0.73	±12.1%
2600	39.0	1.96	7.28	7.28	7.28	0.42	0.85	±12.1%
5250	35.9	4.71	5.28	5.28	5.28	0.45	1.40	±13.3%
5750	35.4	5.22	4.70	4.70	4.70	0.50	1.50	±13.3%

[C] Frequency validity above 300 MHz of ±100MHz only applies for DASY v4.4 and higher (Page 2), else it is restricted to ±50MHz. The uncertainty is the RSS of ConvF uncertainty at calibration frequency and the uncertainty for the indicated frequency band. Frequency validity below 300 MHz is ± 10, 25, 40, 50 and 70 MHz for ConvF assessments at 30, 64, 128, 150 and 220 MHz respectively. Above 5 GHz frequency validity can be extended to ± 110 MHz.

[F] At frequency below 3 GHz, the validity of tissue parameters (ε and σ) can be relaxed to ±10% if liquid compensation formula is applied to measured SAR values. At frequencies above 3 GHz, the validity of tissue parameters (ε and σ) is restricted to ±5%. The uncertainty is the RSS of the ConvF uncertainty for indicated target tissue parameters.

[G] Alpha/Depth are determined during calibration. SPEAG warrants that the remaining deviation due to the boundary effect after compensation is always less than ± 1% for frequencies below 3 GHz and below ± 2% for the frequencies between 3-6 GHz at any distance larger than half the probe tip diameter from the boundary.

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DASY/EASY – Parameters of Probe: EX3DV4 – SN: 7322

Calibration Parameter Determined in Body Tissue Simulating Media

f [MHz][C]	Relative Permittivity[F]	Conductivity (S/m)[F]	ConvF X	ConvF Y	ConvF Z	Alpha[G]	Depth[G] (mm)	Unct. (k=2)
835	55.2	0.97	9.71	9.71	9.71	0.18	1.34	±12.1%
1750	53.4	1.49	8.03	8.03	8.03	0.20	1.18	±12.1%
1900	53.3	1.52	7.75	7.75	7.75	0.20	1.15	±12.1%
2450	52.7	1.95	7.46	7.46	7.46	0.57	0.77	±12.1%
2600	52.5	2.16	7.22	7.22	7.22	0.66	0.70	±12.1%
5250	48.9	5.36	4.74	4.74	4.74	0.47	1.49	±13.3%
5750	48.3	5.94	4.22	4.22	4.22	0.50	1.70	±13.3%

[C] Frequency validity above 300 MHz of ±100MHz only applies for DASY v4.4 and higher (Page 2), else it is restricted to ±50MHz. The uncertainty is the RSS of ConvF uncertainty at calibration frequency and the uncertainty for the indicated frequency band. Frequency validity below 300 MHz is ± 10, 25, 40, 50 and 70 MHz for ConvF assessments at 30, 64, 128, 150 and 220 MHz respectively. Above 5 GHz frequency validity can be extended to ± 110 MHz.
[F] At frequency below 3 GHz, the validity of tissue parameters (ε and σ) can be relaxed to ±10% if liquid compensation formula is applied to measured SAR values. At frequencies above 3 GHz, the validity of tissue parameters (ε and σ) is restricted to ±5%. The uncertainty is the RSS of the ConvF uncertainty for indicated target tissue parameters.
[G] Alpha/Depth are determined during calibration. SPEAG warrants that the remaining deviation due to the boundary effect after compensation is always less than ± 1% for frequencies below 3 GHz and below ± 2% for the frequencies between 3-6 GHz at any distance larger than half the probe tip diameter from the boundary.

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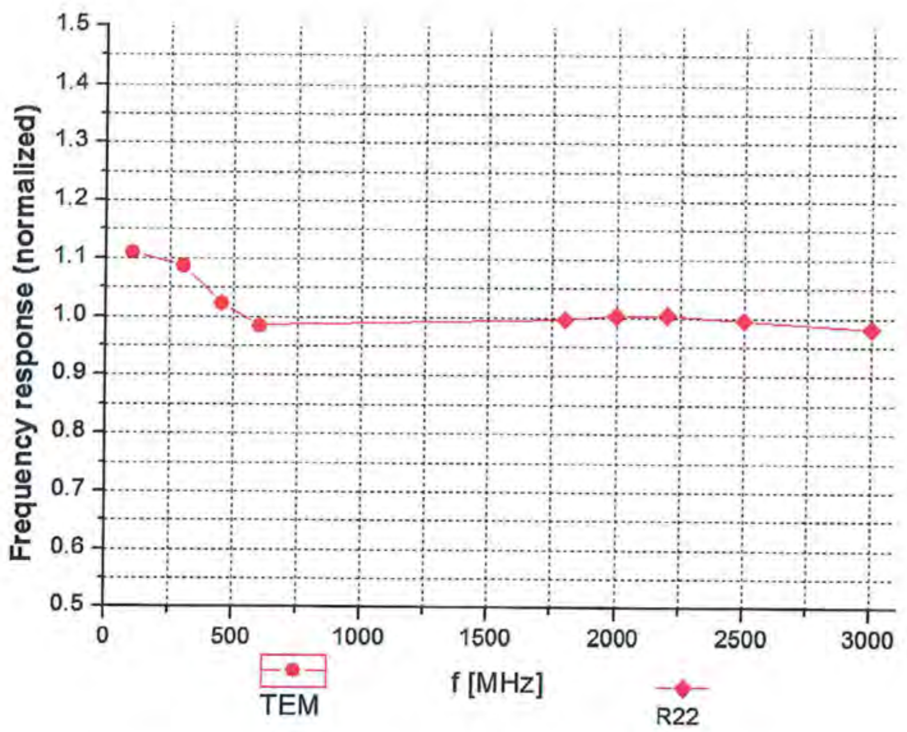
Frequency Response of E-Field
(TEM-Cell: ifi110 EXX, Waveguide: R22)



Uncertainty of Frequency Response of E-field: ±7.4% (k=2)

Certificate No: Z19-60328 Page 7 of 11

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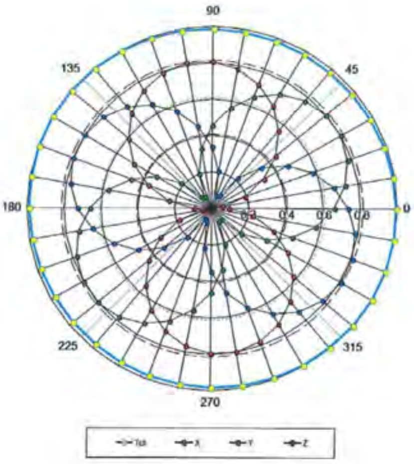
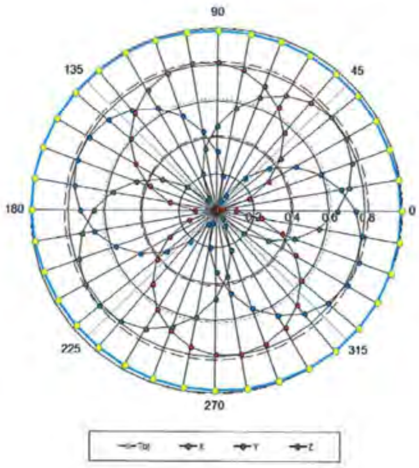
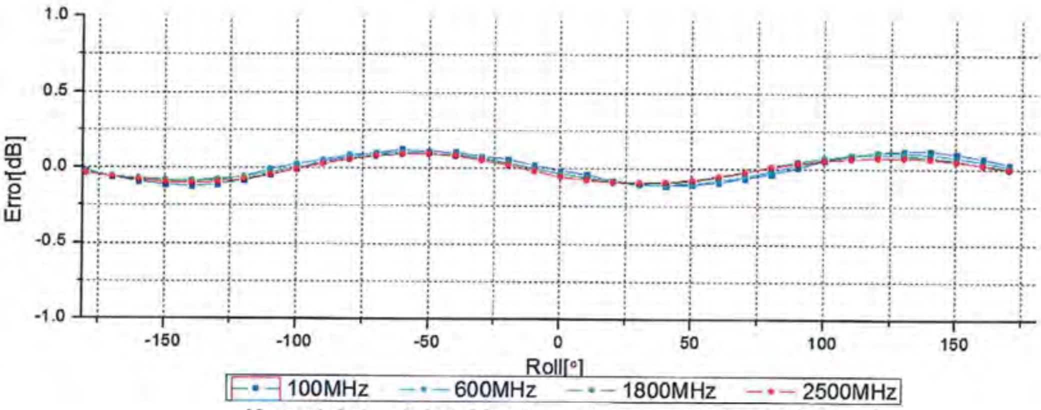
Receiving Pattern (Φ), θ=0°

f=600 MHz, TEM



f=1800 MHz, R22





Uncertainty of Axial Isotropy Assessment: ±1.2% (k=2)

Certificate No: Z19-60328 Page 8 of 11

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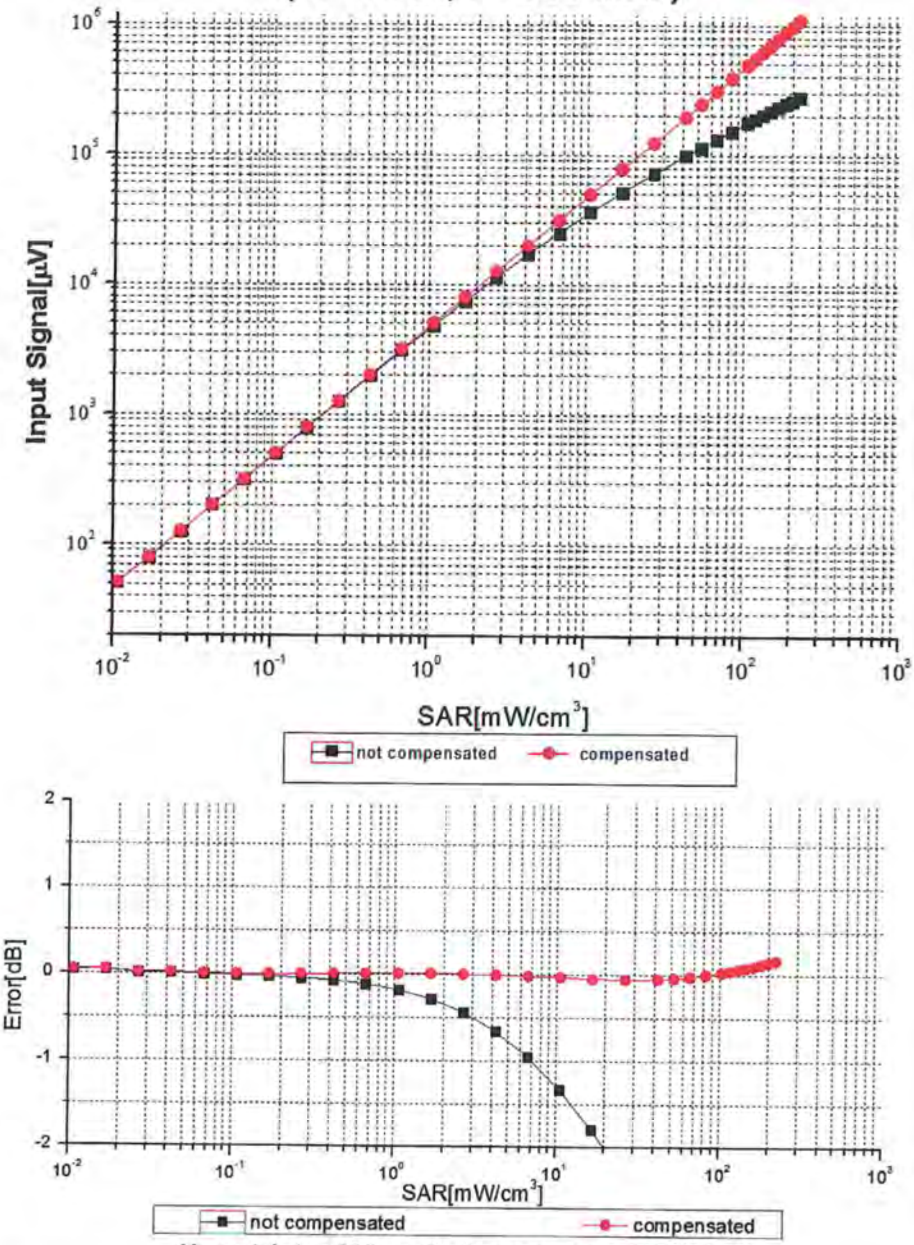
Dynamic Range f(SAR$_{head}$)
(TEM cell, f = 900 MHz)



Uncertainty of Linearity Assessment: ±0.9% (k=2)

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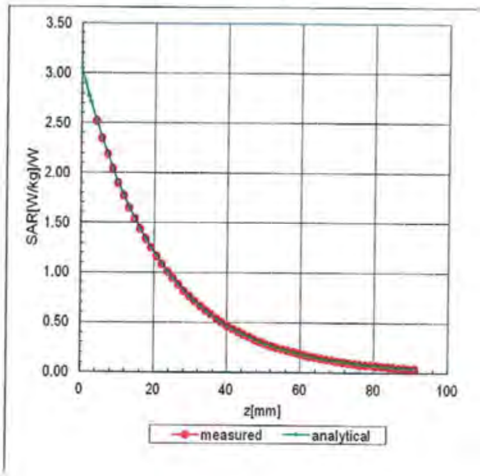
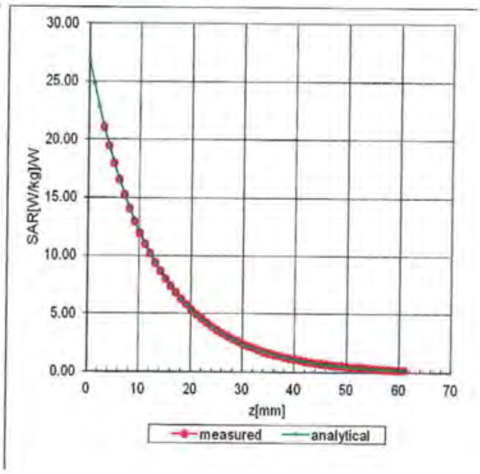
Conversion Factor Assessment

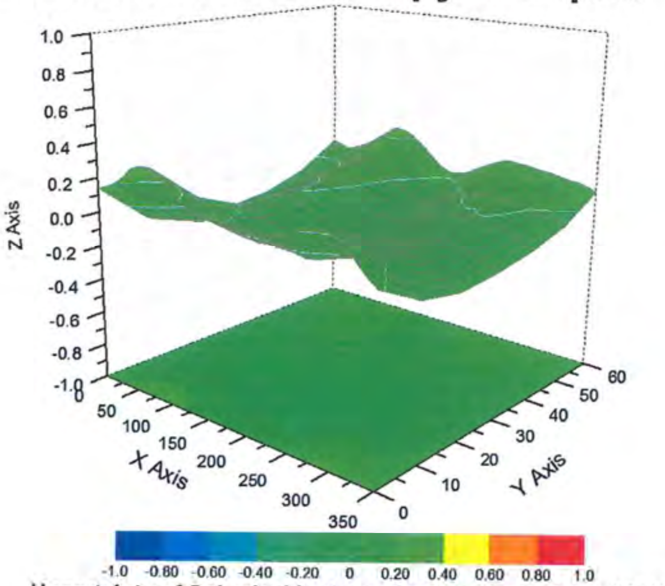
f=750 MHz, WGLS R9(H_convF)



f=1750 MHz, WGLS R22(H_convF)



Deviation from Isotropy in Liquid



Uncertainty of Spherical Isotropy Assessment: ±3.2% (K=2)

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DASY/EASY – Parameters of Probe: EX3DV4 – SN: 7322

Other Probe Parameters

Sensor Arrangement	Triangular
Connector Angle (°)	41.2
Mechanical Surface Detection Mode	enabled
Optical Surface Detection Mode	disable
Probe Overall Length	337mm
Probe Body Diameter	10mm
Tip Length	9mm
Tip Diameter	2.5mm
Probe Tip to Sensor X Calibration Point	1mm
Probe Tip to Sensor Y Calibration Point	1mm
Probe Tip to Sensor Z Calibration Point	1mm
Recommended Measurement Distance from Surface	1.4mm

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CNAS L0570

Client : Intertek

Certificate No: Z19-60329

CALIBRATION CERTIFICATE

Object	DAE4 - SN: 1473
Calibration Procedure(s)	FF-Z11-002-01 Calibration Procedure for the Data Acquisition Electronics (DAEx)
Calibration date:	September 24, 2019

This calibration Certificate documents the traceability to national standards, which realize the physical units of measurements(SI). The measurements and the uncertainties with confidence probability are given on the following pages and are part of the certificate.

All calibrations have been conducted in the closed laboratory facility: environment temperature(22±3)℃ and humidity<70%.

Calibration Equipment used (M&TE critical for calibration)

Primary Standards	ID #	Cal Date(Calibrated by, Certificate No.)	Scheduled Calibration
Process Calibrator 753	1971018	24-Jun-19 (CTTL, No.J19X05126)	Jun-20

	Name	Function	Signature
Calibrated by:	Yu Zongying	SAR Test Engineer	
Reviewed by:	Lin Hao	SAR Test Engineer	
Approved by:	Qi Dianyuan	SAR Project Leader	

Issued: September 26, 2019

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

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Glossary:

DAE	data acquisition electronics
Connector angle	information used in DASY system to align probe sensor X to the robot coordinate system.

Methods Applied and Interpretation of Parameters:

- *DC Voltage Measurement*: Calibration Factor assessed for use in DASY system by comparison with a calibrated instrument traceable to national standards. The figure given corresponds to the full scale range of the voltmeter in the respective range.
- *Connector angle*: The angle of the connector is assessed measuring the angle mechanically by a tool inserted. Uncertainty is not required.
- The report provide only calibration results for DAE, it does not contain other performance test results.

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DC Voltage Measurement

A/D - Converter Resolution nominal
High Range: 1LSB = 6.1μV , full range = -100...+300 mV
Low Range: 1LSB = 61nV , full range = -1.......+3mV
DASY measurement parameters: Auto Zero Time: 3 sec; Measuring time: 3 sec

Calibration Factors	X	Y	Z
High Range	404.010 ± 0.15% (k=2)	404.606 ± 0.15% (k=2)	404.459 ± 0.15% (k=2)
Low Range	3.96560 ± 0.7% (k=2)	3.99656 ± 0.7% (k=2)	3.99009 ± 0.7% (k=2)

Connector Angle

Connector Angle to be used in DASY system	347° ± 1 °

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Client **Intertek** **Certificate No: Z18-60303**

CALIBRATION CERTIFICATE

Object	D2450V2 - SN: 966
Calibration Procedure(s)	FF-Z11-003-01 Calibration Procedures for dipole validation kits
Calibration date:	August 31, 2018

This calibration Certificate documents the traceability to national standards, which realize the physical units of measurements(SI). The measurements and the uncertainties with confidence probability are given on the following pages and are part of the certificate.

All calibrations have been conducted in the closed laboratory facility: environment temperature(22±3)℃ and humidity<70%.

Calibration Equipment used (M&TE critical for calibration)

Primary Standards	ID #	Cal Date(Calibrated by, Certificate No.)	Scheduled Calibration
Power Meter NRVD	102083	01-Nov-17 (CTTL, No.J17X08756)	Oct-18
Power sensor NRV-Z5	100542	01-Nov-17 (CTTL, No.J17X08756)	Oct-18
Reference Probe EX3DV4	SN 7464	12-Sep-17(SPEAG,No.EX3-7464_Sep17)	Sep-18
DAE4	SN 1524	13-Sep-17(SPEAG,No.DAE4-1524_Sep17)	Sep-18
Secondary Standards	**ID #**	**Cal Date(Calibrated by, Certificate No.)**	**Scheduled Calibration**
Signal Generator E4438C	MY49071430	23-Jan-18 (CTTL, No.J18X00560)	Jan-19
NetworkAnalyzer E5071C	MY46110673	24-Jan-18 (CTTL, No.J18X00561)	Jan-19

	Name	Function	Signature
Calibrated by:	Zhao Jing	SAR Test Engineer	
Reviewed by:	Lin Hao	SAR Test Engineer	
Approved by:	Qi Dianyuan	SAR Project Leader	

Issued: September 3, 2018

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Glossary:

TSL	tissue simulating liquid
ConvF	sensitivity in TSL / NORMx,y,z
N/A	not applicable or not measured

Calibration is Performed According to the Following Standards:

a) IEEE Std 1528-2013, "IEEE Recommended Practice for Determining the Peak Spatial-Averaged Specific Absorption Rate (SAR) in the Human Head from Wireless Communications Devices: Measurement Techniques", June 2013

b) IEC 62209-1, "Measurement procedure for assessment of specific absorption rate of human exposure to radio frequency fields from hand-held and body-mounted wireless communication devices- Part 1: Device used next to the ear (Frequency range of 300MHz to 6GHz)", July 2016

c) IEC 62209-2, "Procedure to measure the Specific Absorption Rate (SAR) For wireless communication devices used in close proximity to the human body (frequency range of 30MHz to 6GHz)", March 2010

d) KDB865664, SAR Measurement Requirements for 100 MHz to 6 GHz

Additional Documentation:

e) DASY4/5 System Handbook

Methods Applied and Interpretation of Parameters:

- *Measurement Conditions:* Further details are available from the Validation Report at the end of the certificate. All figures stated in the certificate are valid at the frequency indicated.
- *Antenna Parameters with TSL:* The dipole is mounted with the spacer to position its feed point exactly below the center marking of the flat phantom section, with the arms oriented parallel to the body axis.
- *Feed Point Impedance and Return Loss:* These parameters are measured with the dipole positioned under the liquid filled phantom. The impedance stated is transformed from the measurement at the SMA connector to the feed point. The Return Loss ensures low reflected power. No uncertainty required.
- *Electrical Delay:* One-way delay between the SMA connector and the antenna feed point. No uncertainty required.
- *SAR measured:* SAR measured at the stated antenna input power.
- *SAR normalized:* SAR as measured, normalized to an input power of 1 W at the antenna connector.
- *SAR for nominal TSL parameters:* The measured TSL parameters are used to calculate the nominal SAR result.

The reported uncertainty of measurement is stated as the standard uncertainty of Measurement multiplied by the coverage factor k=2, which for a normal distribution Corresponds to a coverage probability of approximately 95%.

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Measurement Conditions

DASY system configuration, as far as not given on page 1.

DASY Version	DASY52	52.10.1.1476
Extrapolation	Advanced Extrapolation	
Phantom	Triple Flat Phantom 5.1C	
Distance Dipole Center - TSL	10 mm	with Spacer
Zoom Scan Resolution	dx, dy, dz = 5 mm	
Frequency	2450 MHz ± 1 MHz	

Head TSL parameters

The following parameters and calculations were applied.

	Temperature	**Permittivity**	**Conductivity**
Nominal Head TSL parameters	22.0 °C	39.2	1.80 mho/m
Measured Head TSL parameters	(22.0 ± 0.2) °C	38.8 ± 6 %	1.80 mho/m ± 6 %
Head TSL temperature change during test	<1.0 °C	----	----

SAR result with Head TSL

SAR averaged over 1 cm^3 (1 g) of Head TSL	Condition	
SAR measured	250 mW input power	13.3 mW / g
SAR for nominal Head TSL parameters	normalized to 1W	**53.1 mW /g ± 18.8 % (k=2)**
SAR averaged over 10 cm^3 (10 g) of Head TSL	Condition	
SAR measured	250 mW input power	6.20 mW / g
SAR for nominal Head TSL parameters	normalized to 1W	**24.8 mW /g ± 18.7 % (k=2)**

Body TSL parameters

The following parameters and calculations were applied.

	Temperature	**Permittivity**	**Conductivity**
Nominal Body TSL parameters	22.0 °C	52.7	1.95 mho/m
Measured Body TSL parameters	(22.0 ± 0.2) °C	52.3 ± 6 %	1.98 mho/m ± 6 %
Body TSL temperature change during test	<1.0 °C	----	----

SAR result with Body TSL

SAR averaged over 1 cm^3 (1 g) of Body TSL	Condition	
SAR measured	250 mW input power	12.8 mW / g
SAR for nominal Body TSL parameters	normalized to 1W	**50.7 mW /g ± 18.8 % (k=2)**
SAR averaged over 10 cm^3 (10 g) of Body TSL	Condition	
SAR measured	250 mW input power	6.01 mW / g
SAR for nominal Body TSL parameters	normalized to 1W	**23.9 mW /g ± 18.7 % (k=2)**

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Appendix (Additional assessments outside the scope of CNAS L0570)

Antenna Parameters with Head TSL

Impedance, transformed to feed point	53.0Ω+ 2.76jΩ
Return Loss	- 28.1dB

Antenna Parameters with Body TSL

Impedance, transformed to feed point	49.3Ω+ 5.09jΩ
Return Loss	- 25.7dB

General Antenna Parameters and Design

Electrical Delay (one direction)	1.021 ns

After long term use with 100W radiated power, only a slight warming of the dipole near the feedpoint can be measured.

The dipole is made of standard semirigid coaxial cable. The center conductor of the feeding line is directly connected to the second arm of the dipole. The antenna is therefore short-circuited for DC-signals. On some of the dipoles, small end caps are added to the dipole arms in order to improve matching when loaded according to the position as explained in the "Measurement Conditions" paragraph. The SAR data are not affected by this change. The overall dipole length is still according to the Standard.
No excessive force must be applied to the dipole arms, because they might bend or the soldered connections near the feedpoint may be damaged.

Additional EUT Data

Manufactured by	SPEAG

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DASY5 Validation Report for Head TSL Date: 08.31.2018

Test Laboratory: CTTL, Beijing, China

DUT: Dipole 2450 MHz; Type: D2450V2; Serial: D2450V2 - SN: 966

Communication System: UID 0, CW; Frequency: 2450 MHz; Duty Cycle: 1:1

Medium parameters used: f = 2450 MHz; σ = 1.802 S/m; ε_r = 38.84; ρ = 1000 kg/m3

Phantom section: Right Section

DASY5 Configuration:

- Probe: EX3DV4 - SN7464; ConvF(7.89, 7.89, 7.89) @ 2450 MHz; Calibrated: 9/12/2017
- Sensor-Surface: 1.4mm (Mechanical Surface Detection)
- Electronics: DAE4 Sn1524; Calibrated: 9/13/2017
- Phantom: MFP_V5.1C ; Type: QD 000 P51CA; Serial: 1062
- Measurement SW: DASY52, Version 52.10 (1); SEMCAD X Version 14.6.11 (7439)

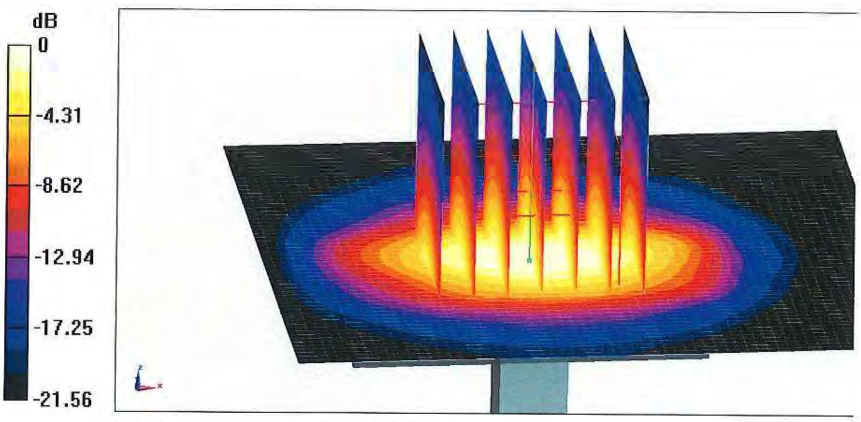
Dipole Calibration/Zoom Scan (7x7x7) (7x7x7)/Cube 0: Measurement grid: dx=5mm, dy=5mm, dz=5mm

Reference Value = 100.1 V/m; Power Drift = 0.02 dB

Peak SAR (extrapolated) = 27.6 W/kg

SAR(1 g) = 13.3 W/kg; SAR(10 g) = 6.2 W/kg

Maximum value of SAR (measured) = 22.2 W/kg



0 dB = 22.2 W/kg = 13.46 dBW/kg

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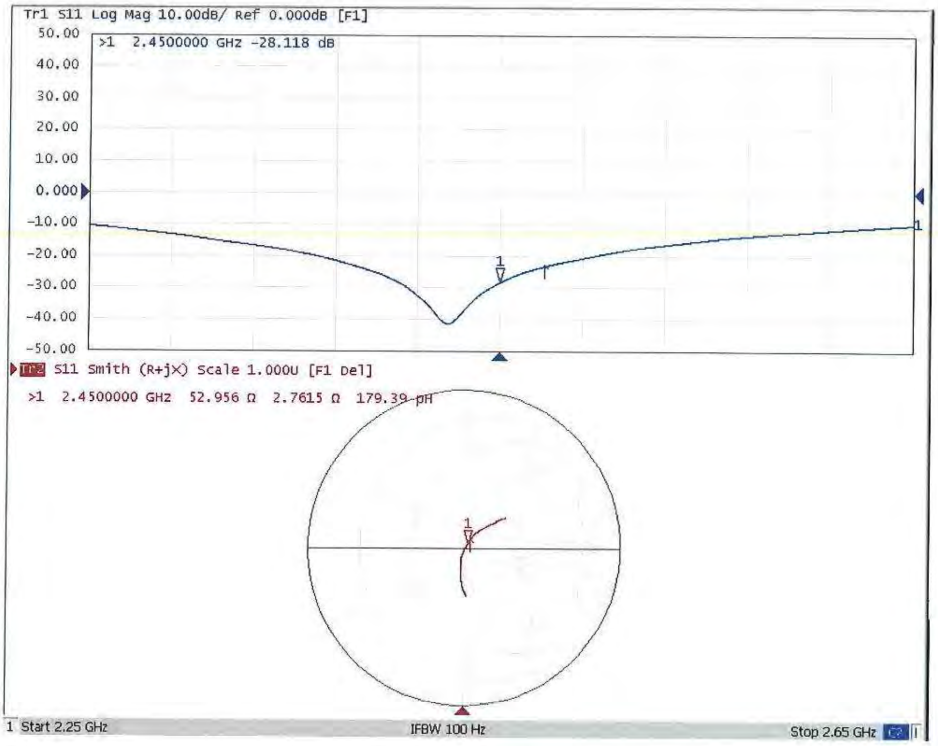
Impedance Measurement Plot for Head TSL



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DASY5 Validation Report for Body TSL Date: 08.30.2018

Test Laboratory: CTTL, Beijing, China

DUT: Dipole 2450 MHz; Type: D2450V2; Serial: D2450V2 - SN: 966

Communication System: UID 0, CW; Frequency: 2450 MHz; Duty Cycle: 1:1

Medium parameters used: f = 2450 MHz; σ = 1.982 S/m; ε_r = 52.34; ρ = 1000 kg/m3

Phantom section: Center Section

DASY5 Configuration:

- Probe: EX3DV4 - SN7464; ConvF(8.09, 8.09, 8.09) @ 2450 MHz; Calibrated: 9/12/2017
- Sensor-Surface: 1.4mm (Mechanical Surface Detection)
- Electronics: DAE4 Sn1524; Calibrated: 9/13/2017
- Phantom: MFP_V5.1C ; Type: QD 000 P51CA; Serial: 1062
- Measurement SW: DASY52, Version 52.10 (1); SEMCAD X Version 14.6.11 (7439)

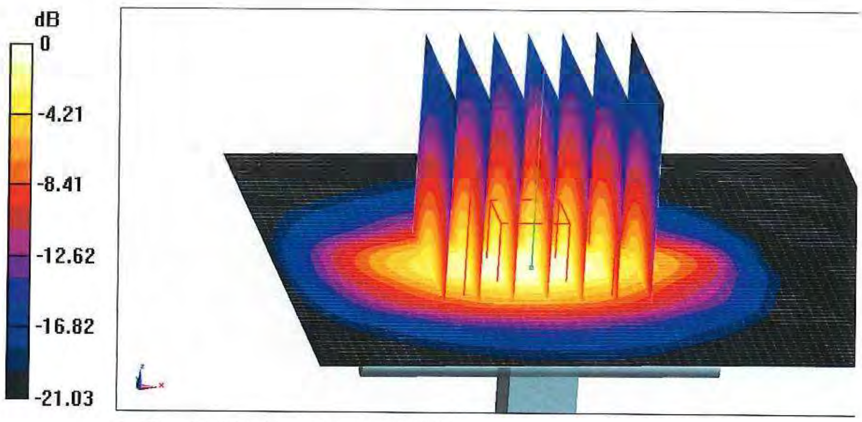
Dipole Calibration/Zoom Scan (7x7x7) (7x7x7)/Cube 0: Measurement grid: dx=5mm, dy=5mm, dz=5mm

Reference Value = 93.62 V/m; Power Drift = 0.03 dB

Peak SAR (extrapolated) = 25.8 W/kg

SAR(1 g) = 12.8 W/kg; SAR(10 g) = 6.01 W/kg

Maximum value of SAR (measured) = 21.0 W/kg



0 dB = 21.0 W/kg = 13.22 dBW/kg

Certificate No: Z18-60303 Page 7 of 8

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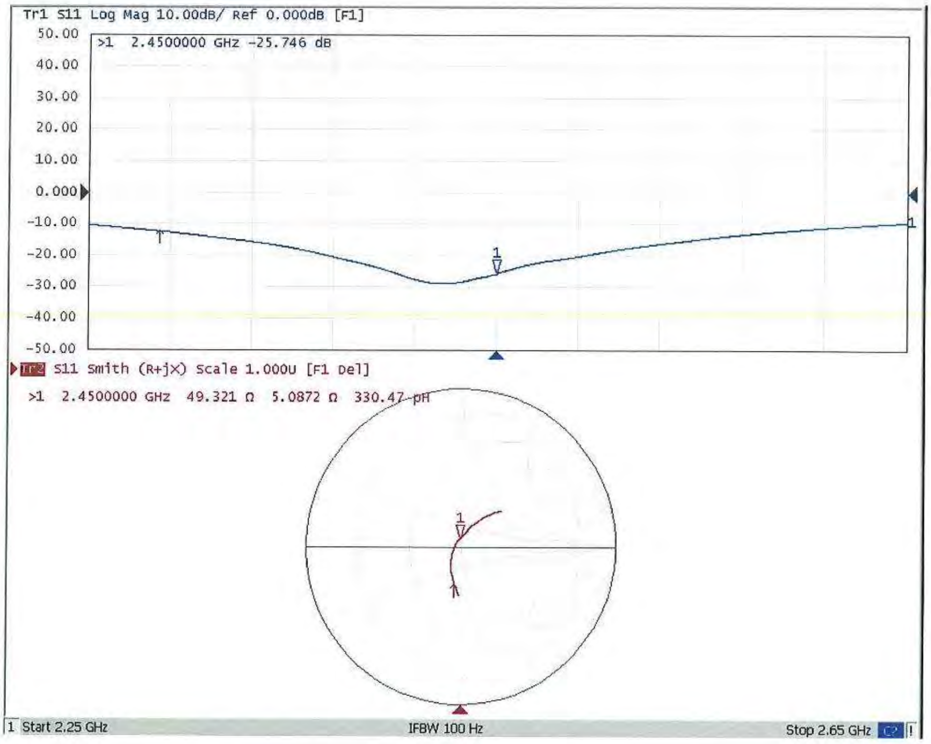
Impedance Measurement Plot for Body TSL



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Client Intertek Certificate No: Z18-60305

CALIBRATION CERTIFICATE

Object	D5GHzV2 - SN: 1218
Calibration Procedure(s)	FF-Z11-003-01 Calibration Procedures for dipole validation kits
Calibration date:	August 31, 2018

This calibration Certificate documents the traceability to national standards, which realize the physical units of measurements(SI). The measurements and the uncertainties with confidence probability are given on the following pages and are part of the certificate.

All calibrations have been conducted in the closed laboratory facility: environment temperature(22±3)℃ and humidity<70%.

Calibration Equipment used (M&TE critical for calibration)

Primary Standards	ID #	Cal Date(Calibrated by, Certificate No.)	Scheduled Calibration
Power Meter NRP2	102083	01-Nov-17 (CTTL, No.J17X08756)	Oct-18
Power sensor NRP-Z91	100542	01-Nov-17 (CTTL, No.J17X08756)	Oct-18
ReferenceProbe EX3DV4	SN 7464	12-Sep-17(SPEAG,No.EX3-7464_Sep17)	Sep-18
DAE4	SN 1524	13-Sep-17(SPEAG,No.DAE4-1524_Sep17)	Sep-18
Secondary Standards	**ID #**	**Cal Date(Calibrated by, Certificate No.)**	**Scheduled Calibration**
Signal Generator E4438C	MY49071430	23-Jan-18 (CTTL, No.J18X00560)	Jan-19
NetworkAnalyzerE5071C	MY46110673	24-Jan-18 (CTTL, No.J18X00561)	Jan-19

	Name	Function	Signature
Calibrated by:	Zhao Jing	SAR Test Engineer	[signature]
Reviewed by:	Lin Hao	SAR Test Engineer	[signature]
Approved by:	Qi Dianyuan	SAR Project Leader	[signature]

Issued: September 3, 2018

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

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Glossary:

TSL	tissue simulating liquid
ConvF	sensitivity in TSL / NORMx,y,z
N/A	not applicable or not measured

Calibration is Performed According to the Following Standards:

a) IEEE Std 1528-2013, "IEEE Recommended Practice for Determining the Peak Spatial-Averaged Specific Absorption Rate (SAR) in the Human Head from Wireless Communications Devices: Measurement Techniques", June 2013
b) IEC 62209-1, "Measurement procedure for assessment of specific absorption rate of human exposure to radio frequency fields from hand-held and body-mounted wireless communication devices- Part 1: Device used next to the ear (Frequency range of 300MHz to 6GHz)", July 2016
c) IEC 62209-2, "Procedure to measure the Specific Absorption Rate (SAR) For wireless communication devices used in close proximity to the human body (frequency range of 30MHz to 6GHz)", March 2010
d) KDB865664, SAR Measurement Requirements for 100 MHz to 6 GHz

Additional Documentation:

e) DASY4/5 System Handbook

Methods Applied and Interpretation of Parameters:

- *Measurement Conditions:* Further details are available from the Validation Report at the end of the certificate. All figures stated in the certificate are valid at the frequency indicated.
- *Antenna Parameters with TSL:* The dipole is mounted with the spacer to position its feed point exactly below the center marking of the flat phantom section, with the arms oriented parallel to the body axis.
- *Feed Point Impedance and Return Loss:* These parameters are measured with the dipole positioned under the liquid filled phantom. The impedance stated is transformed from the measurement at the SMA connector to the feed point. The Return Loss ensures low reflected power. No uncertainty required.
- *Electrical Delay:* One-way delay between the SMA connector and the antenna feed point. No uncertainty required.
- *SAR measured:* SAR measured at the stated antenna input power.
- *SAR normalized:* SAR as measured, normalized to an input power of 1 W at the antenna connector.
- *SAR for nominal TSL parameters:* The measured TSL parameters are used to calculate the nominal SAR result.

The reported uncertainty of measurement is stated as the standard uncertainty of Measurement multiplied by the coverage factor k=2, which for a normal distribution Corresponds to a coverage probability of approximately 95%.

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Measurement Conditions

DASY system configuration, as far as not given on page 1.

DASY Version	DASY52	52.10.1.1476
Extrapolation	Advanced Extrapolation	
Phantom	Triple Flat Phantom 5.1C	
Distance Dipole Center - TSL	10 mm	with Spacer
Zoom Scan Resolution	dx, dy = 4 mm, dz = 1.4 mm	Graded Ratio = 1.4 (Z direction)
Frequency	5200 MHz ± 1 MHz 5300 MHz ± 1 MHz 5800 MHz ± 1 MHz	

Head TSL parameters at 5200 MHz

The following parameters and calculations were applied.

	Temperature	Permittivity	Conductivity
Nominal Head TSL parameters	22.0 °C	36.0	4.66 mho/m
Measured Head TSL parameters	(22.0 ± 0.2) °C	36.0 ± 6 %	4.80 mho/m ± 6 %
Head TSL temperature change during test	<1.0 °C	----	----

SAR result with Head TSL at 5200 MHz

SAR averaged over 1 cm^3 (1 g) of Head TSL	Condition	
SAR measured	100 mW input power	7.61 mW / g
SAR for nominal Head TSL parameters	normalized to 1W	**76.2 mW /g ± 24.4 % (k=2)**
SAR averaged over 10 cm^3 (10 g) of Head TSL	Condition	
SAR measured	100 mW input power	2.20 mW / g
SAR for nominal Head TSL parameters	normalized to 1W	**22.0 mW /g ± 24.2 % (k=2)**

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Head TSL parameters at 5300 MHz

The following parameters and calculations were applied.

	Temperature	Permittivity	Conductivity
Nominal Head TSL parameters	22.0 °C	35.9	4.76 mho/m
Measured Head TSL parameters	(22.0 ± 0.2) °C	35.8 ± 6 %	4.90 mho/m ± 6 %
Head TSL temperature change during test	<1.0 °C	----	----

SAR result with Head TSL at 5300 MHz

SAR averaged over 1 cm^3 (1 g) of Head TSL	Condition	
SAR measured	100 mW input power	7.86 mW / g
SAR for nominal Head TSL parameters	normalized to 1W	**78.6 mW /g ± 24.4 % (k=2)**
SAR averaged over 10 cm^3 (10 g) of Head TSL	Condition	
SAR measured	100 mW input power	2.28 mW / g
SAR for nominal Head TSL parameters	normalized to 1W	**22.8 mW /g ± 24.2 % (k=2)**

Head TSL parameters at 5800 MHz

The following parameters and calculations were applied.

	Temperature	Permittivity	Conductivity
Nominal Head TSL parameters	22.0 °C	35.3	5.27 mho/m
Measured Head TSL parameters	(22.0 ± 0.2) °C	34.8 ± 6 %	5.42 mho/m ± 6 %
Head TSL temperature change during test	<1.0 °C	----	----

SAR result with Head TSL at 5800 MHz

SAR averaged over 1 cm^3 (1 g) of Head TSL	Condition	
SAR measured	100 mW input power	7.76 mW / g
SAR for nominal Head TSL parameters	normalized to 1W	**77.5 mW /g ± 24.4 % (k=2)**
SAR averaged over 10 cm^3 (10 g) of Head TSL	Condition	
SAR measured	100 mW input power	2.23 mW / g
SAR for nominal Head TSL parameters	normalized to 1W	**22.2 mW /g ± 24.2 % (k=2)**

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Body TSL parameters at 5200 MHz

The following parameters and calculations were applied.

	Temperature	Permittivity	Conductivity
Nominal Body TSL parameters	22.0 °C	49.0	5.30 mho/m
Measured Body TSL parameters	(22.0 ± 0.2) °C	48.4 ± 6 %	5.35 mho/m ± 6 %
Body TSL temperature change during test	<1.0 °C	----	----

SAR result with Body TSL at 5200 MHz

SAR averaged over 1 cm^3 (1 g) of Body TSL	Condition	
SAR measured	100 mW input power	7.15 mW / g
SAR for nominal Body TSL parameters	normalized to 1W	**71.3 mW /g ± 24.4 % (k=2)**
SAR averaged over 10 cm^3 (10 g) of Body TSL	Condition	
SAR measured	100 mW input power	2.05 mW / g
SAR for nominal Body TSL parameters	normalized to 1W	**20.5 mW /g ± 24.2 % (k=2)**

Body TSL parameters at 5300 MHz

The following parameters and calculations were applied.

	Temperature	Permittivity	Conductivity
Nominal Body TSL parameters	22.0 °C	48.9	5.42 mho/m
Measured Body TSL parameters	(22.0 ± 0.2) °C	48.1 ± 6 %	5.47 mho/m ± 6 %
Body TSL temperature change during test	<1.0 °C	----	----

SAR result with Body TSL at 5300 MHz

SAR averaged over 1 cm^3 (1 g) of Body TSL	Condition	
SAR measured	100 mW input power	7.39 mW / g
SAR for nominal Body TSL parameters	normalized to 1W	**73.7 mW /g ± 24.4 % (k=2)**
SAR averaged over 10 cm^3 (10 g) of Body TSL	Condition	
SAR measured	100 mW input power	2.12 mW / g
SAR for nominal Body TSL parameters	normalized to 1W	**21.1 mW /g ± 24.2 % (k=2)**

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Body TSL parameters at 5200 MHz

The following parameters and calculations were applied.

	Temperature	Permittivity	Conductivity
Nominal Body TSL parameters	22.0 °C	49.0	5.30 mho/m
Measured Body TSL parameters	(22.0 ± 0.2) °C	48.4 ± 6 %	5.35 mho/m ± 6 %
Body TSL temperature change during test	<1.0 °C	----	----

SAR result with Body TSL at 5200 MHz

SAR averaged over 1 cm^3 (1 g) of Body TSL	Condition	
SAR measured	100 mW input power	7.15 mW / g
SAR for nominal Body TSL parameters	normalized to 1W	**71.3 mW /g ± 24.4 % (k=2)**
SAR averaged over 10 cm^3 (10 g) of Body TSL	Condition	
SAR measured	100 mW input power	2.05 mW / g
SAR for nominal Body TSL parameters	normalized to 1W	**20.5 mW /g ± 24.2 % (k=2)**

Body TSL parameters at 5300 MHz

The following parameters and calculations were applied.

	Temperature	Permittivity	Conductivity
Nominal Body TSL parameters	22.0 °C	48.9	5.42 mho/m
Measured Body TSL parameters	(22.0 ± 0.2) °C	48.1 ± 6 %	5.47 mho/m ± 6 %
Body TSL temperature change during test	<1.0 °C	----	----

SAR result with Body TSL at 5300 MHz

SAR averaged over 1 cm^3 (1 g) of Body TSL	Condition	
SAR measured	100 mW input power	7.39 mW / g
SAR for nominal Body TSL parameters	normalized to 1W	**73.7 mW /g ± 24.4 % (k=2)**
SAR averaged over 10 cm^3 (10 g) of Body TSL	Condition	
SAR measured	100 mW input power	2.12 mW / g
SAR for nominal Body TSL parameters	normalized to 1W	**21.1 mW /g ± 24.2 % (k=2)**

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Body TSL parameters at 5800 MHz

The following parameters and calculations were applied.

	Temperature	Permittivity	Conductivity
Nominal Body TSL parameters	22.0 °C	48.2	6.00 mho/m
Measured Body TSL parameters	(22.0 ± 0.2) °C	47.1 ± 6 %	6.17 mho/m ± 6 %
Body TSL temperature change during test	<1.0 °C	----	----

SAR result with Body TSL at 5800 MHz

SAR averaged over 1 cm^3 (1 g) of Body TSL	Condition	
SAR measured	100 mW input power	7.46 mW / g
SAR for nominal Body TSL parameters	normalized to 1W	**74.3 mW /g ± 24.4 % (k=2)**
SAR averaged over 10 cm^3 (10 g) of Body TSL	Condition	
SAR measured	100 mW input power	2.11 mW / g
SAR for nominal Body TSL parameters	normalized to 1W	**21.0 mW /g ± 24.2 % (k=2)**

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Appendix (Additional assessments outside the scope of CNAS L0570)

Antenna Parameters with Head TSL at 5200 MHz

Impedance, transformed to feed point	53.6Ω - 6.87jΩ
Return Loss	- 22.5dB

Antenna Parameters with Head TSL at 5300 MHz

Impedance, transformed to feed point	50.7Ω + 1.28jΩ
Return Loss	- 36.7dB

Antenna Parameters with Head TSL at 5800 MHz

Impedance, transformed to feed point	55.0Ω +6.61jΩ
Return Loss	- 22.1dB

Antenna Parameters with Body TSL at 5200 MHz

Impedance, transformed to feed point	53.1Ω - 5.01jΩ
Return Loss	- 24.9dB

Antenna Parameters with Body TSL at 5300 MHz

Impedance, transformed to feed point	48.9Ω + 3.26jΩ
Return Loss	- 29.2dB

Antenna Parameters with Body TSL at 5800 MHz

Impedance, transformed to feed point	55.57Ω + 8.75jΩ
Return Loss	- 20.1dB

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General Antenna Parameters and Design

Electrical Delay (one direction)	1.051 ns

After long term use with 100W radiated power, only a slight warming of the dipole near the feedpoint can be measured.

The dipole is made of standard semirigid coaxial cable. The center conductor of the feeding line is directly connected to the second arm of the dipole. The antenna is therefore short-circuited for DC-signals. On some of the dipoles, small end caps are added to the dipole arms in order to improve matching when loaded according to the position as explained in the "Measurement Conditions" paragraph. The SAR data are not affected by this change. The overall dipole length is still according to the Standard.
No excessive force must be applied to the dipole arms, because they might bend or the soldered connections near the feedpoint may be damaged.

Additional EUT Data

Manufactured by	SPEAG

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DASY5 Validation Report for Head TSL Date: 08.29.2018

Test Laboratory: CTTL, Beijing, China

DUT: Dipole 5GHz; Type: D5GHzV2; Serial: D5GHzV2 - SN: 1218

Communication System: CW; Frequency: 5200 MHz, Frequency: 5300 MHz, Frequency: 5800 MHz,

Medium parameters used: f = 5200 MHz; σ = 4.796 S/m; εr = 36.02; ρ = 1000 kg/m3, Medium parameters used: f = 5300 MHz; σ = 4.902 S/m; εr = 35.79; ρ = 1000 kg/m3, Medium parameters used: f = 5800 MHz; σ = 5.424 S/m; εr = 34.79; ρ = 1000 kg/m3,

Phantom section: Center Section

DASY5 Configuration:

- Probe: EX3DV4 - SN7464; ConvF(5.82, 5.82, 5.82) @ 5200 MHz; Calibrated: 9/12/2017, ConvF(5.53, 5.53, 5.53) @ 5300 MHz; Calibrated: 9/12/2017, ConvF(5.11, 5.11, 5.11) @ 5800 MHz; Calibrated: 9/12/2017,
- Sensor-Surface: 1.4mm (Mechanical Surface Detection)
- Electronics: DAE4 Sn1524; Calibrated: 9/13/2017
- Phantom: MFP_V5.1C ; Type: QD 000 P51CA; Serial: 1062
- Measurement SW: DASY52, Version 52.10 (1); SEMCAD X Version 14.6.11 (7439)

Dipole Calibration /Pin=100mW, d=10mm, f=5200 MHz/Zoom Scan, dist=1.4mm (8x8x7)/Cube 0: Measurement grid: dx=4mm, dy=4mm, dz=1.4mm
Reference Value = 57.36 V/m; Power Drift = 0.03 dB
Peak SAR (extrapolated) = 31.5 W/kg
SAR(1 g) = 7.61 W/kg; SAR(10 g) = 2.2 W/kg
Maximum value of SAR (measured) = 17.6 W/kg

Dipole Calibration /Pin=100mW, d=10mm, f=5300 MHz/Zoom Scan, dist=1.4mm (8x8x7)/Cube 0: Measurement grid: dx=4mm, dy=4mm, dz=1.4mm
Reference Value = 59.56 V/m; Power Drift = 0.03 dB
Peak SAR (extrapolated) = 33.9 W/kg
SAR(1 g) = 7.86 W/kg; SAR(10 g) = 2.28 W/kg
Maximum value of SAR (measured) = 19.0 W/kg

Dipole Calibration /Pin=100mW, d=10mm, f=5800 MHz/Zoom Scan, dist=1.4mm (8x8x7)/Cube 0: Measurement grid: dx=4mm, dy=4mm, dz=1.4mm
Reference Value = 57.44 V/m; Power Drift = -0.06 dB
Peak SAR (extrapolated) = 36.9 W/kg
SAR(1 g) = 7.76 W/kg; SAR(10 g) = 2.23 W/kg
Maximum value of SAR (measured) = 19.2 W/kg

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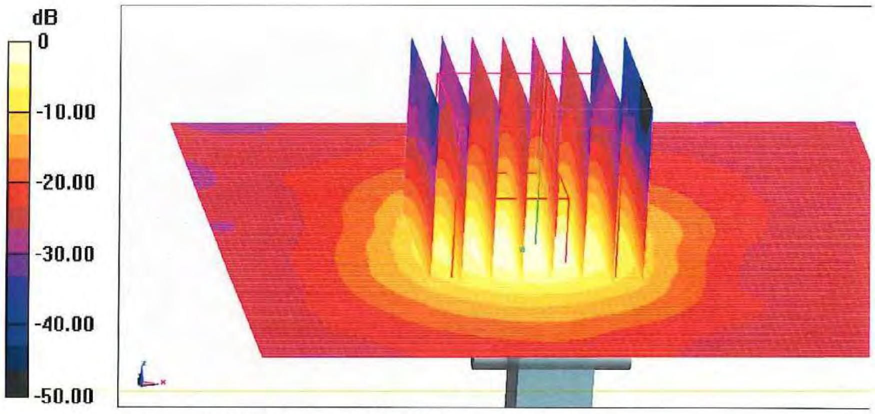

0 dB = 19.2 W/kg = 12.83 dBW/kg

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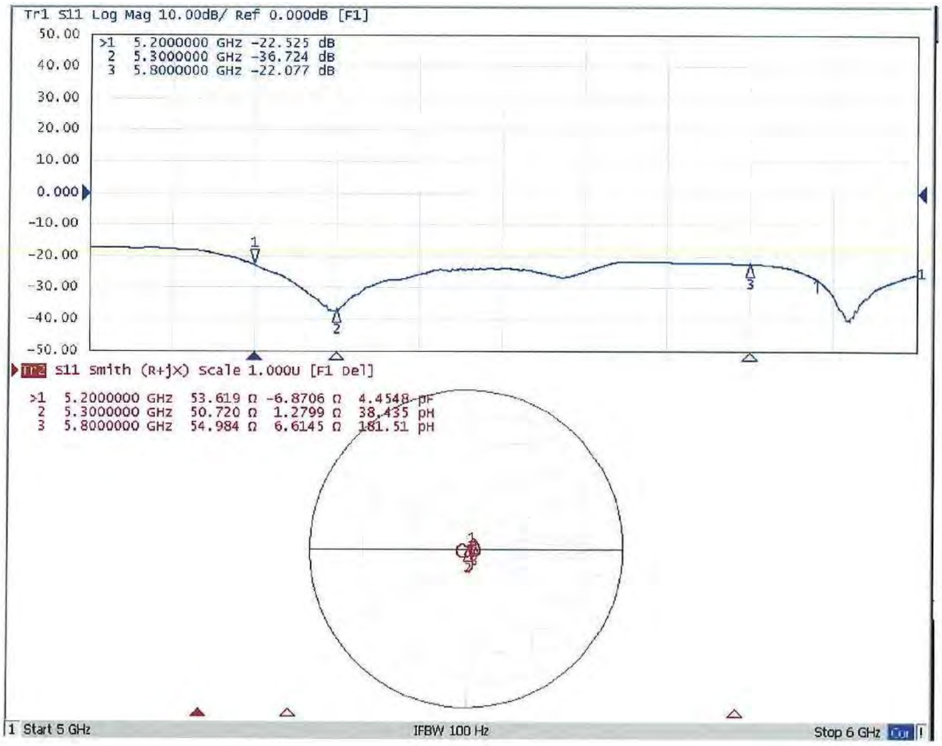
Impedance Measurement Plot for Head TSL



Certificate No: Z18-60305 Page 11 of 14

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DASY5 Validation Report for Body TSL Date: 08.27.2018

Test Laboratory: CTTL, Beijing, China

DUT: Dipole 5GHz; Type: D5GHzV2; Serial: D5GHzV2 - SN: 1218

Communication System: CW; Frequency: 5200 MHz, Frequency: 5300 MHz, Frequency: 5800 MHz,

Medium parameters used: f = 5200 MHz; σ = 5.351 S/m; εr = 48.41; ρ = 1000 kg/m3, Medium parameters used: f = 5300 MHz; σ = 5.466 S/m; εr = 48.14; ρ = 1000 kg/m3, Medium parameters used: f = 5800 MHz; σ = 6.174 S/m; εr = 47.05; ρ = 1000 kg/m3,

Phantom section: Right Section

DASY5 Configuration:

- Probe: EX3DV4 - SN7464; ConvF(5.39, 5.39, 5.39) @ 5200 MHz; Calibrated: 9/12/2017, ConvF(5.19, 5.19, 5.19) @ 5300 MHz; Calibrated: 9/12/2017, ConvF(4.67, 4.67, 4.67) @ 5800 MHz; Calibrated: 9/12/2017,
- Sensor-Surface: 1.4mm (Mechanical Surface Detection)
- Electronics: DAE4 Sn1524; Calibrated: 9/13/2017
- Phantom: MFP_V5.1C ; Type: QD 000 P51CA; Serial: 1062
- Measurement SW: DASY52, Version 52.10 (1); SEMCAD X Version 14.6.11 (7439)

Dipole Calibration /Pin=100mW, d=10mm, f=5200 MHz/Zoom Scan, dist=1.4mm (8x8x7)/Cube 0: Measurement grid: dx=4mm, dy=4mm, dz=1.4mm
Reference Value = 51.03 V/m; Power Drift = 0.03 dB
Peak SAR (extrapolated) = 29.4 W/kg
SAR(1 g) = 7.15 W/kg; SAR(10 g) = 2.05 W/kg
Maximum value of SAR (measured) = 16.7 W/kg

Dipole Calibration /Pin=100mW, d=10mm, f=5300 MHz/Zoom Scan, dist=1.4mm (8x8x7)/Cube 0: Measurement grid: dx=4mm, dy=4mm, dz=1.4mm
Reference Value = 47.69 V/m; Power Drift = 0.06 dB
Peak SAR (extrapolated) = 31.6 W/kg
SAR(1 g) = 7.39 W/kg; SAR(10 g) = 2.12 W/kg
Maximum value of SAR (measured) = 17.5 W/kg

Dipole Calibration /Pin=100mW, d=10mm, f=5800 MHz/Zoom Scan, dist=1.4mm (8x8x7)/Cube 0: Measurement grid: dx=4mm, dy=4mm, dz=1.4mm
Reference Value = 47.44 V/m; Power Drift = -0.01 dB
Peak SAR (extrapolated) = 36.4 W/kg
SAR(1 g) = 7.46 W/kg; SAR(10 g) = 2.11 W/kg
Maximum value of SAR (measured) = 18.7 W/kg

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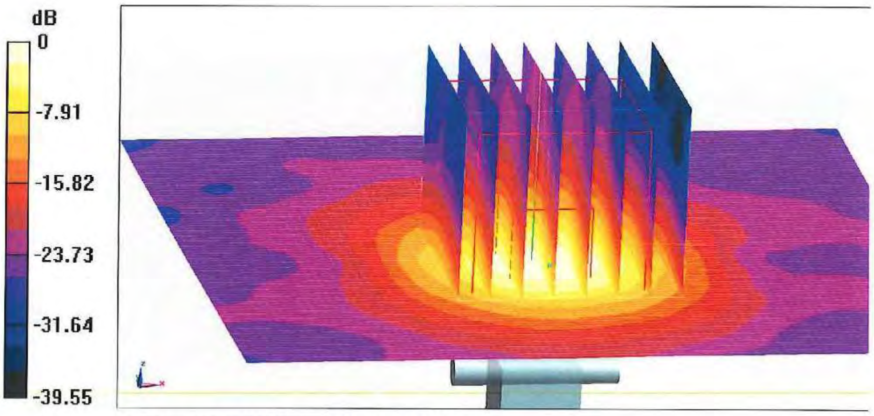

0 dB = 18.7 W/kg = 12.72 dBW/kg

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Impedance Measurement Plot for Body TSL