SAR and Power Density Test Report

Report No.	:	**SFBVCO-WAY-P23090163**
Applicant	:	**Intel Corporation**
Address	:	**100 Center Point Circle Suite 200 Columbia, SC 29210**
Product	:	**Note PC**
FCC ID	:	**PD9AX211D2**
Brand	:	**SAMSUNG**
Model No.	:	**NP960XGL**
Variant Model No.	:	**NP964XGL** **(refer to section 2 for more details)**
Standards	:	**IEEE C95.1:1992, IEEE Std 1528:2013, KDB 865664 D01 v01r04, KDB 865664 D02 v01r02, KDB 248227 D01 v02r02, KDB 447498 D01 v06, KDB 616217 D04 v01r02, IEC TR 63170**
FCC Rule Part		**CFR §2.1093**
Sample Received Date	:	**18 Oct. 2023**
Date of Testing	:	**19 Oct. 2023 ~ 09 Nov. 2023**

CERTIFICATION: The above equipment has been tested by **Bureau Veritas Consumer Products Services ADT Korea Ltd. Mobile Communications Laboratory** and found compliance with the requirement of the above standards. The test record, data evaluation & Equipment Under Test (EUT) configurations represented herein are true and accurate accounts of the measurements of the sample's SAR characteristics under the conditions specified in this report. It should not be reproduced except in full, without the written approval of our laboratory. The client should not use it to claim product certification, approval, or endorsement by A2LA or any government agency.

Prepared By : Jungho Lee / Engineer

Approved By : Dongman Kim / Technical Manager

Certificate #4068.02

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Release Control Record

Report No.	Reason for Change	Date Issued
SFBVCO-WAY-P23090163	Initial release	10 Nov. 2023

1. Summary of Maximum SAR and Power Density Value

Equipment Class	Band & Mode	Tx Frequency	Highest SAR1g Body (W/kg)
DTS	2.4 GHz WLAN	2412 – 2470 MHz	**0.533**
U-NII	5.3 GHz WLAN	5260 – 5320 MHz	**0.951**
	5.6 GHz WLAN	5500 – 5720 MHz	**0.754**
	5.8 GHz WLAN	5745 – 5825 MHz	**0.813**
	6.5 GHz WLAN	5925 – 7125 MHz	**0.444**
DSS/DTS	Bluetooth	2402 – 2480 MHz	**0.155**

Equipment Class	Band & Mode	Highest APD (W/m²)	Highest PD (W/m²)
U-NII	6.5 GHz WLAN	**3.047**	**7.387**

Highest Simultaneous Transmission SAR	Highest SAR1g Body Tested at 0 mm (W/kg)
	1.106
Total Exposure Ratio (TER)	**0.400**

Note:

1. The SAR criteria **(Head & Body: SAR-1g1.6 W/kg, and Extremity: SAR-10g 4.0 W/kg)** for general population/uncontrolled exposure is specified in FCC 47 CFR part 2 (2.1093) and ANSI/IEEE C95.1-1992.
2. According to 47 CFR part 2.1093, the MPE limits specified in part 1.1310 apply to portable devices that transmit at frequencies above 6 GHz. The localized power density limit for general population exposure is **1.0 mW/cm^2 (equal to 10 W/m^2)** for frequency up to 100 GHz.
3. Per FCC guidance in Oct 2022 TCBC workshop, the total exposure ratio calculated by taking ratio of maximum reported SAR divided by SAR limit and adding it to maximum measured power density divided by power density limit. Numerical sum of the ratios should be less than 1.
4. Per FCC interim guidance for near-field power density measurement, the power density was spatially averaged over a circular area of 4 cm^2.

2. Description of Equipment Under Test

EUT Type	Note PC
FCC ID	PD9AX211D2
Brand Name	Samsung
Model Name	NP960XGL
DUT S/N	6F2P9FMWA00002Z, 6F2P9FMWA00003V
HW Version	REV 1.0
SW Version	Windows 11
Testing Program SW Version	DRTU : 05055.23.0.0
Tx Frequency Bands (Unit: MHz)	WLAN: 2412 ~ 2472, 5180 ~ 5240, 5260 ~ 5320, 5500 ~ 5720, 5745 ~ 5825, 5955 ~ 6415, 6435 ~ 6545, 6555 ~ 6885, 6895 ~ 7115 Bluetooth: 2402 ~ 2480
Uplink Modulations	802.11b: DSSS 802.11a/g/n/ac: OFDM 802.11ax: OFDMA Bluetooth: GFSK, π/4-DQPSK, 8DPSK
Maximum Tune-up Conducted Power (Unit: dBm)	Please refer to **Appendix D**
Antenna Type	PIFA Antenna

Note:

1. All models are listed as below.

Brand	Model	Difference
SAMSUNG	NP964XGL	The model difference is there are no HW & SW difference and only between model name for market purpose.

2. The above EUT information is declared by manufacturer and for more detailed features description please refers to the manufacturer's specifications or User's Manual.
3. Test results are valid only for the samples provided by the customer.

List of Accessory :

Battery	**Brand Name**	Samsung
	Model Name	AA-PBKN4VN
	Power Rating	15.52 V, 76.0 Wh 4900mAh
	Type	Li-ion

3. SAR Measurement System

3.1 Definition of Specific Absorption Rate (SAR)

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.

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:

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

SAR is expressed in units of Watts per kilogram (W/kg)
SAR measurement can be related to the electrical field in the tissue by

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

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

3.2 SPEAG DASY System

DASY system consists of high precision robot, probe alignment sensor, phantom, robot controller, controlled measurement server and near-field probe. The robot includes six axes that can move to the precision position of the DASY software defined. The DASY software can define the area that is detected by the probe. The robot is connected to controlled box. Controlled measurement server is connected to the controlled robot box. The DAE includes amplifier, signal multiplexing, AD converter, offset measurement and surface detection. It is connected to the Electro-optical converter (EOC). The EOC performs the conversion form the optical into digital electric signal of the DAE and transfers data to the PC.

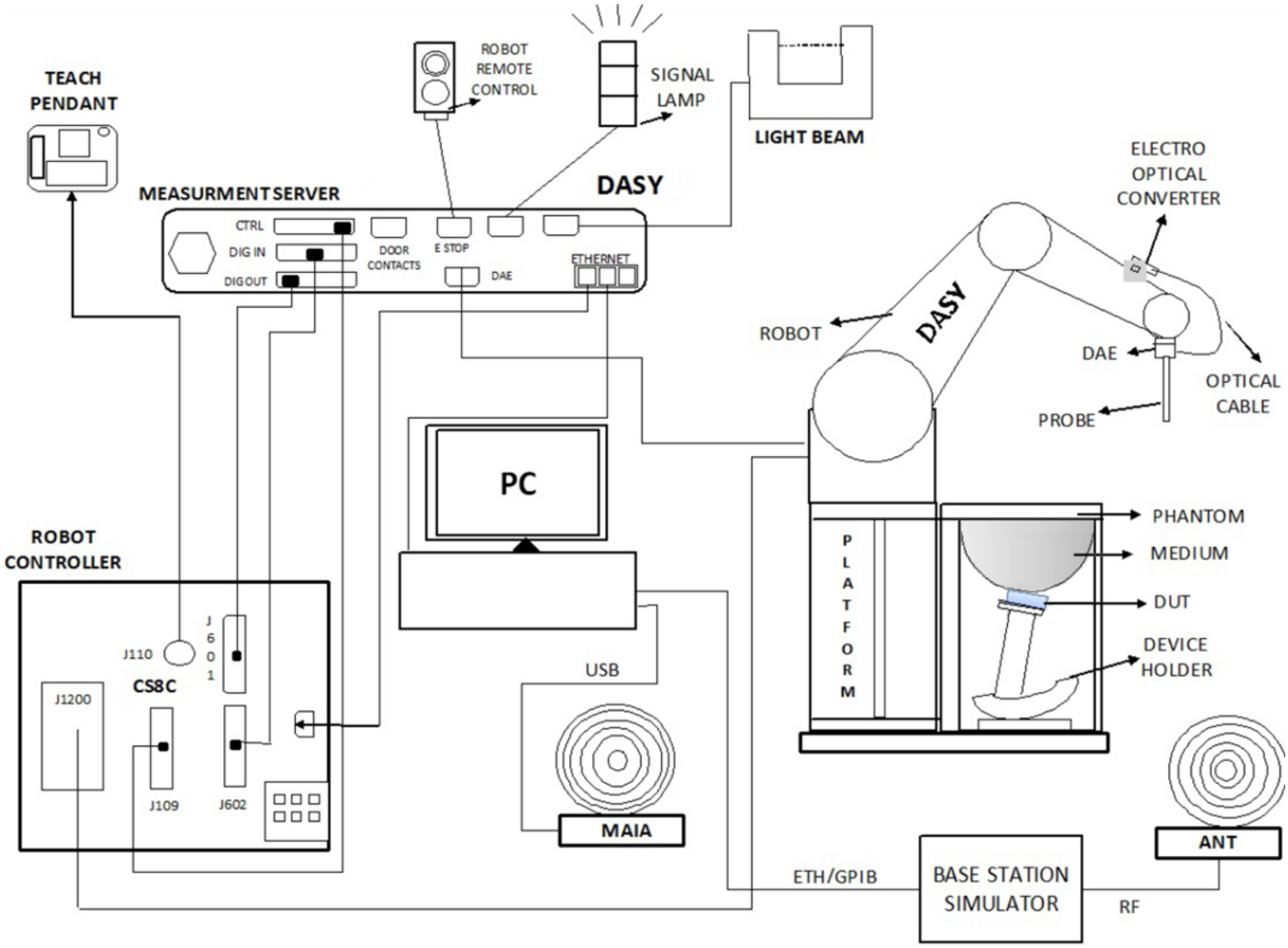


Fig-3.1 DASY System Setup

3.2.1 Robot

The DASY system uses the high precision robots from Stäubli SA (France). For the 6-axis controller system, the robot controller version of CS8c from Stäubli is used. The Stäubli robot series have many features that are important for our application:

- High precision (repeatability ±0.035 mm)
- High reliability (industrial design)
- Jerk-free straight movements
- Low ELF interference (the closed metallic construction shields against motor control fields)

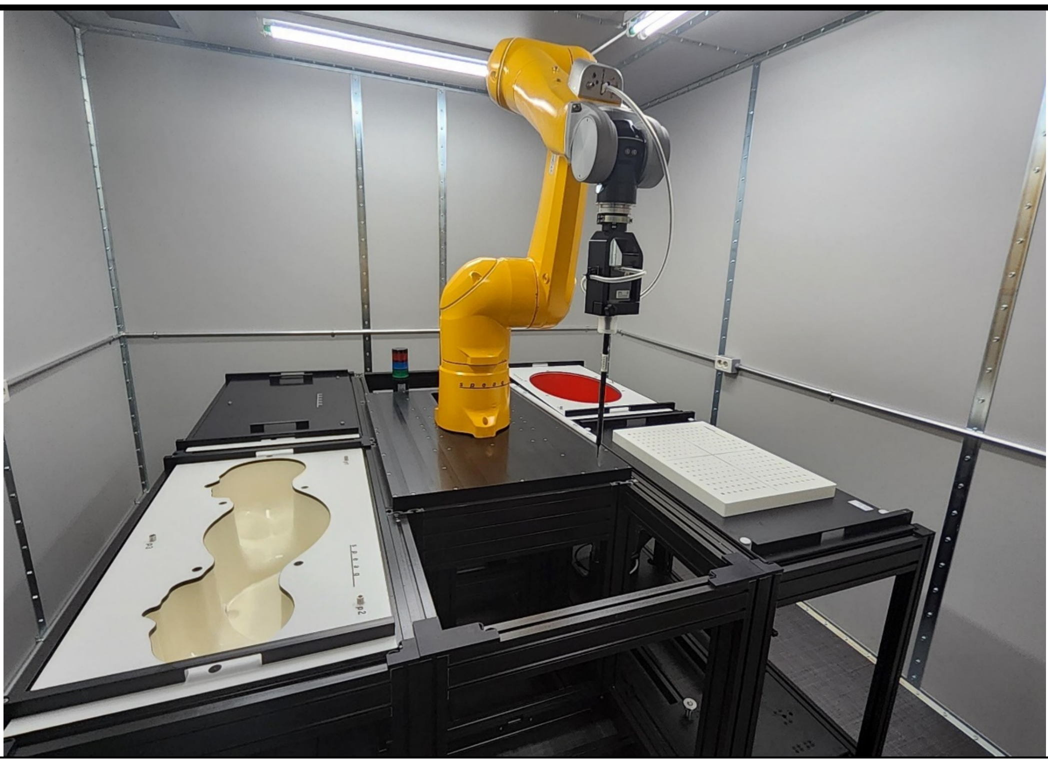


Fig-3.2 DASY SAR System

Robot Model Name	DASY 8
Robot Serial Number	F/22/0040899/A/001 , F/22/0041970/A/001
Program Name	DASY 8 Module SAR
SW Version	V16.2.2.1588

3.2.2 Probes

The SAR measurement is conducted with the dosimetry probe. The probe is specially designed and calibrated for use in liquid with high permittivity. The dosimetry probe has special calibration in liquid at different frequency.

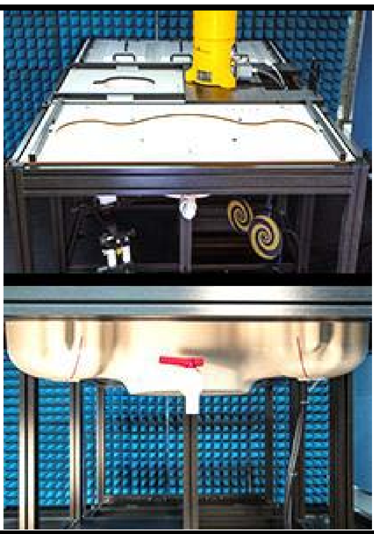
Model	EX3DV4	
Construction	Symmetrical design with triangular core. Built-in shielding against static charges. PEEK enclosure material (resistant to organic solvents, e.g., DGBE).	
Frequency	4 MHz to 10 GHz Linearity: ±0.2 dB	
Directivity	±0.1 dB in TSL (rotation around probe axis) ±0.3 dB in TSL (rotation normal to probe axis)A	
Dynamic Range	10 µW/g to 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: 12 mm) Typical distance from probe tip to dipole centers: 1 mm	

3.2.3 Data Acquisition Electronics (DAE)

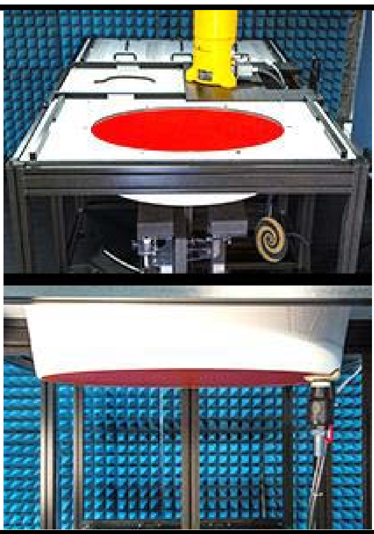
Model	DAE4
Construction	Signal amplifier, multiplexer, A/D converter and control logic. Serial optical link for communication with DASY embedded system (fully remote controlled). Two step probe touch detector for mechanical surface detection and emergency robot stop.
Measurement Range	-100 to +300 mV (16 bit resolution and two range settings: 4mV, 400mV)
Input Offset Voltage	< 5µV (with auto zero)
Input Bias Current	< 50 fA
Dimensions	60 x 60 x 68 mm

3.2.4 Phantoms

Model	SAM-Twin Phantom
Construction	The shell corresponds to the specifications of the Specific Anthropomorphic Mannequin (SAM) phantom defined in IEEE Std 1528. It enables the dosimetric evaluation of left and right hand phone usage as well as body-mounted usage at the flat phantom region. A cover prevents evaporation of the liquid. Reference markings on the phantom allow the complete setup of all predefined phantom positions and measurement grids by teaching three points with the robot.
Material	Vinylester, fiberglass reinforced (VE-GF)
Shell Thickness	2 ± 0.2 mm (6 ± 0.2 mm at ear point)
Dimensions	Length: 1000 mm Width: 500 mm Height: adjustable feet
Filling Volume	approx. 25 liters



Model	ELI
Construction	The ELI phantom is used for compliance testing of handheld and body-mounted wireless devices. ELI is fully compatible with the IEEE Std 1528 standard and all known tissue simulating liquids. ELI has been optimized regarding its performance and can be integrated into our standard phantom tables. A cover prevents evaporation of the liquid. Reference markings on the phantom allow installation of the complete setup, including all predefined phantom positions and measurement grids, by teaching three points. The phantom is compatible with all SPEAG dosimetric probes and dipoles.
Material	Vinylester, glass fiber reinforced (VE-GF)
Shell Thickness	2.0 ± 0.2 mm (bottom plate)
Dimensions	Major axis: 600 mm Minor axis: 400 mm
Filling Volume	approx. 30 liters



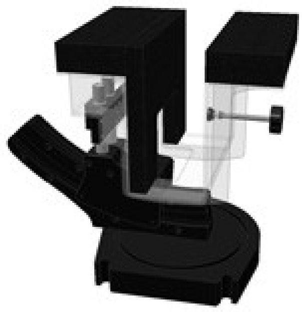
3.2.5 Device Holder

Model	Mounting Device
Construction	In combination with the Twin SAM Phantom or ELI4, the Mounting Device enables the rotation of the mounted transmitter device in spherical coordinates. Rotation point is the ear opening point. Transmitter devices can be easily and accurately positioned according to IEC, IEEE, FCC or other specifications. The device holder can be locked for positioning at different phantom sections (left head, right head, flat).
Material	POM

Model	MDA4WTV5 - Mounting Device Adaptor for Ultra Wide Transmitters
Construction	An upgrade kit to Mounting Device to enable easy mounting of wider devices like big smart-phones, e-books, small tablets, etc. It holds devices with width up to 140 mm.
Material	Polyoxymethylene (POM)

Model	MDA4SPV6 - Mounting Device Adaptor for Smart Phones
Construction	The solid low-density MDA4SPV6 adaptor assuring no impact on the DUT radiation performance and is conform with any DUT design and shape.
Material	ROHACELL

Model	Laptop Extensions Kit
Construction	Simple but effective and easy-to-use extension for Mounting Device that facilitates the testing of larger devices according to IEEE std 1528 (e.g., laptops, cameras, etc.). It is light weight and fits easily on the upper part of the Mounting Device in place of the phone positioner.
Material	POM, Acrylic glass, Foam

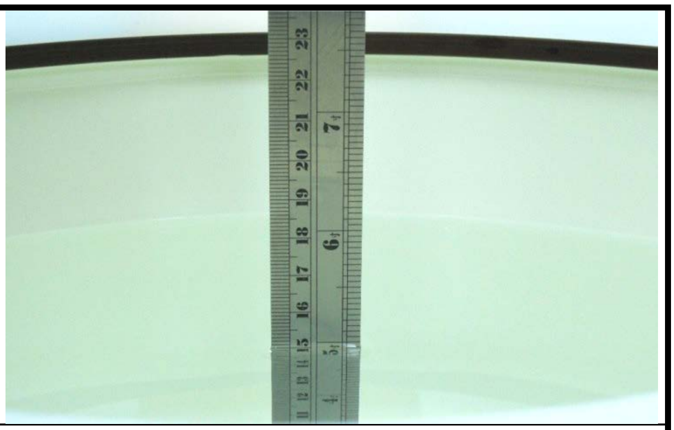


3.2.6 System Validation Dipoles

Model	D-Serial	
Construction	Symmetrical dipole with l/4 balun. Enables measurement of feed point impedance with NWA. Matched for use near flat phantoms filled with tissue simulating solutions.	
Frequency	750 MHz to 6500 MHz	
Return Loss	> 20 dB	
Power Capability	> 100 W (f < 1GHz),> 40 W (f > 1GHz)	

3.2.7 Tissue Simulating Liquids

For SAR measurement of the field distribution inside the phantom, the phantom must be filled with homogeneous tissue simulating liquid to a depth of at least 15 cm. For head SAR testing, the liquid height from the ear reference point (ERP) of the phantom to the liquid top surface is larger than 15 cm. For body SAR testing, the liquid height from the center of the flat phantom to the liquid top surface is larger than 15 cm. The nominal dielectric values of the tissue simulating liquids in the phantom and the tolerance of 5% are listed in Table-3.1.

	
Photo of Liquid Height for Head Position	**Photo of Liquid Height for Body Position**

The dielectric properties of the tissue simulating liquids are defined in IEEE std 1528. The dielectric properties of the tissue simulating liquids were verified prior to the SAR evaluation using a SPEAG DAK3.5 Dielectric Assessment Kit and an Agilent Network Analyzer.

Table-3.1 Probe requirements as a function of frequency and liquid parameter

Frequency (MHz)	Medium relative permittivity (ε'_r)	Medium conductivity (σ) (S/m)
300	45.3	0.87
450	43.5	0.87
750	41.9	0.89
835	41.5	0.90
900	41.5	0.97
1450	40.5	1.20
1500	40.4	1.23
1640	40.2	1.31
1750	40.1	1.37
1800	40.0	1.40
1900	40.0	1.40
2000	40.0	1.40
2100	39.8	1.49
2300	39.5	1.67
2450	39.2	1.80
2600	39.0	1.96
3000	38.5	2.40
4000	37.4	3.43
5000	36.2	4.45
5200	36.0	4.66
5400	35.8	4.86
5600	35.5	5.07
5800	35.3	5.27
6000	35.1	5.48
6500	34.5	6.07

The following table gives the recipes for tissue simulating liquids.

Table-3.2 Recipes of Tissue Simulating Liquid

Tissue Type	Bactericide	DGBE	HEC	NaCl	Sucrose	Triton X-100	Water	Diethylene Glycol Mono-Hexylether
H750	0.2	-	0.2	1.5	56.0	-	42.1	-
H835	0.2	-	0.2	1.5	57.0	-	41.1	-
H900	0.2	-	0.2	1.4	58.0	-	40.2	-
H1450	-	43.3	-	0.6	-	-	56.1	-
H1640	-	45.8	-	0.5	-	-	53.7	-
H1750	-	47.0	-	0.4	-	-	52.6	-
H1800	-	44.5	-	0.3	-	-	55.2	-
H1900	-	44.5	-	0.2	-	-	55.3	-
H2000	-	44.5	-	0.1	-	-	55.4	-
H2300	-	44.9	-	0.1	-	-	55.0	-
H2450	-	45.0	-	0.1	-	-	54.9	-
H2600	-	45.1	-	0.1	-	-	54.8	-
H3500	-	8.0	-	0.2	-	20.0	71.8	-
H5G	-	-	-	-	-	17.2	65.5	17.3
H6G	-	-	-	-	-	-	56.0	-

3.3 SAR System Verification

The system check verifies that the system operates within its specifications. It is performed daily or before every SAR measurement. The system check uses normal SAR measurements in the flat section of the phantom with a matched dipole at a specified distance. The system verification setup is shown as below.

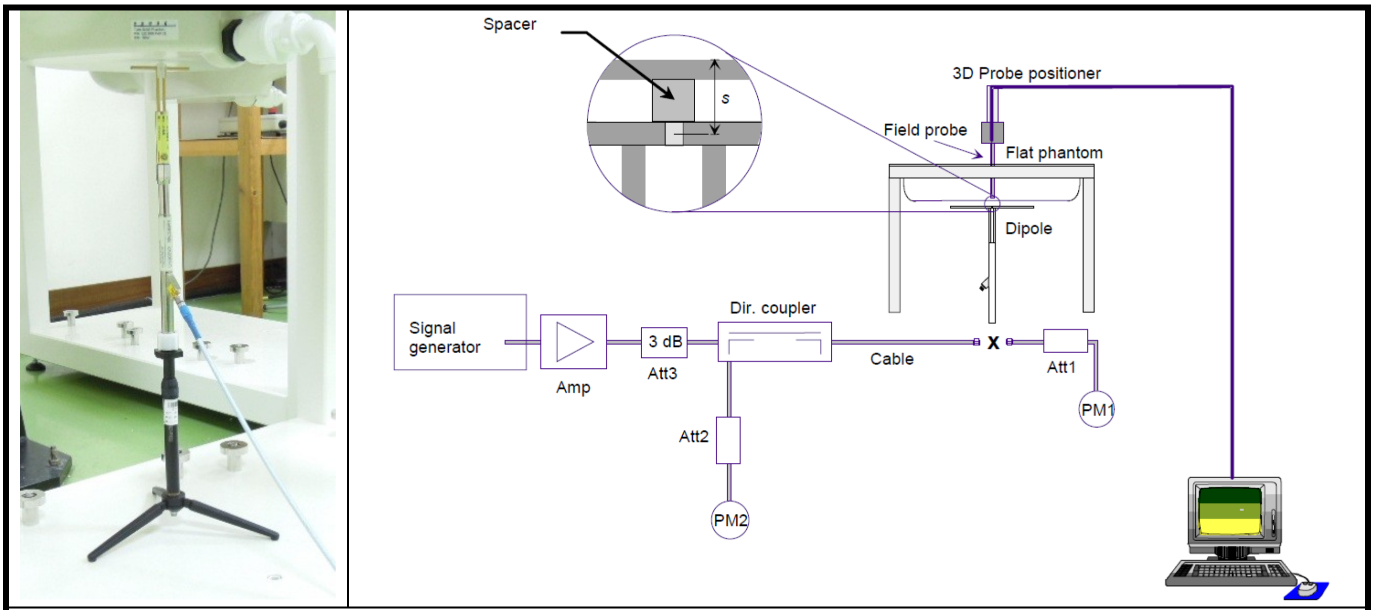


Fig-3.4 System Verification Setup

The validation dipole is placed beneath the flat phantom with the specific spacer in place. The distance spacer is touch the phantom surface with a light pressure at the reference marking and be oriented parallel to the long side of the phantom. The power meter PM1 measures the forward power at the location of the system check dipole connector. The signal generator is adjusted for the desired forward power (250 mW is used for 700 MHz to 3 GHz, 100 mW is used for 3.5 GHz to 6.5 GHz) at the dipole connector and the power meter PM2 is read at that level. After connecting the cable to the dipole, the signal generator is readjusted for the same reading at power meter PM2.

After system check testing, the SAR result will be normalized to 1W forward input power and compared with the reference SAR value derived from validation dipole certificate report. The deviation of system check should be within 10 %.

3.4 SAR Measurement Procedure

According to the SAR test standard, the recommended procedure for assessing the peak spatial-average SAR value consists of the following steps:

(a) Power reference measurement
(b) Area scan
(c) Zoom scan
(d) Power drift measurement

The SAR measurement procedures for each of test conditions are as follows:

(a) Make EUT to transmit maximum output power
(b) Measure conducted output power through RF cable
(c) Place the EUT in the specific position of phantom
(d) Perform SAR testing steps on the DASY system
(e) Record the SAR value

3.4.1 Area & Zoom Scan Procedure

First area scan is used to locate the approximate location(s) of the local peak SAR value(s). The measurement grid within an area scan is defined by the grid extent, grid step size and grid offset. Next, in order to determine the EM field distribution in a three-dimensional spatial extension, zoom scan is required. The zoom scan is performed around the highest E-field value to determine the averaged SAR-distribution.

Measure the local SAR at a test point at 1.4 mm of the inner surface of the phantom recommended by SEPAG. The area scan (two-dimensional SAR distribution) is performed cover at least an area larger than the projection of the EUT or antenna. The measurement resolution and spatial resolution for interpolation shall be chosen to allow identification of the local peak locations to within one-half of the linear dimension of the corresponding side of the zoom scan volume. Following table provides the measurement parameters required for the area scan.

Parameter	$f \leq$ 3 GHz	3 GHz < $f \leq$ 6 GHz
Maximum distance from closest measurement point to phantom surface	5 ± 1	δ ln(2)/2 ±0.5
Maximum probe angle from probe axis to phantom surface normal at the measurement location	30° ±1°	20° ±1°
Maximum area scan spatial resolution: Δx_{Area}, Δy_{Area}	≦2 GHz: ≦15 mm 2 – 3 GHz: ≦12 mm	3 – 4 GHz: ≦12 mm 4 – 6 GHz: ≦10 mm

From the scanned SAR distribution, identify the position of the maximum SAR value, in addition identify the positions of any local maxima with SAR values within 2 dB of the maximum value that will not be within the zoom scan of other peaks. Additional peaks shall be measured only when the primary peak is within 2 dB of the SAR compliance limit (e.g. 1 W/kg for 1.6 W/kg, 1 g limit; or 1.26 W/kg for 2 W/kg, 10 g limit).

The zoom scan (three-dimensional SAR distribution) is performed at the local maxima locations identified in previous area scan procedure. The zoom scan volume must be larger than the required minimum dimensions. When graded grids are used, which only applies in the direction normal to the phantom surface, the initial grid separation closest to the phantom surface and subsequent graded grid increment ratios must satisfy the required protocols. The 1-g SAR averaging volume must be fully contained within the zoom scan measurement volume boundaries; otherwise, the measurement must be repeated by shifting or expanding the zoom scan volume. The similar requirements also apply to 10-g SAR measurements. Following table provides the measurement parameters required for the zoom scan.

Parameter		$f \leq 3$ GHz	3 GHz < $f \leq 6$ GHz
Maximum zoom scan spatial resolution: Δx_{Zoom}, Δy_{Zoom}		≤2 GHz: ≤8 mm 2 – 3 GHz: ≤5 mm	3 – 4 GHz: ≤5 mm 4 – 6 GHz: ≤4 mm
Maximum zoom scan spatial resolution, normal to phantom surface	*uniform grid:* $\Delta z_{Zoom}(n)$	≤5 mm	3 – 4 GHz: ≤4 mm 4 – 5 GHz: ≤3 mm 5 – 6 GHz: ≤2 mm
	graded grids: $\Delta z_{Zoom}(1)$	≤4 mm	3 – 4 GHz: ≤3.0 mm 4 – 5 GHz: ≤2.5 mm 5 – 6 GHz: ≤2.0 mm
	$\Delta z_{Zoom}(n>1)$	≤1.5·$\Delta z_{Zoom}(n-1)$ mm	
Minimum zoom scan volume (x, y, z)		≥30 mm	3 – 4 GHz: ≥28 mm 4 – 5 GHz: ≥25 mm 5 – 6 GHz: ≥22 mm

Per IEC 62209-1528, the successively higher resolution zoom scan is required if the zoom scan measured as defined above complies with both of the following criteria, or if the peak spatial-average SAR is below 0.1 W/kg, no additional measurements are needed:

(1) The smallest horizontal distance from the local SAR peaks to all points 3 dB below the SAR peak shall be larger than the horizontal grid steps in both x and y directions (Δx, Δy). This shall be checked for the measured zoom scan plane conformal to the phantom at the distance zM1.

(2) The ratio of the SAR at the second measured point (M2) to the SAR at the closest measured point (M1) at the x-y location of the measured maximum SAR value shall be at least 30 %.

If one or both above criteria are not met, the zoom scan measurement shall be repeated using a finer resolution. New horizontal and vertical grid steps shall be determined from the measured SAR distribution so that the above criteria are met. Compliance with the above two criteria shall be demonstrated for the new measured zoom scan.

3.4.2 Volume Scan Procedure

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

3.4.3 Power Drift Monitoring

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

3.4.4 Spatial Peak SAR Evaluation

The procedure for spatial peak SAR evaluation has been implemented according to the test standard. It can be conducted for 1g and 10g, as well as for user-specific masses. The DASY software includes all numerical procedures necessary to evaluate the spatial peak SAR value.

The base for the evaluation is a "cube" measurement. The measured volume must include the 1g and 10g cubes with the highest averaged SAR values. For that purpose, the center of the measured volume is aligned to the interpolated peak SAR value of a previously performed area scan.

The entire evaluation of the spatial peak values is performed within the post-processing engine (SEMCAD). The system always gives the maximum values for the 1g and 10g cubes. The algorithm to find the cube with highest averaged SAR is divided into the following stages:

(a) Extraction of the measured data (grid and values) from the Zoom Scan
(b) Calculation of the SAR value at every measurement point based on all stored data (A/D values and measurement parameters)
(c) Generation of a high-resolution mesh within the measured volume
(d) Interpolation of all measured values form the measurement grid to the high-resolution grid
(e) Extrapolation of the entire 3-D field distribution to the phantom surface over the distance from sensor to surface
(f) Calculation of the averaged SAR within masses of 1g and 10g

3.4.5 SAR Averaged Methods

In DASY, the interpolation and extrapolation are both based on the modified Quadratic Shepard's method. The interpolation scheme combines a least square fitted function method and a weighted average method which are the two basic types of computational interpolation and approximation.

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. The uncertainty increases with the extrapolation distance. To keep the uncertainty within 1% for the 1 g and 10 g cubes, the extrapolation distance should not be larger than 5 mm.

4. Power Density Measurement System

4.1 Power Density System Verification

The power density for an electromagnetic field represents the rate of energy transfer per unit area. The local power density (i.e. Poynting vector) at a given spatial point is deduced from electromagnetic fields by the following formula:

$$S = \frac{1}{2}\mathrm{Re}\{E \times H^{*}\} \cdot \vec{n}$$

Where: E is the complex electric field peak phasor and H is the complex conjugate magnetic field peak phasor.

$$S_{av} = \frac{1}{2A}\Re\left(\int E \times H^{*} \cdot \hat{n} dA\right)$$

The spatial-average power density distribution on the evaluation surface is determined per the IEC TR 63170. The spatial area, A is specified by the applicable exposure limit or regulatory requirements. The circular shape was used.

4.2 SPEAG DASY System

The SPEAG DASY system consists of high precision robot, probe alignment sensor, phantom, robot controller, controlled measurement server and near-field probe. The robot includes six axes that can move to the precision position of the DASY software defined. The DASY software can define the area that is detected by the probe. The robot is connected to controlled box. Controlled measurement server is connected to the controlled robot box. The DAE includes amplifier, signal multiplexing, AD converter, offset measurement and surface detection. It is connected to the Electro-optical coupler (EOC). The EOC performs the conversion form the optical into digital electric signal of the DAE and transfers data to the PC.

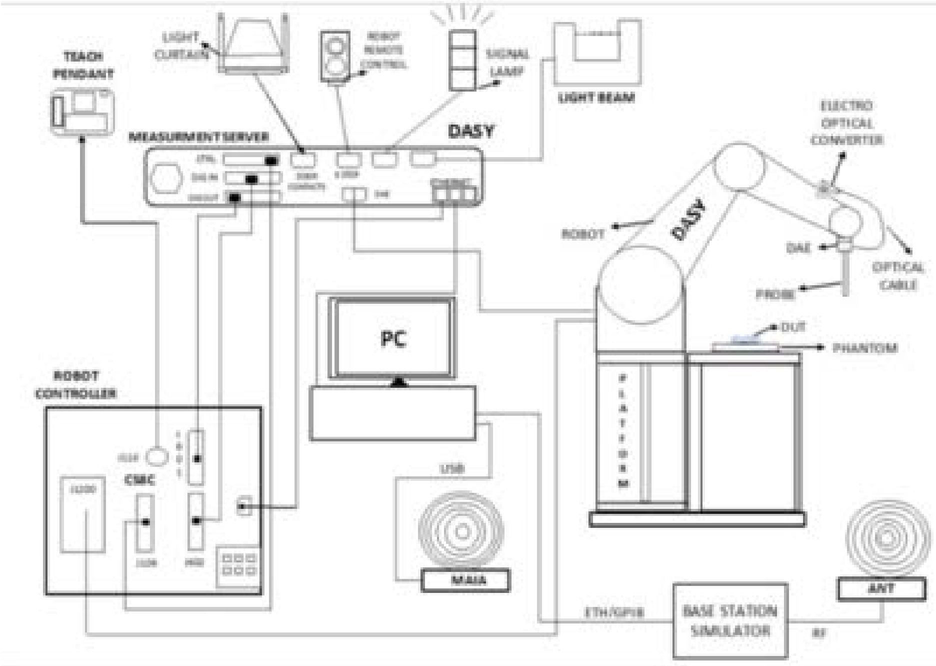


Fig-4.1 SPEAG DASY System Configuration

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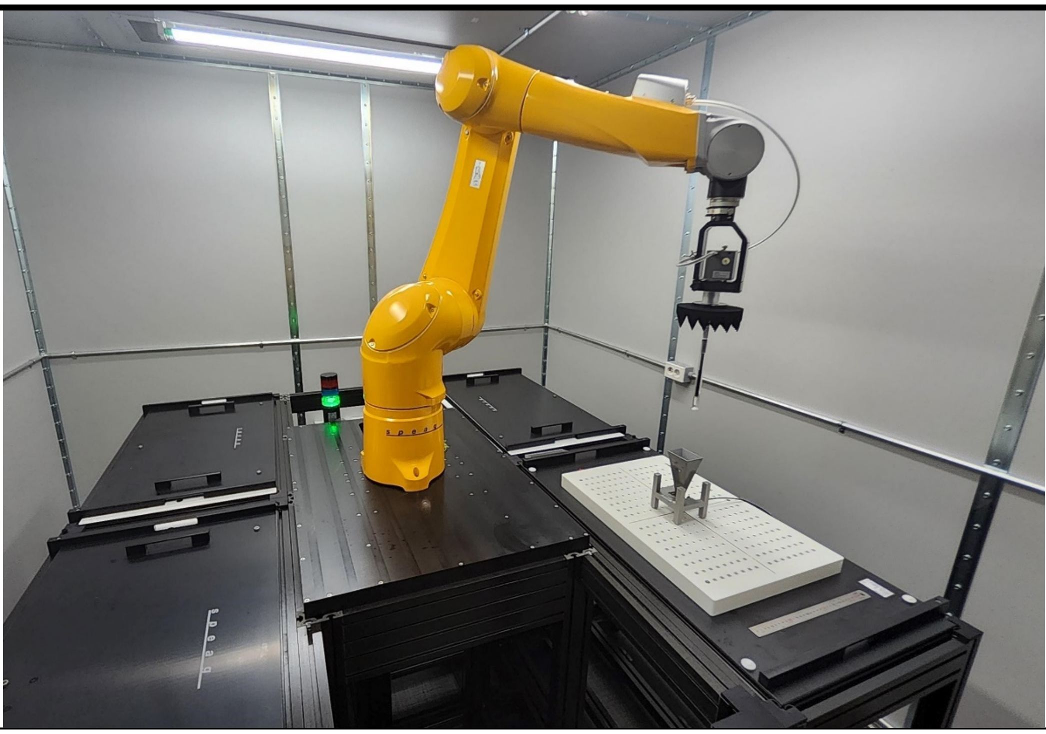


Fig-4.2 DASY Power Density System

Robot Model Name	DASY 8
Robot Serial Number	F/22/0040899/A/001
Program Name	DASY 8 Module mmWAVE
SW Version	V 3.2.0.1840

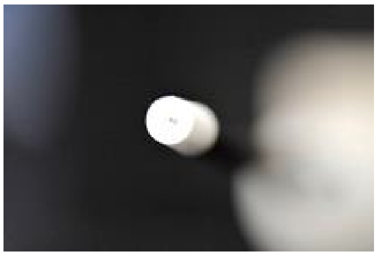
4.2.2 EUmmWV2 mm-Wave Probe

The EUmmWV2 probe is an electric (E) universal (U) field probe with two dipole sensors for field measurements at frequencies up to 110 GHz and as close as 2 mm from any field source or transmitter. The sensors consist of two diode-loaded small dipoles that provide the rectified voltage from the coupled E-field. From the voltages at three different orientations in the field at known angles, both the magnitude of the field component and the field polarization can be calculated. Due to the small size of the sensors, the probe can be used for measurements over an extremely wide frequency range from <1 GHz to 110 GHz. The probe sensors are protected by non-removable 8 mm high- density foam.

The EUmmWV2 probe is based on the pseudo-vector probe design, which not only measures the field magnitude but also derives its polarization ellipse. This probe concept also has the advantage that the sensor angle errors or distortions of the field by the substrate can be largely nullified by calibration. This is particularly important as, at these very high frequencies, field distortions by the substrate are dependent on the wavelength. The design entails two small 0.8 mm dipole sensors mechanically protected by high-density foam, printed on both sides of a 0.9 mm wide and 0.12 mm thick glass substrate. The body of the probe is specifically constructed to minimize distortion by the scattered fields.

The probe consists of two sensors with different angles arranged in the same plane in the probe axis. Three or more measurements of the two sensors are taken for different probe rotational angles to derive the amplitude and polarization information. These probes are the most flexible and accurate probes currently available for measuring field amplitude.

The probe design allows measurements at distances as small as 2 mm from the sensors to the surface of the device under test (DUT). The typical sensor to probe tip distance is 1.5 mm. The exact distance is calibrated.

Model	EUmmWV2	
Frequency	750 MHz to 110 GHz	
Dynamic Range	< 20 V/m - 10000 V/m with PRE-10 < 50 V/m - 3000 V/m minimum	
Linearity	±0.1 dB in TSL (rotation around probe axis) ±0.3 dB in TSL (rotation normal to probe axis) A	
Hemispherical Isotropy	< 0.5 dB	
Position Precision	< 0.2 mm	
Dimensions	Overall length: 337 mm (tip: 20 mm) Tip diameter: encapsulation 8 mm (internal sensor < 1mm) Distance from probe tip to dipole centers: < 2 mm Sensor displacement to probe's calibration point: < 0.3 mm	

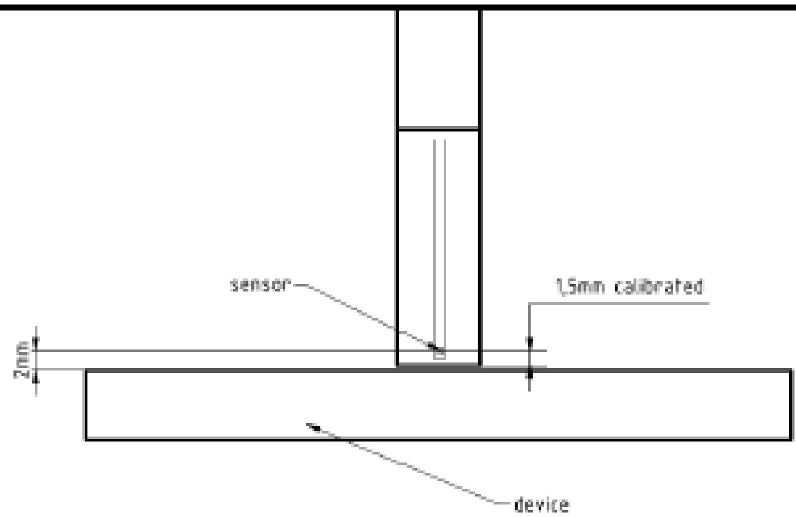


Fig-4.3 Distance - Sensor to DUT Surface

4.3 Power Density System Verification

System check provides a fast and reliable method to routinely verify that the measurement system is operational with no system component failures, including probe defects, drifts or deviation from target performance requirements. A system check also verifies the repeatability of the measurement system before compliance testing.

The measurement of a verification source is started from 5G probe installed and the phantom taught. The verification source is placed on the 5G phantom. Due to the internal distance from the horn to the outer surface of the verification source, the measurement distance set in the software should be offset by -4.45 mm; e.g., for measurement of the verification source at 10 mm, the measurement distance set in the software should be 5.55 mm (10mm - 4.45 mm).

The system check is a complete measurement using simple well-defined reference sources. According to the DASY specification in the user's manual and SPEAG's recommendation, the deviation threshold of ±0.66 dB represents the expanded standard uncertainty for system performance check. The system check is successful if the measured results are within ±0.66 dB tolerances to the target value shown in the calibration certificate of the verification source.
The instrumentation and procedures used for system check should ensure the system is ready for performing compliance tests.

System check using 10 GHz source to support 6-7GHz incident-PD results done with EUmmWV probe, the test procedure was following by the SPEAG AppNote Procedures for Device Operating at 6 – 10GHz.

Frequency [GHz]	Grid Step	Grid Extent X/Y [mm]	Measurement Points
10	0.125 (λ /8)	60 / 60	18 x 18

Table-4.1 Settings for Measurement of Verification Sources

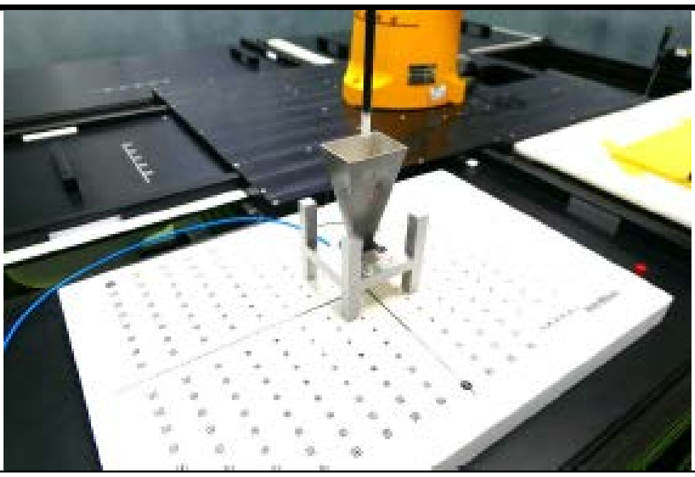


Fig-4.4 System Verification Setup

4.4 Power Density Measurement Procedure

Within a short distance from the transmitting source, power density is determined based on both electric and magnetic fields. Generally, the magnitude and phase of two components of either the E-field or H-field are needed on a sufficiently large surface to fully characterize the total E-field and H-field distributions. Nevertheless, solutions based on direct measurement of E-field and H-field can be used to compute power density. When the measurement surface does not correspond to the evaluation surface, reconstruction algorithms are necessary to project or transform the fields from the measurement surface to the evaluation surface. The general measurement approach is summarized in following:

(a) Measure the E-field on the measurement surface at a reference location where the field is well above the noise level. This reference level will be used at the end of this procedure to assess output power drift of the DUT during the measurement.

(b) Scan the electric field on the measurement surface. The requirements of measurement surface dimensions and spatial resolution are dependent on the measurement system and assessment methodology applied. Measurements are therefore conducted according to the instructions provided by the measurement system manufacturer.

(c) Measurement spatial resolution can depend on the measured field characteristic and measurement methodology used by the system. Planar scanners typically require a step size of less than $\lambda / 2$. When measurements are acquired in regions where evanescent modes are not negligible, smaller spatial resolution may be required. Similar criteria also apply to cylindrical scanning systems where the spatial resolution in the vertical direction should be less than $\lambda / 2$.

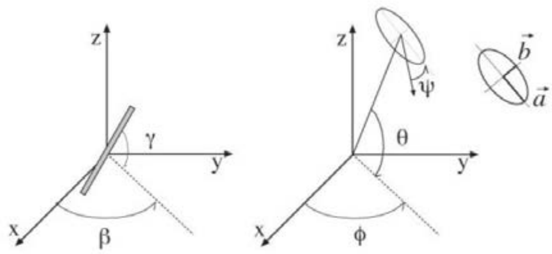
(d) Since only E-field is measured on the measurement system, the H-field is calculated from the measured field using a reconstruction algorithm. As power density requires knowledge of both amplitude and phase, reconstruction algorithms can also be used to obtain field information from the measured data (e.g. the phase from the amplitude if only the amplitude is measured). The measurement involves two planes with three different probe rotations on two measurement planes separated by $\lambda / 4$. The grid steps are optimized by the software based on the test frequency. The location of the lowest measurement plane is defined by the distance of first measurement layer from device under test entered by the user. In addition, when the measurement surface does not correspond to the evaluation surface, reconstruction algorithms are employed to project or transform the fields from the measurement surface to the evaluation surface. In substance, reconstruction algorithms are the set of algorithms, mathematical techniques and procedures that are applied to the measured field on the measurement surface to determine E- and H-field (amplitude and phase) on the evaluation surface.

(e) To determine the spatial-average power density distribution on the evaluation surface. The spatial averaging area, A, is specified by the applicable exposure limits or regulatory requirements. If the shape of the area is not provided by the relevant regulatory requirements, a circular shape is recommended.

(f) Measure the E-field on the measurement surface position at the reference location chosen in step (a). The power drift of the DUT is estimated as the difference between the squared amplitude of the field values taken in steps (a) and (f). When the drift is smaller than ± 5 %, this term should be considered in the uncertainty budget. Drifts larger than 5 % due to the design and operating characteristics of the device should be accounted for or addressed according to regulatory requirements to determine compliance.

4.4.1 Computation of the Electric Field Polarization Ellipse

For the numerical description of an arbitrarily oriented ellipse in three-dimensional space, five parameters are needed: the semi-major axis (a), the semi-minor axis (b), two angles describing the orientation of the normal vector of the ellipse (Φ, θ), and one angle describing the tilt of the semi-major axis (ψ). For the two extreme cases, i.e., circular and linear polarizations, three parameters only (a, Φ, and θ) are sufficient for the description of the incident field.



For the reconstruction of the ellipse parameters from measured data, the problem can be reformulated as a nonlinear search problem. The semi-major and semi-minor axes of an elliptical field can be expressed as functions of the three angles (Φ, θ, and ψ). The parameters can be uniquely determined towards minimizing the error based on least-squares for the given set of angles and the measured data. In this way, the number of free parameters is reduced from five to three, which means that at least three sensor readings are necessary to gain sufficient information for the reconstruction of the ellipse parameters. However, to suppress the noise and increase the reconstruction accuracy, it is desirable that the system of equations be over-determined. The solution use a probe consisting of two sensors angled by γ_1 and γ_2 toward the probe axis and to perform measurements at three angular positions of the probe, i.e., at β_1, β_2, and β_3, results in over-determinations by a factor of two. If there is a need for more information or increased accuracy, more rotation angles can be added.

The reconstruction of the ellipse parameters can be separated into linear and non-linear parts that are best solved by the givens algorithm combined with a downhill simplex algorithm. To minimize the mutual coupling, sensor angles are set with a shift of 90° ($\gamma_2 = \gamma_1 + 90°$), and, to simplify, the first rotation angle of the probe (β_1) can be set to 0°.

4.4.2 Total Field and Power Flux Density Flux Density Reconstruction

Computation of the power density in general requires knowledge of the electric (E-) and magnetic (H-) field amplitudes and phases in the plane of incidence. Reconstruction of these quantities from pseudo-vector E-field measurements is feasible, as they are constrained by Maxwell's equations. The SPEAG have developed a reconstruction approach based on the Gerchberg-Saxton algorithm, which benefits from the availability of the E-field polarization ellipse information obtained with the EUmmWV2 probe. This reconstruction algorithm, together with the ability of the probe to measure extremely close to the source without perturbing the field, permits reconstruction of the E- and H-fields, as well as of the power density, on measurement planes located as near as λ / 5 away.

4.4.3 Power Flux Density Averaging

The average of the reconstructed power density is evaluated over a circular area in each measurement plane. The area of the circle is defined by the user; the default is 1 cm2. The computed peak average value is displayed in the box at the top right. Note that the average is evaluated only for grid points where the averaging circle is completely filled with values; for points at the edge where the averaging circle is only partly filled with values, the average power density is set to zero. Two average power density values are computed:

1) |Re(S)| is the average total power density.
2) ň· Re(S) is the average incident power density.

5. SAR Measurement Evaluation

5.1 EUT Configuration and Setting

<Considerations Related to WLAN for Setup and Testing>

In general, various vendor specific external test software and chipset based internal test modes are typically used for SAR measurement. These chipset-based test mode utilities are generally hardware and manufacturer dependent, and often include substantial flexibility to reconfigure or reprogram a device. A Wi-Fi device must be configured to transmit continuously at the required data rate, channel bandwidth and signal modulation, using the highest transmission duty factor supported by the test mode tools for SAR measurement. The test frequencies established using test mode must correspond to the actual channel frequencies. When 802.11 frame gaps are accounted for in the transmission, a maximum transmission duty factor of 92 - 96% is typically achievable in most test mode configurations. A minimum transmission duty factor of 85% is required to avoid certain hardware and device implementation issues related to wide range SAR scaling. In addition, a periodic transmission duty factor is required for current generation SAR systems to measure SAR correctly. The reported SAR must be scaled to 100% transmission duty factor to determine compliance at the maximum tune-up tolerance limit.

According to KDB 248227 D01, this device has installed WLAN engineering testing software which can provide continuous transmitting RF signal. During WLAN SAR testing, this device was operated to transmit continuously at the maximum transmission duty with specified transmission mode, operating frequency, lowest data rate, and maximum output power.

<Initial Test Configuration>

An initial test configuration is determined for OFDM transmission modes in 2.4 GHz and 5 GHz bands according to the channel bandwidth, modulation and data rate combination(s) with the highest maximum output power specified for production units in each standalone and aggregated frequency band. When the same maximum power is specified for multiple transmission modes in a frequency band, the largest channel bandwidth, lowest order modulation, lowest data rate and lowest order 802.11a/g/n/ac mode is used for SAR measurement, on the highest measured output power channel in the initial test configuration, for each frequency band.

<Subsequent Test Configuration>

SAR measurement requirements for the remaining 802.11 transmission mode configurations that have not been tested in the initial test configuration are determined separately for each standalone and aggregated frequency band, in each exposure condition, according to the maximum output power specified for production units. Additional power measurements may be required to determine if SAR measurements are required for subsequent highest output power channels in a subsequent test configuration. When the highest reported SAR for the initial test configuration according to the initial test position or fixed exposure position requirements, is adjusted by the ratio of the subsequent test configuration to initial test configuration specified maximum output power and the adjusted SAR is ≤ 1.2 W/kg, SAR is not required for that subsequent test configuration.

<SAR Test Configuration and Channel Selection>

When multiple channel bandwidth configurations in a frequency band have the same specified maximum output power, the initial test configuration is using largest channel bandwidth, lowest order modulation, lowest data rate, and lowest order 802.11 mode (i.e., 802.11a is chosen over 802.11n then 802.11ac or 802.11g is chosen over 802.11n).After an initial test configuration is determined, if multiple test channels have the same measured maximum output power, the channel chosen for SAR measurement is determined according to the following.

1) The channel closest to mid-band frequency is selected for SAR measurement.
2) For channels with equal separation from mid-band frequency; for example, high and low channels or two mid-band channels, the higher frequency (number) channel is selected for SAR measurement.

<Test Reduction for U-NII-1 (5.2 GHz) and U-NII-2A (5.3 GHz) Bands>

For devices that operate in both U-NII bands using the same transmitter and antenna(s), SAR test reduction is determined according to the following.

1) When the same maximum output power is specified for both bands, begin SAR measurement in U-NII-2A band by applying the OFDM SAR requirements. If the highest reported SAR for a test configuration is ≤ 1.2 W/kg, SAR is not required for U-NII-1 band for that configuration (802.11 mode and exposure condition).
2) When different maximum output power is specified for the bands, begin SAR measurement in the band with higher specified maximum output power. The highest reported SAR for the tested configuration is adjusted by the ratio of lower to higher specified maximum output power for the two bands. When the adjusted SAR is ≤ 1.2 W/kg, SAR is not required for the band with lower maximum output power in that test configuration.

<Considerations Related to Bluetooth for Setup and Testing>

This device has installed Bluetooth engineering testing software which can provide continuous transmitting RF signal.
During Bluetooth SAR testing, this device was operated to transmit continuously at the maximum transmission duty with specified transmission mode, operating frequency, lowest data rate, and maximum output power.
The Bluetooth call box has been used during SAR measurement and the EUT was set to DH5 mode at the maximum output power. Its duty factor was calculated as below, and the measured SAR for Bluetooth would be scaled to the 100% transmission duty factor to determine compliance. The duty factor of Bluetooth signal please refer to Appendix K

5.2 EUT Testing Position

According to technical standards, handsets are tested for SAR compliance in head and body-worn accessory described in the following subsections.

5.2.1 Body – Worn Accessory Exposure Conditions

For laptop PC, according to KDB 616217 D04, SAR evaluation is required for the bottom surface of the keyboard. This EUT was tested in the base of EUT directly against the flat phantom. The required minimum test separation distance for incorporating transmitters and antennas into laptop computer display is determined with the display screen opened at an angle of 90° to the keyboard compartment.

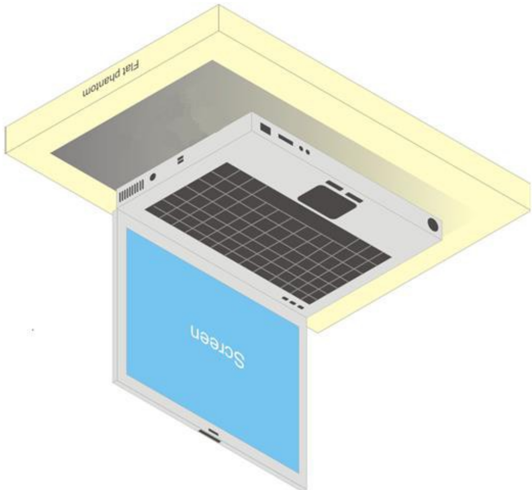


Fig-5.1 Illustration for Laptop Setup

5.3 Tissue Verification

Refer to **Appendix C.**

5.4 System Validation

Refer to **Appendix C.**

5.5 System Verification

Refer to **Appendix C.**

5.6 Maximum Output Power

5.6.1 Maximum Target Power Conducted Power

Refer to **Appendix D.**

5.6.2 Measured Conducted Power Result

Refer to **Appendix E.**

5.7 SAR Testing Results

5.7.1 SAR Test Reduction Considerations

<KDB 447498 D01, General RF Exposure Guidance>

Testing of other required channels within the operating mode of a frequency band is not required when the reported SAR for the mid-band or highest output power channel is:

(1) ≤ 0.8 W/kg or 2.0 W/kg, for 1-g or 10-g respectively, when the transmission band is ≤ 100 MHz
(2) ≤ 0.6 W/kg or 1.5 W/kg, for 1-g or 10-g respectively, when the transmission band is between 100 MHz and 200 MHz
(3) ≤ 0.4 W/kg or 1.0 W/kg, for 1-g or 10-g respectively, when the transmission band is ≥ 200 MHz

When SAR is not measured at the maximum power level allowed for production units, the measured SAR will be scaled to the maximum tune-up tolerance limit to determine compliance. The scaling factor for the tune-up power is defined as maximum tune-up limit (mW) / measured conducted power (mW). The reported SAR would be calculated by measured SAR x tune-up power scaling factor.

The SAR has been measured with highest transmission duty factor supported by the test mode tools for WLAN and/or Bluetooth. When the transmission duty factor could not achieve 100%, the reported SAR will be scaled to 100% transmission duty factor to determine compliance at the maximum tune-up power. The scaling factor for the duty factor is defined as 100% / transmission duty cycle (%). The reported SAR would be calculated by measured SAR x tune-up power scaling factor x duty cycle scaling factor.

<KDB 248227 D01, SAR Guidance for Wi-Fi Transmitters>

(1) For handsets operating next to ear, hotspot mode or mini-tablet configurations, the initial test position procedures were applied. The test position with the highest extrapolated peak SAR will be used as the initial test position. When the reported SAR of initial test position is <= 0.4 W/kg, SAR testing for remaining test positions is not required. Otherwise, SAR is evaluated at the subsequent highest peak SAR positions until the reported SAR result is <= 0.8 W/kg or all test positions are measured.

(2) For WLAN 2.4 GHz, the highest measured maximum output power channel for DSSS was selected for SAR measurement. When the reported SAR is <= 0.8 W/kg, no further SAR testing is required. Otherwise, SAR is evaluated at the next highest measured output power channel. When any reported SAR is >1.2 W/kg, SAR is required for the third channel. For OFDM modes (802.11g/n), SAR is not required when the highest reported SAR for DSSS is adjusted by the ratio of OFDM to DSSS specified maximum output power and it is <= 1.2 W/kg.

(3) For WLAN 5GHz, the initial test configuration was selected according to the transmission mode with the highest maximum output power. When the reported SAR of initial test configuration is > 0.8 W/kg, SAR is required for the subsequent highest measured output power channel until the reported SAR result is <=1.2 W/kg or all required channels are measured. For other transmission modes, SAR is not required when the highest reported SAR for initial test configuration is adjusted by the ratio of subsequent test configuration to initial test configuration specified maximum output power and it is <= 1.2 W/kg.

(4) For WLAN MIMO mode, the power-based standalone SAR test exclusion or the sum of SAR provision in KDB 447498 to determine simultaneous transmission SAR test exclusion should be applied. Otherwise, SAR for MIMO mode will be measured with all applicable antennas transmitting simultaneously at the specified maximum output power of MIMO operation.

5.7.2 SAR and APD Results for Body Exposure Condition

Refer to **Appendix F**

5.7.3 Power Density Test Result for Body Exposure Condition

Refer to **Appendix F**

5.7.4 SAR Measurement Variability

<SAR Summation Analysis>

According to KDB 865664 D01, SAR measurement variability was assessed for each frequency band, which is determined by the SAR probe calibration point and tissue-equivalent medium used for the device measurements. When both head and body tissue-equivalent media are required for SAR measurements in a frequency band, the variability measurement procedures should be applied to the tissue medium with the highest measured SAR, using the highest measured SAR configuration for that tissue-equivalent medium. Alternatively, if the highest measured SAR for both head and body tissue-equivalent media are ≤ 1.45 W/kg and the ratio of these highest SAR values, i.e., largest divided by smallest value, is ≤ 1.10, the highest SAR configuration for either head or body tissue-equivalent medium maybe used to perform the repeated measurement. These additional measurements are repeated after the completion of all measurements requiring the same head or body tissue-equivalent medium in a frequency band. The test device should be returned to ambient conditions (normal room temperature) with the battery fully charged before it is re-mounted on the device holder for the repeated measurement(s) to minimize any unexpected variations in the repeated results.

<SAR repeated measurement procedure:>

1. When the highest measured SAR is < 0.80 W/kg, repeated measurement is not required.
2. When the highest measured SAR is >= 0.80 W/kg, repeat that measurement once.
3. If the ratio of largest to smallest SAR for the original and first repeated measurements is > 1.20, or when the original or repeated measurement is >= 1.45 W/kg, perform a second repeated measurement.
4. If the ratio of largest to smallest SAR for the original, first and second repeated measurements is > 1.20, and the original, first or second repeated measurement is >= 1.5 W/kg, perform a third repeated measurement.

The SAR repeated measurement refer to **Appendix G.**

<Simultaneous Multi-band Transmission Evaluation>

Simultaneous transmission SAR test exclusion is determined for each operating configuration and exposure condition according to the reported standalone SAR of each applicable simultaneous transmitting antenna. When the sum of SAR_{1g} of all simultaneously transmitting antennas in an operating mode and exposure condition combination is within the SAR limit(SAR_{1g} 1.6 W/kg), the simultaneous transmission SAR is not required. When the sum of SAR_{1g} is greater than the SAR limit (SAR_{1g} 1.6 W/kg), SAR test exclusion is determined by the SPLSR.
The Simultaneous transmission SAR analysis for this device, refer to **Appendix H**

5.7.5 SAR to Peak Location Separation Ratio Analysis

The simultaneous transmitting antennas in each operating mode and exposure condition combination are considered one pair at a time to determine the SPLSR. When SAR is measured for both antennas in the pair, the peak location separation distance is computed by the following formula.

$$\text{Peak Location Separation Distance} = \sqrt{(x_1 - x_2)^2 + (y_1 - y_2)^2 + (z_1 - z_2)^2}$$

Where (x_1, y_1, z_1) and (x_2, y_2, z_2) are the coordinates of the extrapolated peak SAR locations in the area or zoom scans.
When standalone test exclusion applies, SAR is estimated; the peak location is assumed to be at the feed-point or geometric center of the antenna. Due to curvatures on the SAM phantom, when SAR is estimated for one of the antennas in an antenna pair, the measured peak SAR location will be translated onto the test device to determine the peak location separation for the antenna pair.
The SPLSR is determined by the following formula.

$$\text{SPLSR} = \frac{(\text{SAR}_1 + \text{SAR}_2)^{1.5}}{\text{R}_i}$$

Where SAR_1 and SAR_2 are the highest reported or estimated SAR for each antenna in the pair, and R_i is the separation distance between the peak SAR locations for the antenna pair in mm.
When the SPLSR is <= 0.04, the simultaneous transmission SAR is not required. Otherwise, the enlarged zoom scan and volume scan post-processing procedures will be performed.
The SPLSR analysis for this device, refer to **Appendix I.**

5.7.6 Total Exposure Ratio Analysis

The fields generated by the antennas can be correlated or uncorrelated. At different frequencies, fields are always uncorrelated, and the aggregate power density contributions can be summed according to spatially averaged values of corresponding sources at any point in space, r, to determine the total exposure ratio (TER). Assuming I sources, the TER at each point in space is equal to

$$\mathrm{TER}^{\mathrm{uncorr}}(\mathrm{r}) = \sum_{i=1}^{I} \mathrm{ER}_i = \sum_{i=1}^{I} \frac{S_{av,i}(r, f_i)}{S_{lim}(f_i)}$$

where Sav,i is the power density for the source i operating at a frequency fi, and Slim is the power density limit as specified by the relevant standard.

Exposure from transmitters operating above and below 6 GHz, where 6 GHz denotes the transition frequency where the basic restrictions change from being defined in terms of SAR to being defined in terms of power density, are therefore uncorrelated and the TER is determined as

$$\mathrm{TER}^{\mathrm{uncorr}}(\mathrm{r}) = \mathrm{TER}(\mathrm{r})_{f \le 6\mathrm{GHz}} + \mathrm{TER}(\mathrm{r})_{f > 6GHz}$$

According to the FCC guidance in Oct. 2022 TCB workshop and IEC TR 63170, the total exposure ratio calculated by taking ratio of maximum reported SAR divided by SAR limit and adding it to maximum measured power density divided by power density limit. Numerical sum of the ratios should be less than 1.

Refer to **Appendix J.**

Test Engineer： Jungho Lee

6. Calibration of Test Equipment

Equipment	Manufacturer	Model	SN	Cal. Date	Cal. Interval
Amplifier (AMP2027ADB / SN 10007)	EAC	AMP2027ADB	10007	03 Mar, 2023	1Y
3.5mm Standard Calibration Kit	Agilent	85033E	MY39204943	07 Mar, 2023	1Y
Wireless communication system test set	Agilent	E5515C	MY53201107	21 Jun, 2023	1Y
Radio communaction analyzer	Anritsu	MT8820C	6201300614	01 Jun, 2023	1Y
EXA Signal Analyzer	Agilent	N9010A	MY53400225	01 Jun, 2023	1Y
Power Meter (ML2495A / SN 1337003)	Anritsu	ML2495A	1337003	21 Jun, 2023	1Y
Power Meter (ML2411B / SN 1306054)	Anritsu	MA2411B	1306054	21 Jun, 2023	1Y
DC Power Supply (DP30-03A / SN 13050033)	Toyotech	DP30-03A	13050033	01 Jun, 2023	1Y
Data Acquisition Electronic (SN 1397)	SPEAG	DAE4	1397	26 Apr, 2023	1Y
Dipole Antenna (D2450V2 / SN 716)	SPEAG	D2450V2	716	24 May, 2023	2Y
Dipole Antenna (D5GHzV2 / SN 1018)	SPEAG	D5GHzV2	1018	25 Nov, 2022	2Y
Attenuator(10 dB)	Weinschel	3M-10	25847	01 Jun, 2023	1Y
Attenuator(10 dB)	Weinschel	3M-10	25699	01 Jun, 2023	1Y
Attenuator(3 dB)	Woken Technology Unc.	WATT-518FS-03	WATT-518FS-03-1	01 Jun, 2023	1Y
Power Meter (ML2496A/ SN 1430004)	Anritsu	ML2496A	1430004	21 Jun, 2023	1Y
Power Sensor (MA2411B / SN 1339169)	Anritsu	MA2411B	1339169	03 Mar, 2023	1Y
Directional Coupler (778D / SN MY52180426)	Agilent(KEYSIGHT)	778D	MY52180426	02 Jun, 2023	1Y
Directional Coupler (772D / SN MY52180195)	Agilent(KEYSIGHT)	772D	MY52180195	02 Jun, 2023	1Y
Probe (EX3DV4 / 7300 / Freq 6500)	SPEAG	EX3DV4	7300	25 May, 2023	1Y
Dielectric Assessment Kit	SPEAG	DAK3.5	1133	20 Feb, 2023	1Y
Signal Generator	Aid-Tech	E8257D	MY44321099	03 Feb, 2023	1Y
Low Pass Filter (VLF-8400+ / SN 15542)	Aid-Tech	VLF-8400+	15542	19 Apr, 2023	1Y
Thermometer	LUTRON	HT-3007SD	52871	12 Oct, 2023	1Y
Thermometer	LUTRON	HT-3007SD	58287	12 Oct, 2023	1Y
Dipole Antenna (D6.5GHzV2 / SN 1035)	SPEAG	D6.5GHzV2	1035	27 May, 2022	2Y
Amplifier (BPA01T72W2T / SN S3008-0001)	L2Microwave	BPA01T72W2T	S3008-0001	22 Nov, 2022	1Y
Low Pass Filter (VLF-1500+ / SN 32136)	Mini-Circuits	VLF-1500+	32136	22 Nov, 2022	1Y
Low Pass Filter (VLF-3000+ / SN 32226)	Mini-Circuits	VLF-3000+	32226	22 Nov, 2022	1Y
Low Pass Filter (VLF-6000+ / SN 32044)	Mini-Circuits	VLF-6000+	32044	22 Nov, 2022	1Y
Power Sensor (8487A / SN 3318A03540)	AGILENT	8487A	3318A03540	17 Aug, 2023	1Y

Data Acquisition Electronic (SN 1748)	SPEAG	DAE4	1748	07 Jul, 2023	1Y
System Verification Antenna (10GHz)	SPEAG	5G Verification Source 10GHz	1057	11 Jul, 2023	1Y
Isotropic E-field probe for 5G Evaluation	SPEAG	EUmmWVx	9671	05 Jul, 2023	1Y
Probe (EX3DV4 / 7762 / Freq 6500)	SPEAG	EX3DV4	7762	13 Jul, 2023	1Y
ENA Network Analyzer	Agilent	E5071C	MY46212858	10 Oct, 2023	1Y

7. Measurement Uncertainty

Source of Uncertainty	Uncertainty (± %)	Probability Distribution	Divisor	Ci (1g)	Ci (10g)	Standard Uncertainty (± %, 1g)	Standard Uncertainty (± %, 10g)	Vi
Measurement System								
Probe calibration	6	N	1	1	1	6.0	6.0	∞
Axial isotropy	4.7	R	√3	1	1	1.9	1.9	∞
Hemispherical isotropy	9.6	R	√3	1	1	3.9	3.9	∞
Linearity	1.0	R	√3	1	1	0.6	0.6	∞
Probe modulation response	4.7	R	√3	1	1	2.7	2.7	∞
Detection limits	0.25	R	√3	1	1	0.1	0.1	∞
Boundary effect	2.4	R	√3	1	1	1.4	1.4	∞
Readout electronics	0.3	N	1	1	1	0.3	0.3	∞
Response time	0.0	R	√3	1	1	0.0	0.0	∞
Integration time	2.6	R	√3	1	1	1.5	1.5	∞
RF ambient conditions – noise	3.0	R	√3	1	1	1.7	1.7	∞
RF ambient conditions – reflections	3.0	R	√3	1	1	1.7	1.7	∞
Probe positioner mech. restrictions	0.4	R	√3	1	1	0.2	0.2	∞
Probe positioning with respect to phantom shell	2.9	R	√3	1	1	1.7	1.7	∞
Post-processing	2.0	R	√3	1	1	1.2	1.2	∞
Test Sample Related								
Device holder uncertainty	1.9 / 3.2	N	1	1	1	1.9	3.2	13
Test sample positioning	0.97 / 0.41	N	1	1	1	1.0	0.4	29
Power scaling	0.0	R	√3	1	1	0.0	0.0	∞
Drift of output power (measured SAR drift)	5.0	R	√3	1	1	2.9	2.9	∞
Phantom and Setup								
Phantom Uncertainty (Shape and Thickness Tolerances)	7.6	R	√3	1	1	4.4	4.4	∞
Uncertainty in SAR correction for deviations in permittivity and conductivity	1.9	N	1	1	0.84	1.9	1.6	∞
Liquid conductivity (meas.)	2.08	N	1	0.78	0.71	1.6	1.5	4
Liquid permittivity (meas.)	1.55	N	1	0.23	0.26	0.4	0.4	4
Liquid permittivity - temperature uncertainty	1.27	R	√3	0.78	0.71	0.6	0.5	∞
Liquid conductivity - temperature uncertainty	1.41	R	√3	0.23	0.26	0.2	0.2	∞
Combined Standard Uncertainty						± 10.8 %	± 11.0 %	
Expanded Uncertainty (K=2)						**± 21.5 %**	**± 21.9 %**	

SAR Body Measurement Uncertainty Budget (3GHz Below)

Source of Uncertainty	Uncertainty (± %)	Probability Distribution	Divisor	Ci (1g)	Ci (10g)	Standard Uncertainty (± %, 1g)	Standard Uncertainty (± %, 10g)	Vi
Measurement System								
Probe calibration	6.55	N	1	1	1	6.6	6.6	∞
Axial isotropy	4.7	R	√3	1	1	1.9	1.9	∞
Hemispherical isotropy	9.6	R	√3	1	1	3.9	3.9	∞
Linearity	4.7	R	√3	1	1	2.7	2.7	∞
Probe modulation response	9.4	R	√3	1	1	5.4	5.4	∞
Detection limits	0.25	R	√3	1	1	0.1	0.1	∞
Boundary effect	2	R	√3	1	1	1.2	1.2	∞
Readout electronics	0.3	N	1	1	1	0.3	0.3	∞
Response time	0	R	√3	1	1	0.0	0.0	∞
Integration time	2.6	R	√3	1	1	1.5	1.5	∞
RF ambient conditions – noise	3	R	√3	1	1	1.7	1.7	∞
RF ambient conditions – reflections	3	R	√3	1	1	1.7	1.7	∞
Probe positioner mech. restrictions	0.4	R	√3	1	1	0.2	0.2	∞
Probe positioning with respect to phantom shell	6.7	R	√3	1	1	3.9	3.9	∞
Post-processing	4	R	√3	1	1	2.3	2.3	∞
Test Sample Related								
Device holder uncertainty	2.4 / 3.4	N	1	1	1	2.4	3.4	23
Test sample positioning	1.3 / 0.45	N	1	1	1	3.7	1.8	39
Power scaling	0.0	R	√3	1	1	0.0	0.0	∞
Drift of output power (measured SAR drift)	5.0	R	√3	1	1	2.9	2.9	∞
Phantom and Setup								
Phantom Uncertainty (Shape and Thickness Tolerances)	7.6	R	√3	1	1	4.4	4.4	∞
Uncertainty in SAR correction for deviations in permittivity and conductivity	1.9	N	1	1	0.84	1.9	1.6	∞
Liquid conductivity (meas.)	2.08	N	1	0.78	0.71	1.6	1.5	4
Liquid permittivity (meas.)	1.58	N	1	0.23	0.26	0.4	0.4	4
Liquid permittivity - temperature uncertainty	1.27	R	√3	0.78	0.71	0.6	0.5	∞
Liquid conductivity - temperature uncertainty	1.41	R	√3	0.23	0.26	0.2	0.2	∞
Combined Standard Uncertainty						± 12.0 %	± 12.1 %	
Expanded Uncertainty (K=2)						**± 23.9 %**	**± 24.2 %**	

SAR Body Measurement Uncertainty Budget (3GHz Upper)

Source of Uncertainty	Uncertainty (± dB)	Probability Distibution	Divisor	C_i	Standard Uncertainty (± dB)	V_i
Measurement System						
Probe Calibration	0.49	Normal	1	1	0.49	∞
Probe Correction	0.00	Rectangular	√3	1	0.00	∞
Frequency response	0.2	Rectangular	√3	1	0.12	∞
Sensor cross coupling	0.00	Rectangular	√3	1	0.00	∞
Isotropy	0.5	Rectangular	√3	1	0.29	∞
Linearity	0.20	Rectangular	√3	1	0.12	∞
Probe scattering	0.00	Rectangular	√3	1	0.00	∞
Probe positioning offset	0.30	Rectangular	√3	1	0.17	∞
Probe positioning repeatability	0.04	Rectangular	√3	1	0.02	∞
Sensor mechanical offset	0.00	Rectangular	√3	1	0.00	∞
Probe spatial resolution	0.00	Rectangular	√3	1	0.00	∞
Field impedance dependence	0.00	Rectangular	√3	1	0.00	∞
Amplitude and phase drift	0.00	Rectangular	√3	1	0.00	∞
Amplitude and phase noise	0.04	Rectangular	√3	1	0.02	∞
Measurement area truncation	0.00	Rectangular	√3	1	0.00	∞
Data acquisition	0.03	Normal	1	1	0.03	∞
Sampling	0.00	Rectangular	√3	1	0.00	∞
Field reconstruction	2	Rectangular	√3	1	1.15	∞
Field Transformation (FTE/MEO)	0.00	Rectangular	√3	1	0.00	∞
Power density scaling	0	Rectangular	√3	1	0.00	∞
Spatial averaging	0.10	Rectangular	√3	1	0.06	∞
System detection limit	0.04	Rectangular	√3	1	0.02	∞
DUT and enviromental factors						
Probe coupling with DUT	0.00	Rectangular	√3	1	0.00	∞
Modulation response	0.40	Rectangular	√3	1	0.23	∞
Intergration time	0.00	Rectangular	√3	1	0.00	∞
Response time	0.00	Rectangular	√3	1	0.00	∞
Device holder influence	0.10	Rectangular	√3	1	0.06	∞
DUT alignment	0.00	Rectangular	√3	1	0.00	∞
RF ambient conditions	0.04	Rectangular	√3	1	0.02	∞
Ambient reflections	0.04	Rectangular	√3	1	0.02	∞
Immunity / secondary reception	0.00	Rectangular	√3	1	0.00	∞
Drift of the DUT	0.21	Rectangular	√3	1	0.12	∞
Combined Standard Uncertainty					1.34	∞
Expanded Uncertainty (k=2)					2.68	

SAR PD Measurement Uncertainty Budget

8. Information on the Testing Laboratories

We, Bureau Veritas Consumer Products Services ADT Korea Ltd. Mobile Communications Laboratory were founded in 1988 to provide our best service in EMC, Radio, Telecom and Safety consultation. Our laboratories are accredited and approved according to ISO/IEC 17025.

FCC

Designation Number : KR0158
Test Firm Registration Number : 666061

If you have any comments, please feel free to contact us at the following:

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The address and road map of all our labs can be found in our web site also.

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