



RF EXPOSURE EVALUATION REPORT

APPLICANT : Reliance Communications LLC
PRODUCT NAME : Orbic AirSurf 5G UW
MODEL NAME : R141TL5
BRAND NAME : Orbic
FCC ID : 2ABGH-R141TL5
STANDARD(S) : FCC 47 CFR Part 2(2.1093)
RECEIPT DATE : 2021-10-09
TEST DATE : 2021-11-08 to 2021-11-12
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Changed History		
Version	Date	Reason for Change
1.0	2021-12-30	First edition



1. Power Density Summary

The maximum results of power density found during test as bellows:

<Highest Total Power Density>

Frequency Band		Standalone Transmission	
		Total PD over 4cm ² (mW/cm ²)	Limit (FCC Part 1.310) (mW/cm ²)
5G NR	n260	0.141	1.0
	n261	0.282	

Highest Simultaneous Transmission with Multiple transmitters	Total Exposure Radio
SAR & Power Density	0.899

Note:

1. This device is in compliance with power density for general population or uncontrolled exposure limits (1.0 mW/cm² specified in FCC 47 CFR part 1.310), and had been tested in accordance with the measurement methods and procedures specified in TCBC workshop notes and IEC TR 63170.
2. When the test result is a critical value, we will use the measurement uncertainty give the judgment result based on the 95% confidence intervals.



2. Technical Information

Note: Provide by applicant.

2.1. Applicant and Manufacturer Information

Applicant:	Reliance Communications LLC
Applicant Address:	91 Colin Drive, Unit 1, HOLBROOK, New York 11741, United States
Manufacturer:	Unimaxcomm
Manufacturer Address:	35F,HBC HuiLong Center Building-II Minzhi Street,Longhua, Shenzhen, P.R. China 518110

2.2. Equipment under Test (EUT) Description

Product Name:	Orbic AirSurf 5G UW
EUT No.:	6#
Hardware Version:	R141-REV12
Software Version:	ORB141TL5_V1.1.9_SVZ
Frequency Bands:	5G NR n260(120kHz): 37 GHz ~ 40 GHz 5G NR n261(120kHz): 27.5 GHz ~ 28.35 GHz
Modulation Mode:	5G NR: QPSK, 16QAM, 64QAM for CP-OFDM and DFT-s-OFDM
Channel Bandwidth:	50MHz, 100MHz
Maximum Number of Contiguous Component Carriers:	8CC
SCS	120kHz
5G NR Operation:	NSA
Antenna Information:	Fixed Internal Antenna

Note: For a more detailed description, please refer to specification or user manual supplied by the applicant and/or manufacturer.



2.3. Environment of Test Site/Conditions

Normal Temperature (NT):	20-25 °C
Relative Humidity:	30-75 %
Air Pressure:	980-1020 hPa

Test Frequency:	5G NR n260/261
Operation Mode:	Call established
Power Level:	TDD 5G NR n260/261 (Maximum output power)

During SAR test, EUT is in Traffic Mode (Channel Allocated) at Normal Voltage Condition. A communication link is set up with a System Simulator (SS) by air link, and a call is established.

The EUT shall use its internal transmitter. The antenna(s), battery and accessories shall be those specified by the Factory. The EUT battery must be fully charged and checked periodically during the test to ascertain uniform power output. If a wireless link is used, the antenna connected to the output of the base station simulator shall be placed at least 50 cm away from the handset.

The signal transmitted by the simulator to the antenna feeding point shall be lower than the output power level of the handset by at least 35 dB.



3. RF Exposure Limits

3.1. 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 Maximum Permissible Exposure (MPE)

Frequency range (MHz)	Electric field strength (V/m)	Magnetic field strength (A/m)	Power density (mW/cm ²)	Averaging time (minutes)
(A) Limits for Occupational/Controlled Exposures				
0.3-3.0	614	1.63	*(100)	6
3.0-30	1842/f	4.89/f	*(900/f ²)	6
30-300	61.4	0.163	1.0	6
300-1500			f/300	6
1500-100,000			5	6
(B) Limits for General Population/Uncontrolled Exposure				
0.3-1.34	614	1.63	*(100)	30
1.34-30	824/f	2.19/f	*(180/f ²)	30
30-300	27.5	0.073	0.2	30
300-1500			f/1500	30
1500-100,000			1.0	30

3.2. Controlled Environment

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

4. Applied Reference Documents

Leading reference documents for testing:

Identity	Document Title	Method Determination /Remark
FCC 47 CFR Part 2(2.1093)	Radio Frequency Radiation Exposure Evaluation: Portable Devices	No deviation
KDB 447498 D01v06	General RF Exposure Guidance	No deviation
KDB 616217 D04v01r02	SAR Evaluation Consideration for Laptop, Notebook, Netbook and Tablet computers	No deviation
KDB 648474 D04v01r03	SAR Evaluation Consideration for Wireless Handset	No deviation
KDB 865664 D01v01r04	SAR Measurement 100 MHz to 6 GHz	No deviation
KDB 865664 D02v01r02	RF Exposure Reporting	No deviation
KDB 941225 D06v02r01	SAR Evaluation procedure for portable devices with wireless router capabilities	No deviation
IEC TR 63170:2018	Measurement procedure for the evaluation of power density related to human exposure to radio frequency fields from wireless communication devices operating between 6 GHz and 100 GHz	No deviation
The November 2019, TCB Workshop presentation	RF Exposure Procedures	No deviation
<p>Note 1: The test item is not applicable.</p> <p>Note 2: Additions to, deviation, or exclusions from the method shall be judged in the "method determination" column of add, deviate or exclude from the specific method shall be explained in the "Remark" of the above table.</p>		

5. Power Density Measurement System

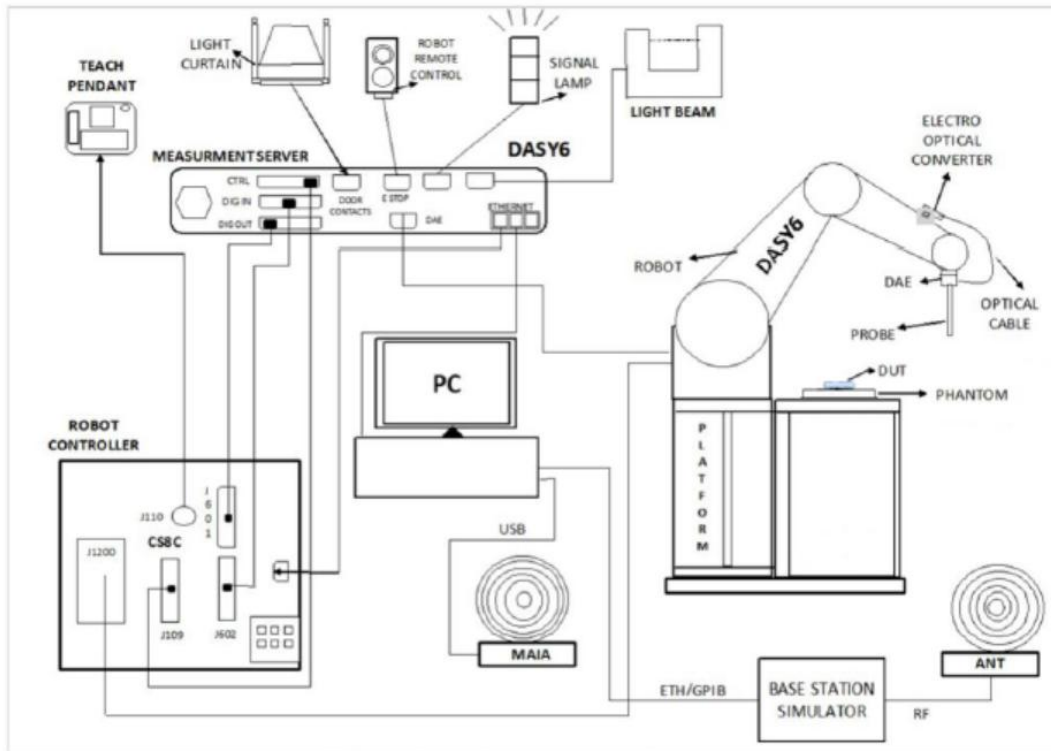


Fig 5.1 SPEAG DASY System Configurations

The DASY system for performance compliance tests is illustrated above graphically. This system consists of the following items:

- A standard high precision 6-axis robot with controller, a teach pendant and software.
- A data acquisition electronic (DAE) attached to the robot arm extension.
- A dosimetric probe equipped with an optical surface detector system.
- The electro-optical converter (ECO) performs the conversion between optical and electrical signals
- A measurement server performs the time critical tasks such as signal filtering, control of the robot operation and fast movement interrupts.
- A probe alignment unit which improves the accuracy of the probe positioning.
- A computer operating Windows XP.
- DASY software.
- Remote control with teach pendant and additional circuitry for robot safety such as warning lamps, etc.
- The SAM twin phantom.
- A device holder.
- Tissue simulating liquid.
- Dipole for evaluating the proper functioning of the system.
- Some of the components are described in details in the following sub-sections.

5.1. E UmmWave Probe

The probe designed allows measurement at distances as small as 2mm from the sensor to the surface of EUT. The typical sensor to the tip of probe is 1.5mm.

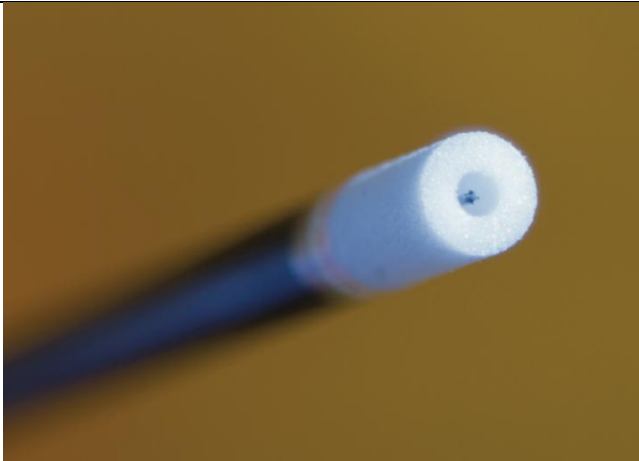
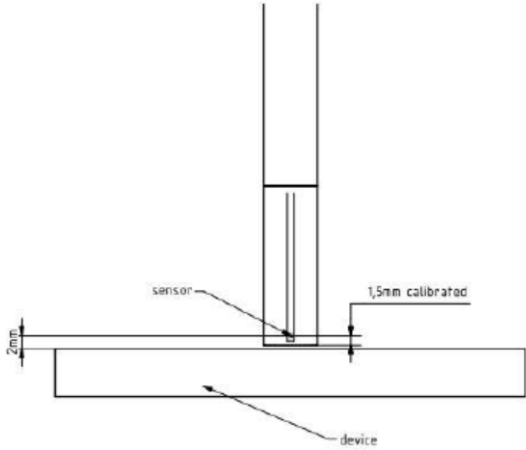
Frequency	750 MHz ~110 GHz
Probe Overall Length	320 mm
Probe Body Diameter	8.0 mm
Tip Length	23.0 mm
Tip Diameter	8.0 mm
Two dipoles' Length of Probe	0.9 mm – Diode located
Dynamic Range	<20 V/m – 10000 V/m with PRE-10 (min <50 V/m – 3000 V/m)
Linearity	<0.2 dB
Position Precision	<0.2 mm
Distance between Diode Sensors and Probe's tip	1.5 mm
Minimum Mechanical Separation between Probe Tip and a Surface	0.5 mm
Applications	E-field measurement of mm-Wave transmitters operating above 10 GHz in < 2mm distance from device (free-space) power density H-field and far-field analysis using total field reconstruction.
Compatibility	cDASY 6 + 5G Module SW1.0 and higher
	

Fig 5.2 Photo of E UmmWave Probe

5.2. Data Acquisition Electronics (DAE)

The data acquisition electronics (DAE) consists 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 and control logic unit. AD-converter and a command decoder and 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 input impedance of the DAE is 200M Ω ; the inputs are symmetrical and floating. Common mode rejection is above 80 dB.



Fig 5.3 Photo of DAE

5.3. Robot

The SPEAG DASY system uses the high precision robots (DASY4: RX90BL; DASY5: TX90XL) type from Stäubli SA (France). For the 6-axis controller system, the robot controller version (DASY4: CS7MB; DASY5: 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 5.4 Photo of DASY6

5.4. Measurement Server

The measurement server is based on a PC/104 CPU board with CPU (DASY4: 166 MHz, Intel Pentium; DASY5: 400 MHz, Intel Celeron), chip disk (DASY4: 32 MB; DASY5: 128 MB), RAM (DASY4: 64 MB, DASY5: 128 MB). 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 board, which is directly connected to the PC/104 bus of the CPU board.

The measurement server performs all the real-time data evaluation for field measurements and surface detection, controls robot movements and handles safety operations.



5.5. Data Storage and Evaluation

➤ Data Storage

The DASY software stores the assessed data from the data acquisition electronics as raw data (in microvolt readings from the probe sensors), together with all the necessary software parameters for the data evaluation (probe calibration data, liquid parameters and device frequency and modulation data) in measurement files. The post-processing 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 erroneous parameter settings. For example, if a measurement has been performed with an incorrect crest factor parameter in the device setup, the parameter can be corrected afterwards and the data can be reevaluated.

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

➤ Data Evaluation

The DASY post-processing software (SEMCAD) 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	dcpi
Device parameters:	- Frequency	f
	- Crest factor	cf
Media parameters:	- Conductivity	σ
	- Density	ρ

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 DASY components. In the direct measuring mode of the multi-meter 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:

$$V_i = U_i + U_i^2 \times \frac{cf}{dcp_i}$$

With V_i = compensated signal of channel i , ($i = x, y, z$)
 U_i = input signal of channel i , ($i = x, y, z$)
 cf = crest factor of exciting field (DASY parameter)
 dcp_i = diode compression point (DASY parameter)

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

$$\text{E-field Probes: } E_i = \sqrt{\frac{V_i}{\text{Norm}_i \times \text{ConvF}}}$$

$$\text{H-field Probes: } H_i = \sqrt{V_i} \times \frac{a_{i0} + a_{i1} + a_{i2}f^2}{f}$$

With V_i = compensated signal of channel i , ($i = x, y, z$)
 Norm_i = sensor sensitivity of channel i , ($i = x, y, z$), $\mu\text{V}/(\text{V/m})^2$ for E-field Probes
 ConvF = sensitivity enhancement in solution
 a_{ij} = sensor sensitivity factors for H-field probes
 f = carrier frequency [GHz]
 E_i = electric field strength of channel i in V/m
 H_i = magnetic field strength of channel i in A/m

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

$$E_{\text{tot}} = \sqrt{E_x^2 + E_y^2 + E_z^2}$$

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

$$\text{SAR} = E_{\text{tot}}^2 \times \frac{\sigma}{\rho \times 1000}$$

with SAR = local specific absorption rate in mW/g

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

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

ρ = equivalent tissue density in g/cm^3

Note that the density is set to 1, to account for actual head tissue density rather than the density of the tissue simulating liquid.



5.6. Test Equipment List

Manufacturer	Name of Equipment	Type/Model	Serial Number	Calibration	
				Last Cal.	Due Date
SPEAG	DOSIMETRIC ASSESSMENT SYSTEM	cDASY6 mmWave	V2.0.2.34	N/A	N/A
SPEAG	5G Verification Source	30GHz	1077	2020.12.02	2023.12.01
SPEAG	EUmmWave Probe	EUmmMV4	9512	2020.12.02	2021.12.01
SPEAG	Data Acquisition Electronics	DAE4	1643	2020.11.30	2021.11.29
R&S	Spectrum Analyzer	E4445A	MY44300685	2021.10.20	2022.10.19
KTJ	Thermo meter	TA298	N/A	2021.01.15	2022.01.14

Note:

The calibration certificate of DASY can be referred to annex E of this report.

6. System Verification Source

The system verification sources at 30GHz and above comprise born-antennas and very stable signal generators.

Model	Ka-band born antenna
Calibrated Frequency	30GHz and above at 10mm from the case surface
Frequency Accuracy	± 100 MHz
E-field Polarization	Linear
Harmonics	-20dBc
Total Radio Power	14dBm
Power Stability	0.05 dB
Power Consumption	5W
Size	100 x 100 x 100 mm
Weight	1 kg

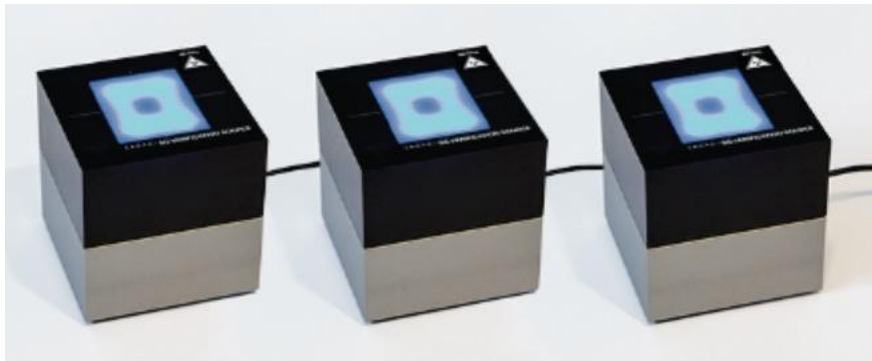


Fig 6.1 Photos of Verification Sources

7. Power Density System Verification

➤ General description

The EUT is replaced by a calibrated source, the same spatial resolution, measurement region and test separation used in the calibration was applied to system check. Through visual inspection into the measured power density distribution, both the spatially (shape) and numerically (level) have no noticeable difference. The measurement results should be within $\pm 10\%$ of the calibrated targets.

Frequency [GHz]	Grid step	Grid extent X/Y [mm]	Measurement points
10	$0.25 \left(\frac{\lambda}{4}\right)$	120/120	16×16
30	$0.25 \left(\frac{\lambda}{4}\right)$	60/60	24×24
60	$0.25 \left(\frac{\lambda}{4}\right)$	32.5/32.5	26×26
90	$0.25 \left(\frac{\lambda}{4}\right)$	30/30	36×36

Setting for measurement of verification sources

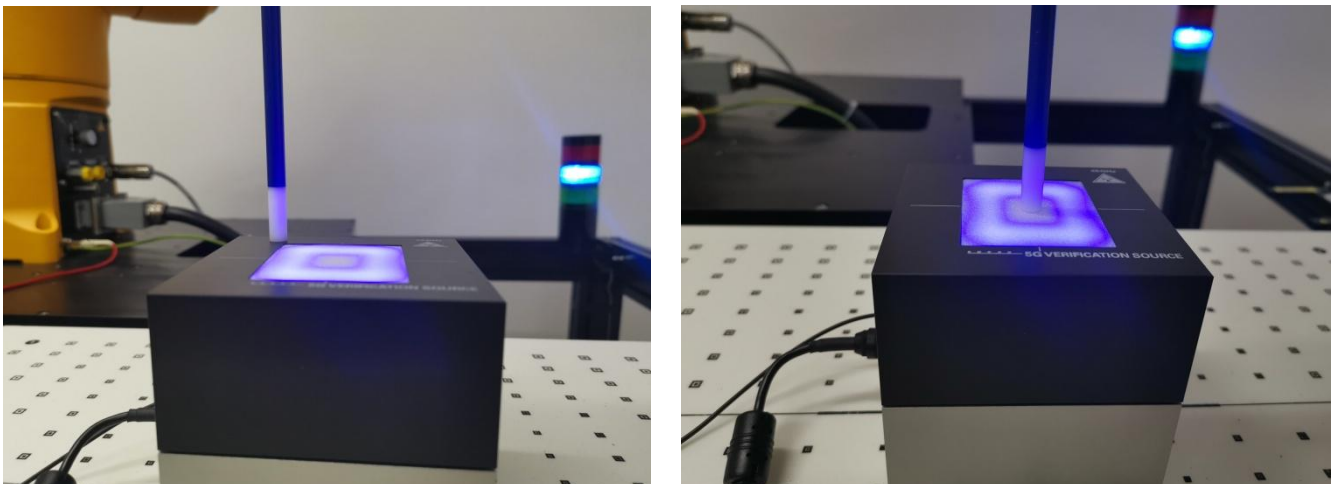


Fig 7.1 Photos of Verification Setup

➤ Validation Results

After system check testing, the results of power density will be compared with the reference value derived from the certificate report. The deviation of system check should be within $\pm 10\%$.

<Validation Setup>

Frequency (GHz)	5G Verification Source	Probe S/N	DAE S/N
30	30GHz-SN 1077	9512	1643

<Validation Results>

Date	Frequency (GHz)	Test Distance (mm)	Measured 4cm ² (W/m ²)	Targeted 4cm ² (W/m ²)	Deviation (%)
2021.11.08	30	5.55	27.6	28.0	-2.8

Note: System checks the specific test data please refer to Annex C.

➤ 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.

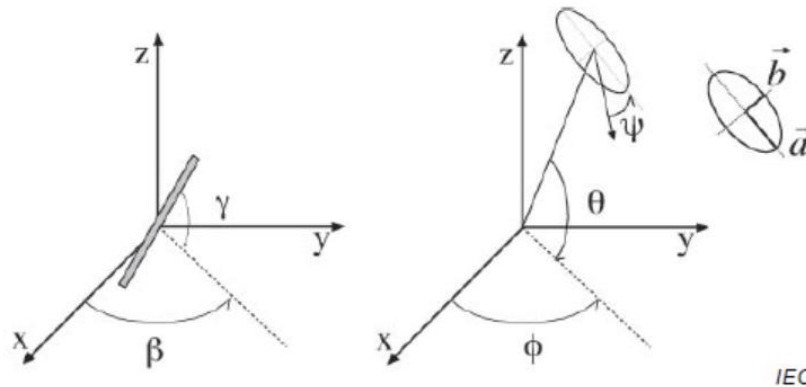


Fig 9.1 Illustration of the angles used for the numerical description of the sensor and the orientation of an ellipse in 3-D space

For the construction 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 three 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 ellipse parameters.

However, to suppress the noise and increase the reconstruction accuracy, it is desirable to have an over-determined system of equations. The solution is to 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-determination of two. If there is a need for more information or increased accuracy, more rotation angles can be added.

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



➤ Total Field and Power Density Reconstruction

Computation of the power density in general requires knowledge of the electric and magnetic 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. 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.

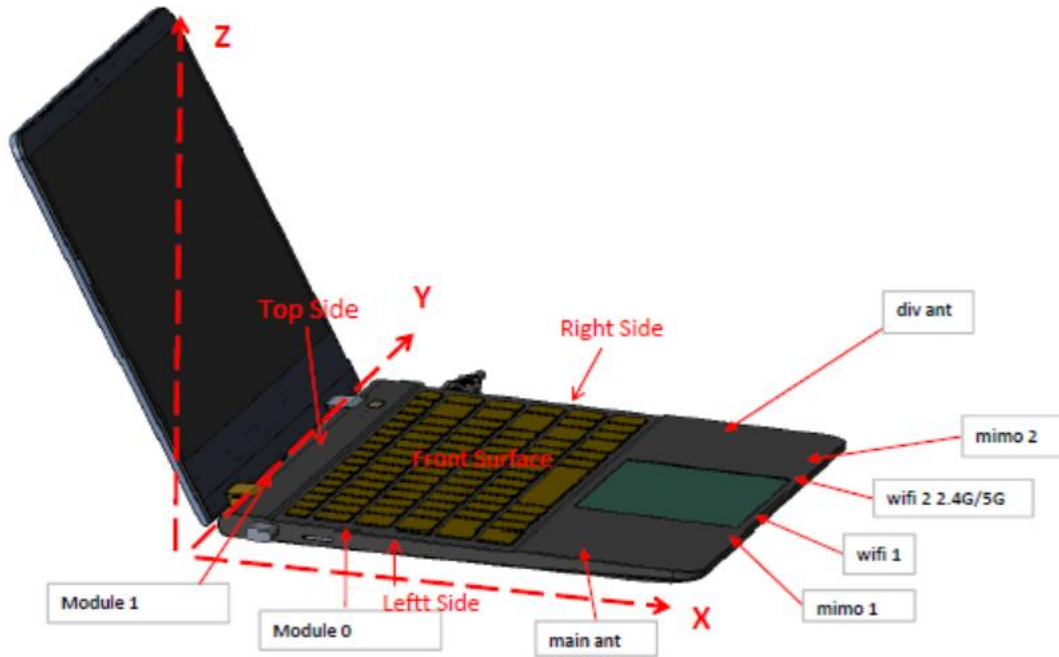
The average of the reconstructed power density is evaluated over a circular area in each measurement plane. Two average power density values can be computed, the average total power density and the average incident power density, and the average total power density is used to determine compliance.

- $|Re\{S\}|$ is the total Poynting vector
- $n \cdot Re\{S\}$ is the normal Poything vector

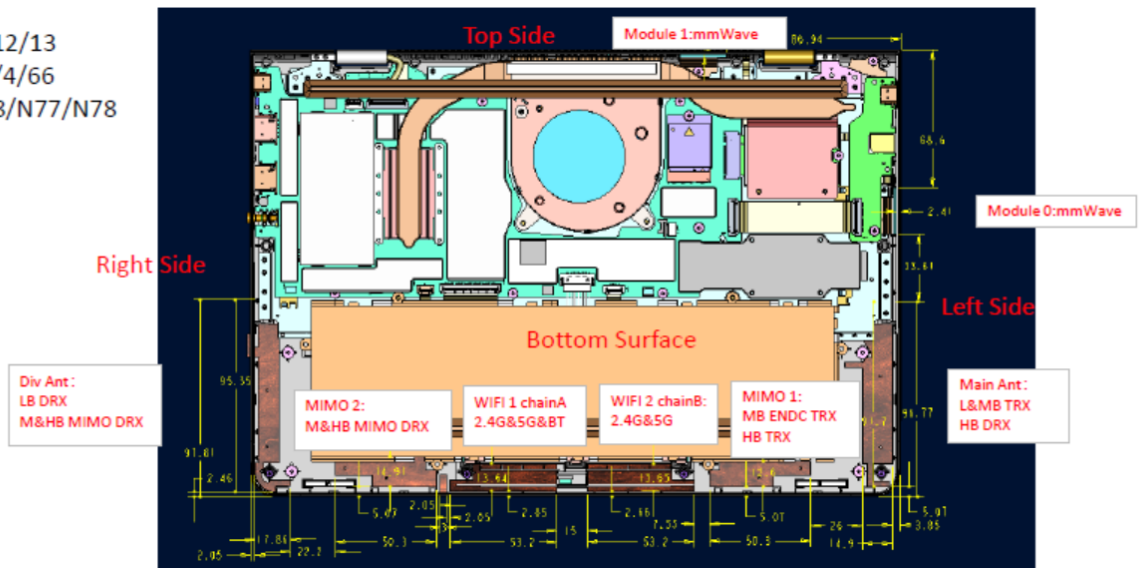
The software post-processing reports to values, "S avg tot" and "S avg inc". "S avg tot" represents average total power density (all three xyz components included), and "S avg inc" represents average normal power density. The average total power density "S avg tot" is reported to determine the device compliance.

8. Antenna Information

8.1. Antenna Location



LB:B5/12/13
 MB:B2/4/66
 HB: B48/N77/N78





Antenna	Frequency Bands	TX/RX	Remark
Main Ant	WCDMA B2/4/5 LTE B2/4/5/12/13/66 5G NR n2/5/66	TRX	Only RX (LTE B48, 5G NR n77/78)
Div Ant	LTE 2/4/5/12/13/66/48 5G NR n2/5/66/77/78	RX	N/A
MIMO 1	LTE B48 5G n77/78	TRX	Only RX (LTE B2/4/66, 5G n2/66)
MIMO 2	LTE B2/4/66/48 5G NR n2/66/77/78	RX	N/A
WIFI 1	2.4G/5G/BT	TRX	N/A
WIFI 2	2.4G/5G	TRX	N/A
Module 0	5G mmWave n260/261	TRX	N/A
Module 1	5G mmWave n260/261	TRX	N/A

8.2. Test Positions

Antenna Module	Measurement Plane at 2mm					
	Front Surface	Bottom Surface	Left Side	Right Side	Top Side	Bottom Side
Module 0	Yes	Yes	Yes	No	No	No
Module 1	Yes	Yes	No	No	Yes	No

Note:

From the Part0 report, beam IDs with the highest PD and corresponding input.power.limit were selected to be tested for each antenna module and frequency bands.



9. Power Density Assessment

➤ General Description

1. The 5G NR mmWave signal under testing was configured by the test tool of Qualcomm Software, and it is only limited to operate at EN-DC for 5G NR implementation according to the character of the device.
2. This device would be configured to maximum power when transmitting and tested at the maximum duty cycle for each RB configuration, modulation, bandwidth, and channel.
3. According to the manufacturer that summation for different antenna modules and exposure planes, the worst case would be selected for power density measurement.

➤ mmWave EN-DC Combination

EN-DC Combination	mmWave (FR2) 4G DL 4x4 MIMO	4G UL	5G-NR UL
DC_2A_n261A	2A	2A	n261A
DC_4A_n261A	4A	4A	n261A
DC_5A_n261A	-	5A	n261A
DC_13A_n261A	-	13A	n261A
DC_66A_n261A	66A	66A	n261A
DC_2A_n260A	2A	2A	n260A
DC_4A_n260A	4A	4A	n260A
DC_5A_n260A	-	5A	n260A
DC_13A_n260A	-	13A	n260A
DC_66A_n260A	66A	66A	n260A
DC_2A-2A-12A-66A_n260A	2A-2A-66A	2A, 12A, 66A	n260A
DC_2A-66A-66A_n260A	2A-66A-66A	2A, 66A	n260A
DC_2A-2A-5A_n260A	2A-2A	2A, 5A	n260A
DC_2A-2A-12A_n260A	2A-2A	2A, 12A	n260A
DC_2A-13A_n261A	2A	2A, 13A	n261A
DC_2A-13A_n261(2A)	2A	2A, 13A	n261A
DC_2A-13A_n261(3A)	2A	2A, 13A	n261A
DC_2A-13A_n261(4A)	2A	2A, 13A	n261A
DC_2A-66A_n261A	2A-66A	2A, 66A	n261A
DC_2A-66A_n261(2A)	2A-66A	2A, 66A	n261A
DC_2A-66A_n261(3A)	2A-66A	2A, 66A	n261A
DC_2A-66A_n261(4A)	2A-66A	2A, 66A	n261A



➤ PD Measurement Plan

<n260>

Antenna Module	Channel	Beam ID		BW (MHz)	RB offset	Exposure Position	Input Power Limit (dBm)
		AG0(V)	AG1(H)				
Module 0	2254165	18	-	100	22#20	Left Side	0.42
	2254165	18	-	100	22#20	Front Surface	0.42
	2254165	18	-	100	22#20	Bottom Surface	0.42
	2254165	-	146	100	22#20	Left Side	0.63
	2254165	-	146	100	22#20	Front Surface	0.63
	2254165	-	146	100	22#20	Bottom Surface	0.63
Module 1	2254165	35	-	100	22#20	Top Side	-2.54
	2254165	35	-	100	22#20	Front Surface	-2.54
	2254165	35	-	100	22#20	Bottom Surface	-2.54
	2254165	-	163	100	22#20	Top Side	0.1
	2254165	-	163	100	22#20	Front Surface	0.1
	2254165	-	163	100	22#20	Bottom Surface	0.1

<n261>

Antenna Module	Channel	Beam ID		BW (MHz)	RB offset	Exposure Position	Input Power Limit (dBm)
		AG0(V)	AG1(H)				
Module 0	2077915	20	-	100	22#20	Left Side	1.34
	2077915	20	-	100	22#20	Front Surface	1.34
	2077915	20	-	100	22#20	Bottom Surface	1.34
	2077915	-	158	100	22#20	Left Side	1.17
	2077915	-	158	100	22#20	Front Surface	1.17
	2077915	-	158	100	22#20	Bottom Surface	1.17
Module 1	2077915	25	-	100	22#20	Top Side	1.26
	2077915	25	-	100	22#20	Front Surface	1.26
	2077915	25	-	100	22#20	Bottom Surface	1.26
	2077915	-	153	100	22#20	Top Side	0.44
	2077915	-	153	100	22#20	Front Surface	0.44
	2077915	-	153	100	22#20	Bottom Surface	0.44



10. Test Results of RF Exposure

➤ General Note

1. The worst beam ID from Part 0 would be selected for power density testing according to the antenna information.
2. The power density measurement was performed at 2mm separation distance between the sensor and EUT surface.
3. According to TCB Workshop publications in Oct. 2018, 4cm² averaging area total power density should be recorded in the test report.
4. There is a protrusion less than 5mm on the bottom of this device, and the 0mm distance with its thickness was tested.
5. This device is enabled with Qualcomm Smart Transmit feature by C2PC later, it will manage and ensure LTE and 5G NR simultaneous transmission is compliant. The validation of the time-averaging algorithm and compliance under the TX varying transmission scenario for WWAN technologies are recorded in Part 2.
6. For 5G mmWave, there is total design-related uncertainty arising from TxAGC and device-to-device variation, the worst condition RF exposure should be determined by accounting for the uncertainty 2.1dB, as well as n260/261 PD design target of 0.462 mW/cm² for antenna module 0/1. Smart Transmit algorithm limits PD exposure to 75% of maximum to provide at least 25% margin allocated for LTE anchor.
7. For EFS version 16 or higher, secondary radio (5G NR mmWave) can get up to 100% reserve factor irrespective of reserve_power_margin setting. Therefore 5G NR mmWave RF exposure for this device is evaluated by reported PD calculated follows:

$$\text{Reported PD} = \text{PD design target} + 2.1\text{dB} = 0.75 \text{ mW/cm}^2$$



➤ Test Results

<n260>

Antenna Module	Channel	Beam ID		BW (MHz)	RB offset	Exposure Position	Measured Total psPD over 4cm ² (W/m ²)
		AG0(V)	AG1(H)				
Module 0	2254165	18	-	100	22#20	Left Side	1.34
	2254165	18	-	100	22#20	Front Surface	0.704
	2254165	18	-	100	22#20	Bottom Surface	0.759
	2254165	-	146	100	22#20	Left Side	1.054
	2254165	-	146	100	22#20	Front Surface	0.954
	2254165	-	146	100	22#20	Bottom Surface	0.88
Module 1	2254165	35	-	100	22#20	Top Side	1.16
	2254165	35	-	100	22#20	Front Surface	0.281
	2254165	35	-	100	22#20	Bottom Surface	0.81
	2254165	-	163	100	22#20	Top Side	1.41
	2254165	-	163	100	22#20	Front Surface	0.73
	2254165	-	163	100	22#20	Bottom Surface	0.7

<n261>

Antenna Module	Channel	Beam ID		BW (MHz)	RB offset	Exposure Position	Measured Total psPD over 4cm ² (W/m ²)
		AG0(V)	AG1(H)				
Module 0	2077915	20	-	100	22#20	Left Side	1.73
	2077915	20	-	100	22#20	Front Surface	0.982
	2077915	20	-	100	22#20	Bottom Surface	1.17
	2077915	-	158	100	22#20	Left Side	1.32
	2077915	-	158	100	22#20	Front Surface	1.05
	2077915	-	158	100	22#20	Bottom Surface	1.03
Module 1	2077915	25	-	100	22#20	Top Side	2.82
	2077915	25	-	100	22#20	Front Surface	1.82
	2077915	25	-	100	22#20	Bottom Surface	1.17
	2077915	-	153	100	22#20	Top Side	2.34
	2077915	-	153	100	22#20	Front Surface	1.31
	2077915	-	153	100	22#20	Bottom Surface	1.07



11. Simultaneous Transmission Assessment

11.1. Simultaneous Transmission Consideration

No.	Simultaneous Transmission Consideration	Exposure Position	
		Body	Extremity
1	WWAN (WCDMA/LTE)+WLAN 2.4GHz/5GHz (SISO/MIMO)	Yes	Yes
2	WWAN (WCDMA/LTE)+Bluetooth	Yes	Yes
3	WWAN (5G FR1 SA/NSA)+WLAN 2.4GHz/5GHz (SISO/MIMO)	Yes	Yes
4	WWAN (5G FR1 SA/NSA)+Bluetooth	Yes	Yes
5	WWAN (LTE+5G FR2)+WLAN 2.4GHz/5GHz (SISO/MIMO)	Yes	Yes
6	WWAN (LTE+5G FR2)+Bluetooth	Yes	Yes

Note:

1. Simultaneous Transmission evaluation is not required for BT and Wi-Fi, because the software mechanism have been incorporated to guarantee that the WLAN and Bluetooth transmitters would not simultaneously operate.
2. The WWAN (Sub-6G), WLAN and Bluetooth SAR test results were recorded in the FCC SAR report SZ21070331S01.

11.2. Simultaneous Transmission Analysis

The EUT supports simultaneous transmission of multiple radios. RF exposure compliance in simultaneous transmission scenarios is evaluated in this section.

It must be noted here that Qualcomm Smart Transmit time-averaging algorithm was applied to only WWAN, where the time-averaged power level is controlled so that RF exposure is \leq SAR_design_target for sub-6 WWAN and \leq PD_design_target for 5G mmW NR. Since there is total design-related uncertainty arising from TxAGC and device-to-device variation, the worst-case RF exposure should be determined by accounting for this uncertainty in the corresponding design target, thus, with 1dB of device uncertainty for sub-6 WWAN and 2.2dB of device uncertainty for 5G mmW. Therefore, the worst-case RF exposure for this EUT is:

Worst-case Time-averaged RF Exposure for WWAN

Title	WWAN Wireless System	
	Sub-6G	5G mmWave
Maximum time-averaged power level	P_{limit}	<i>input.power.limit</i>
Maximum time-averaged exposure	SAR_design_target=0.8W/kg (1gSAR)	PD_design_target = 6 W/m ²
Maximum Design-related	1.0 dB	2.1 dB



uncertainty		
Worst-case time-averaged RF exposure	Reported SAR = 1.0W/kg (1g)	reported PD* = 75% × PD_design_target + 2.1dB = 7.5 W/m ²

Note:

1. The highest SAR value obtained from UL FCC SAR Test Report. For scenarios where ($P_{limit} + 1.0\text{dB}$ uncertainty) $\geq P_{max}$ (maximum RF tune-up output power), time-averaged SAR exposure from Smart Transmit enabled EUT (at P_{limit}) cannot exceed reported SAR corresponding to P_{max} .
2. Smart Transmit allows only 75% of maximum PD exposure for this EUT using EFS entries listed in R141TL5 sub6_mmw power density simulation report.

RF exposure compliance with WWAN+WLAN simultaneous transmission scenarios is demonstrated for various radio configurations using below equation:

$$\text{Total norm. RF exposure} = \text{norm. RF exposure from Smart Transmit enabled WWAN (norm. SAR from 4G} + \text{norm. PD from 5G mmW)} + \text{norm. SAR from WLAN} \leq 1.0 \text{ normalized limit (1)}$$

Smart Transmit algorithm in WWAN adds directly the time-averaged RF exposure from 4G and time-averaged RF exposure from 5G mmW, i.e.,

$$\text{norm. RF exposure from Smart Transmit enabled WWAN: (normalized SAR exposure from 4G)} + \text{(normalized PD exposure from 5G mmW)} \leq 1.0 \text{ normalized limit (2)}$$

In other words, Smart Transmit algorithm controls the total RF exposure from both 4G radio and 5G mmW NR to not exceed FCC limit. Smart transmit algorithm assumes hotspots are collocated (i.e., ignoring spatial distribution of hotspots) and directly adds normalized RF exposures from 4G and from 5G mmW, i.e.,

$$\begin{aligned} \text{If } A &= \text{max normalized time-averaged SAR exposure from 4G,} \\ B &= \text{max normalized time-averaged PD exposure from 5G mmW,} \end{aligned}$$

Then, equation (2) can be re-written as below because Smart Transmit assumes 4G hotspots are collocated with 5G mmW hotspot:

$$\text{Smart Transmit enabled WWAN: } x(t) * A + (1-x(t)) * B \leq 1.0 \text{ normalized limit (3)}$$

Here, " $x(t)*A$ " represents percentage of normalized time-averaged RF exposure from 4G, and $x(t)$ ranges between $[0,1]$; " $(1-x(t))*B$ " is remaining percentage of RF exposure contribution from 5G mmW. Smart Transmit controls 'x' in real time such that the sum of these exposures never exceeds 1.0 normalized limit.



Note that mathematically:

$$(t) * A + (1-(t))*B \leq \max(A,B) \leq 1.0 \text{ normalized limit for } x(t) \in [0,1] \text{ (4)}$$

Therefore, if below equations (5a) and (5b) are proven:

$$A + \text{norm.SAR from WLAN} \leq 1.0 \text{ norm.limit (5a),}$$

$$B + \text{norm.SAR from WLAN} \leq 1.0 \text{ norm.limit (5b),}$$

Then, based on equation (4), below condition is also proved:

$$[(t) * A + (1-(t))*B] + \text{norm.SAR from WLAN} \leq 1.0 \text{ norm.limit (5c)}$$

Which is the same as equation (1), to demonstrate compliance for simultaneous transmission.

Additionally, it should be noted that in the absence of 5G mm, Smart Transmit limits the maximum RF exposure contributed from 4G to 100% normalized exposure (i.e., $x=1.0$ in equation 3), while with 5G mmW active, Smart Transmit limits the maximum RF exposure contributed from 5G mmW to 75% normalized exposure to guarantee at least 25% margin allocated to 4G LTE anchor to maintain the link (i.e., $x=0.25$ in equation 3). Therefore:

$$\text{Smart Transmit enabled WWAN: } A = \max(\text{normalized SAR exposure from 4G}) \leq 1.0 \text{ normalized limit (6a)}$$

$$\text{Smart Transmit enabled WWAN: } B = \max(\text{normalized PD exposure from 5G mmW}) \leq 0.75 \text{ normalized limit (6b)}$$

Thus, for compliance demonstration given by equation (1), below equation (7) obtained by combining equations (5a & 5b) and (6a & 6b), should be proven to guarantee simultaneous transmission compliance:

$$\text{Total normalized RF exposure} = \text{norm. SAR from 4G WWAN} + \text{norm. SAR from WLAN} < 1.0 \text{ normalized FCC limit (7a)}$$

$$\text{Total normalized RF exposure} = 0.75 * \text{norm. PD from 5G mmW WWAN} + \text{norm. SAR from WLAN} < 1.0 \text{ normalized FCC limit (7b)}$$

The compliance for simultaneous transmission scenarios of WWAN (4G/5G mmW) radio enabled with Smart Transmit and WLAN without Smart Transmit is re-evaluated for all transmission scenarios supported by this EUT.



As described in equation (7), simultaneous transmission analysis for WWAN + WLAN is performed in two parts:

4G WWAN + WLAN (i.e., Eq. (7a) with compliance demonstration in SAR report SZ21070331S01 Section 19

5G mmW WWAN + WLAN (i.e., Eq. (7b) with compliance demonstration in Section 11.1

By combining above a. and b., the FCC requirement expressed in Eq. (1), re-written below, is met:

$$\text{Total norm. RF exposure} = \text{norm. RF exposure from Smart Transmit enabled WWAN (norm. SAR from 4G} + \text{norm. PD from 5G mmW NR)} + \text{norm. SAR from WLAN} \leq 1.0 \text{ normalized limit (1)}$$

➤ **Simultaneous Transmission Analysis for 5G mmW + WLAN**

NR Bands	Antenna Module	Exposure Position	Distance (mm)	Ratio*	PD design Target+Total Uncertainty (W/m ²)	PD design Target+Total Uncertainty (W/m ²)*Ratio	Remark	
n260	Module 0	Front Surface	2	0.34	7.5	2.55	Extremity	
		Bottom Surface	2	0.22	7.5	1.65	Body	
		Left Side	2	1.0	7.5	7.5	Extremity	
		Right Side	Excluded					
		Top Side	Excluded					
		Bottom Side	Excluded					
	Module 1	Front Surface	2	0.22	7.5	1.65	Extremity	
		Bottom Surface	2	0.3	7.5	2.25	Body	
		Left Side	Excluded					
		Right Side	Excluded					
		Top Side	2	1.0	7.5	7.5	Extremity	
		Bottom Side	Excluded					
n261	Module 0	Front Surface	2	0.44	7.5	3.3	Extremity	
		Bottom Surface	2	0.31	7.5	2.33	Body	
		Left Side	2	1.0	7.5	7.5	Extremity	
		Right Side	Excluded					
		Top Side	Excluded					
		Bottom Side	Excluded					
	Module 1	Front Surface	2	0.38	7.5	2.85	Extremity	
		Bottom Surface	2	0.31	7.5	2.33	Body	
		Left Side	Excluded					
		Right Side	Excluded					
		Top Side	2	1.0	7.5	7.5	Extremity	
		Bottom Side	Excluded					

Note: *Ratio is the highest ratio of (PD on desired exposure plane) / (PD on 2mm worst exposure plane) out of all beams and channels including in power density simulating report.

11.3. 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

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

Where $S_{av,i}$ is the power density for the source I operating at a frequency f_i and S_{lim} is the power density limit as specified by the relevant standard.

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

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

According to the FCC guidance in TCBC 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 by its limit. Numerical sum of the ratios should be less or equal to 1. Therefore the simultaneous transmission should be follows:

$$TER = \sum_{n=1}^N \frac{SAR_n}{SAR_{n,limit}} + \sum_{n=1}^N \frac{S_{m,avg}}{S_{m,limit}} < 1$$



➤ **Body SAR for WLAN**

Exposure Position	Distance (mm)	1	2	3	4	1+2	3+4
		2.4GHz WLAN Chain A	2.4GHz WLAN Chain B	5GHz WLAN Chain A	5GHz WLAN Chain B	2.4GHz WLAN	5GHz WLAN
		1g SAR (W/kg)	1g SAR (W/kg)	1g SAR (W/kg)	1g SAR (W/kg)	1g SAR (W/kg)	1g SAR (W/kg)
Bottom Surface	0	0.379	0.365	0.443	0.619	0.744	1.062

➤ **Extremity SAR for WLAN**

Exposure Position	Distance (mm)	1	2	3	4	1+2	3+4
		2.4GHz WLAN Chain A	2.4GHz WLAN Chain B	5GHz WLAN Chain A	5GHz WLAN Chain B	2.4GHz WLAN	5GHz WLAN
		10g SAR (W/kg)	10g SAR (W/kg)	10g SAR (W/kg)	10g SAR (W/kg)	10g SAR (W/kg)	10g SAR (W/kg)
Front Surface	0	0.083	0.094	0.092	0.035	0.177	0.127

Note:

The WLAN SAR results are from the SAR report SZ21070331S01.

➤ **Total Exposure Ratio for mmW + WLAN MIMO**

mmW Bands	Antenna Module	Exposure Position	1	2	3	Total Exposure Ratio (SAR + PD)	
			4cm ² PD	WLAN 2.4GHz	WLAN 5GHz	1+2	1+3
			(W/m ²)	1g/10g SAR (W/kg)	1g/10g SAR (W/kg)	Summation	Summation
n260	Module 0	Front Surface*	2.55	0.177	0.127	0.299	0.287
		Bottom Surface	1.65	0.744	1.062	0.63	0.829
		Left Side*	7.5			0.75	0.75
	Module 1	Front Surface*	1.65	0.177	0.127	0.209	0.197
		Bottom Surface	2.25	0.744	1.062	0.69	0.889
		Top Side*	7.5			0.75	0.75

Remark:

- For the exposure position of Front surface, Left Side and Top Side, the limit of 4.0 W/kg on 10-g should be applied to calculating the extremity SAR exposure ratio, and limit of 1.6 W/kg on 1-g applied to general SAR exposure ratio.
- For PD, 10 W/m² should be applied to calculating the extremity and general exposure ratio.



mmW Bands	Antenna Module	Exposure Position	1	2	3	Total Exposure Ratio (SAR + PD)	
			4cm ² PD	WLAN 2.4GHz	WLAN 5GHz	1+2	1+3
			(W/m ²)	1g/10g SAR (W/kg)	1g/10g SAR (W/kg)	Summation	Summation
n261	Module 0	Front Surface*	3.3	0.177	0.127	0.374	0.362
		Bottom Surface	2.35	0.744	1.062	0.7	0.899
		Left Side*	7.5			0.75	0.75
	Module 1	Front Surface*	2.85	0.177	0.127	0.329	0.317
		Bottom Surface	2.33	0.744	1.062	0.698	0.897
		Top Side*	7.5			0.75	0.75

Remark:

- For the exposure position of Front surface, Left Side and Top Side, the limit of 4.0 W/kg on 10-g should be applied to calculating the extremity SAR exposure ratio, and limit of 1.6 W/kg on 1-g applied to general SAR exposure ratio.
- For PD, 10 W/m² should be applied to calculating the extremity and general exposure ratio.

➤ **Total Exposure Ratio for mmW + Bluetooth**

mmW Bands	Antenna Module	Exposure Position	1	2	Total Exposure Ratio (SAR + PD)
			4cm ² PD	Bluetooth	1+2
			(W/m ²)	1g/10g SAR (W/kg)	Summation
n260	Module 0	Front Surface*	3.3	0.091	0.353
		Bottom Surface	2.35	0.482	0.536
		Left Side*	7.5		0.75
	Module 1	Front Surface*	2.85	0.091	0.308
		Bottom Surface	2.33	0.482	0.534
		Top Side*	7.5		0.75

Remark:

- For the exposure position of Front surface, Left Side and Top Side, the limit of 4.0 W/kg on 10-g should be applied to calculating the extremity SAR exposure ratio, and limit of 1.6 W/kg on 1-g applied to general SAR exposure ratio.
- For PD, 10 W/m² should be applied to calculating the extremity and general exposure ratio.



mmW Bands	Antenna Module	Exposure Position	1	2	Total Exposure Ratio (SAR + PD)
			4cm ² PD	Bluetooth	1+2
			(W/m ²)	1g/10g SAR (W/kg)	Summation
n261	Module 0	Front Surface*	2.55	0.091	0.278
		Bottom Surface	1.65	0.482	0.466
		Left Side*	7.5		0.75
	Module 1	Front Surface*	1.65	0.091	0.188
		Bottom Surface	2.25	0.482	0.526
		Top Side*	7.5		0.75

Remark:

1. For the exposure position of Front surface, Left Side and Top Side, the limit of 4.0 W/kg on 10-g should be applied to calculating the extremity SAR exposure ratio, and limit of 1.6 W/kg on 1-g applied to general SAR exposure ratio.
2. For PD, 10 W/m² should be applied to calculating the extremity and general exposure ratio.

Note:

The Bluetooth SAR results are from the SAR report SZ21070331S01.

12. Uncertainty Assessment

The budget is valid for evaluation distance $> \lambda / 2\pi$. For specific tests and configurations, the uncertainty can be considered smaller.

Error Description	Uncertainty $\pm \%$	Probability	Divisor	c_i	Standard Uncertainty ($\pm\%$)	ν_i or ν_{eff}
Uncertainty terms dependent on the measurement system						
Probe calibration	0.43	1	R	1	0.49	∞
Probe correction	0.48	1.732	R	0.7	0.49	∞
Isotropy	0.48	1.732	R	0.7	0.29	∞
Multiple reflections	0.19	1.732	R	1	0.12	∞
System linearity	0.24	1.732	R	1	0.12	∞
Probe positioning	0.28	1.732	R	1	0.17	∞
Sensor location	0.2	1.732	R	1	0.18	∞
Amplitude and phase drift	0.02	1	R	1	0.0	∞
Amplitude and phase noise	0.18	1.732	R	1	0.12	∞
Data point spacing	0.06	1.732	R	1	0.08	∞
Measurement area truncation	0.63	1.732	R	1	0.6	∞
Reconstruction algorithms	0.04	1.732	R	1	0.05	∞
Uncertainty terms dependent on the DUT and environmental factors						
Probe coupling with DUT	0.05	1.732	R	1	0.08	∞
Modulation response	0.34	1.732	R	1	0.23	∞
Integration time	0.01	1	R	1	0.00	∞
DUT alignment	0.12	1.732	R	1	0.3	∞
RF ambient conditions	0.20	1.732	R	1	0.12	∞
Immunity / secondary reception	0.03	1.732	R	1	0.04	∞
Drift of the DUT	0.06	1	R	1	0.01	∞
Combined standard uncertainty					0.71 dB	∞
Coverage Factor for 95%					K=2	N/A
Expanded standard uncertainty					1.52 dB	



Annex A General Information

1. Identification of the Responsible Testing Laboratory

Laboratory Name:	Shenzhen Morlab Communications Technology Co., Ltd.
Laboratory Address:	FL.1-3, Building A, FeiYang Science Park, No.8 LongChang Road, Block 67, BaoAn District, ShenZhen, GuangDong Province, P. R. China
Telephone:	+86 755 36698555
Facsimile:	+86 755 36698525

2. Identification of the Responsible Testing Location

Name:	Shenzhen Morlab Communications Technology Co., Ltd.
Address:	FL.3, Building A, FeiYang Science Park, No.8 LongChang Road, Block 67, BaoAn District, ShenZhen, GuangDong Province, P. R. China

3. Facilities and Accreditations

The FCC designation number is CN1192, the test firm registration number is 226174.

***** END OF MAIN REPORT *****