Power Density Evaluation Report

FCC ID : A4RG0DZQ
Equipment : Phone
Applicant : Google LLC
1600 Amphitheatre Parkway,
Mountain View, California, 94043 USA
Standard : FCC 47 CFR Part 2 (2.1093)

The product was received on Sep. 08, 2022 and testing was started from Sep. 12, 2022 and completed on Sep. 17, 2022. We, SPORTON INTERNATIONAL INC., would like to declare that the tested sample provide by manufacturer and the test data has been evaluated in accordance with the test procedures given in 47 CFR part2.1093 and has been pass the FCC requirement.

The test results in this report apply exclusively to the tested model / sample. Without written approval of SPORTON INTERNATIONAL INC. Laboratory, the test report shall not be reproduced except in full.

Approved by: Cona Huang / Deputy Manager

Sporton International Inc. EMC & Wireless Communications Laboratory
No.52, Huaya 1st Rd., Guishan Dist., Taoyuan City 333, Taiwan

Table of Contents

1. Summary **4**
2. Guidance Applied **4**
3. Equipment Under Test (EUT) Information **5**
3.1 General Information 5
4. RF Exposure Limits **6**
4.1 Uncontrolled Environment 6
4.2 Controlled Environment 6
5. System Description and Setup **7**
5.1 Test Site Location 7
5.2 EUmmWave Probe / E-Field 5G Probe 8
5.3 Data Acquisition Electronics (DAE) 9
5.4 Scan configuration 9
6. Test Equipment List **9**
7. System Verification Source **10**
8. Power Density System Verification **11**
9. System Verification Results **11**
9.1 Computation of the Electric Field Polarization Ellipse 12
9.2 Total Field and Power Flux Density Reconstruction 12
9.3 Test Positions 13
10. RF Exposure Evaluation Results **13**
11. 5G NR + LTE + WLAN + BT Sim-Tx analysis **15**
12. Standalone and Simultaneous-Tx combination **16**
12.1 Simultaneous transmission analysis for WiFi/BT + 5G NR 17
13. Uncertainty Assessment **22**
14. References **23**

Appendix A. Plots of System Performance Check
Appendix B. Plots of Power Density Measurement
Appendix C. DASY Calibration Certificate
Appendix D. Setup Photo

History of this test report

Report No.	Version	Description	Issued Date
FA241215-02C	01	Initial issue of report	Nov. 14, 2022
FA241215-02C	02	Update section 12.	Dec. 14, 2022

1. Summary

The maximum measured average power density found during testing for Google LLC, Phone, are as follows.

Standalone transmission				Simultaneous transmission with other transmitters
RF Transmitter		Measured PD (mW/cm^2)	Reported PD (mW/cm^2)	Summation of Exposure Ratio
5G FR2	n261	0.411	0.75	0.991
	n260	0.490	0.75	
Result		PASS		

This device is compliance with human exposure to RF radiation limit (1.0 mW/cm^2) specified in FCC 47 CFR part1.1310

Reviewed by: Jason Wang
Report Producer: Daisy Peng

2. Guidance Applied

The Power Density testing specification, method, and procedure for this device is in accordance with the following standards, if the KDB standards were not list within TAF approval, because it is included in the KDB 447498.

- FCC 47 CFR Part 2.1091
- FCC 47 CFR Part 2.1093
- FCC KDB 865664 D02 SAR Reporting v01r02
- FCC KDB 447498 D01 General RF Exposure Guidance v06
- FCC KDB 648474 D04 SAR Evaluation Considerations for Wireless Handsets v01r03
- TCBC workshop notes
- IEC TR 63170

3. Equipment Under Test (EUT) Information

3.1 General Information

Product Feature & Specification	
Equipment Name	Phone
FCC ID	A4RG0DZQ
SN	28291FQHN00111 28291FQHN00132 28291FQHN00129 28291FQHN00117 28291FQHN00144 28291FQHN00163 28291FQHN00160
Wireless Technology and Frequency Range	GSM850: 824.2 MHz ~ 848.8 MHz GSM1900: 1850.2 MHz ~ 1909.8 MHz WCDMA Band II: 1850 MHz ~ 1910 MHz WCDMA Band IV: 1710 MHz ~ 1755 MHz WCDMA Band V: 824 MHz ~ 849 MHz LTE Band 2: 1850 MHz ~ 1910 MHz LTE Band 4: 1710 MHz ~ 1755 MHz LTE Band 5: 824 MHz ~ 849 MHz LTE Band 7: 2500 MHz ~ 2570 MHz LTE Band 12: 699 MHz ~ 716 MHz LTE Band 13: 777 MHz ~ 787 MHz LTE Band 14: 788 MHz ~ 798 MHz LTE Band 17: 704 MHz ~ 716 MHz LTE Band 25: 1850 MHz ~ 1915 MHz LTE Band 26: 814 MHz ~ 849 MHz LTE Band 30: 2305 MHz ~ 2315 MHz LTE Band 38: 2570 MHz ~ 2620 MHz LTE Band 41: 2496 MHz ~ 2690 MHz LTE Band 48: 3550 MHz ~ 3700 MHz LTE Band 66: 1710 MHz ~ 1780 MHz LTE Band 71: 663 MHz ~ 698 MHz 5G NR n2 : 1850 MHz ~ 1910 MHz 5G NR n5 : 824 MHz ~ 849 MHz 5G NR n7 : 2500 MHz ~ 2570 MHz 5G NR n12 : 699 MHz ~ 716 MHz 5G NR n14 : 788 MHz ~ 798 MHz 5G NR n25 : 1850 MHz ~ 1915 MHz 5G NR n30 : 2305 MHz ~ 2315 MHz 5G NR n38 : 2570 MHz ~ 2620 MHz 5G NR n41 : 2496 MHz ~ 2690 MHz 5G NR n48 : 3550 MHz ~ 3700 MHz 5G NR n66 : 1710 MHz ~ 1780 MHz 5G NR n71 : 663 MHz ~ 698 MHz 5G NR n77: 3450 MHz ~ 3550 MHz, 3700 MHz ~ 3980 MHz 5G NR n260 : 37 GHz~40 GHz 5G NR n261 : 27.5 GHz~28.35 GHz WLAN 2.4GHz Band: 2400 MHz ~ 2483.5 MHz WLAN 5.2G Band: 5150 MHz ~ 5250 MHz WLAN 5.3G Band: 5250 MHz ~ 5350 MHz WLAN 5.5G Band: 5470 MHz ~ 5725 MHz WLAN 5.8G Band: 5725 MHz ~ 5850 MHz WLAN 5.9G UNII4 Band: 5850 MHz ~ 5895 MHz WLAN 6E: 5925 MHz ~ 6425 MHz, 6425 MHz ~ 6525 MHz, 6525 MHz ~ 6875 MHz, 6875 MHz ~ 7125 MHz Bluetooth: 2400 MHz ~ 2483.5 MHz NFC : 13.56 MHz
Mode	GSM/GPRS/EGPRS RMC/AMR 12.2Kbps HSDPA HSUPA LTE: QPSK, 16QAM, 64QAM, 256QAM 5G NR: DFT-s-OFDM/CP-OFDM, Pi/2 BPSK/QPSK/16QAM/64QAM/256QAM WLAN: 802.11a/b/g/n/ac/ax HT20/HT40/VHT20/VHT40/VHT80/HE20/HE40/HE80 Bluetooth BR/EDR/LE NFC: ASK

4. RF Exposure Limits

4.1 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.

4.2 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.

The criteria listed in Table 1 shall be used to evaluate the environmental impact of human exposure above 6GHz to radio frequency (RF) radiation as specified in §1.1310.

General Population Basic restriction for power density for frequencies between 1.5GHz and 100 GHz is 1.0 mW/cm^2 = 10 W/m^2

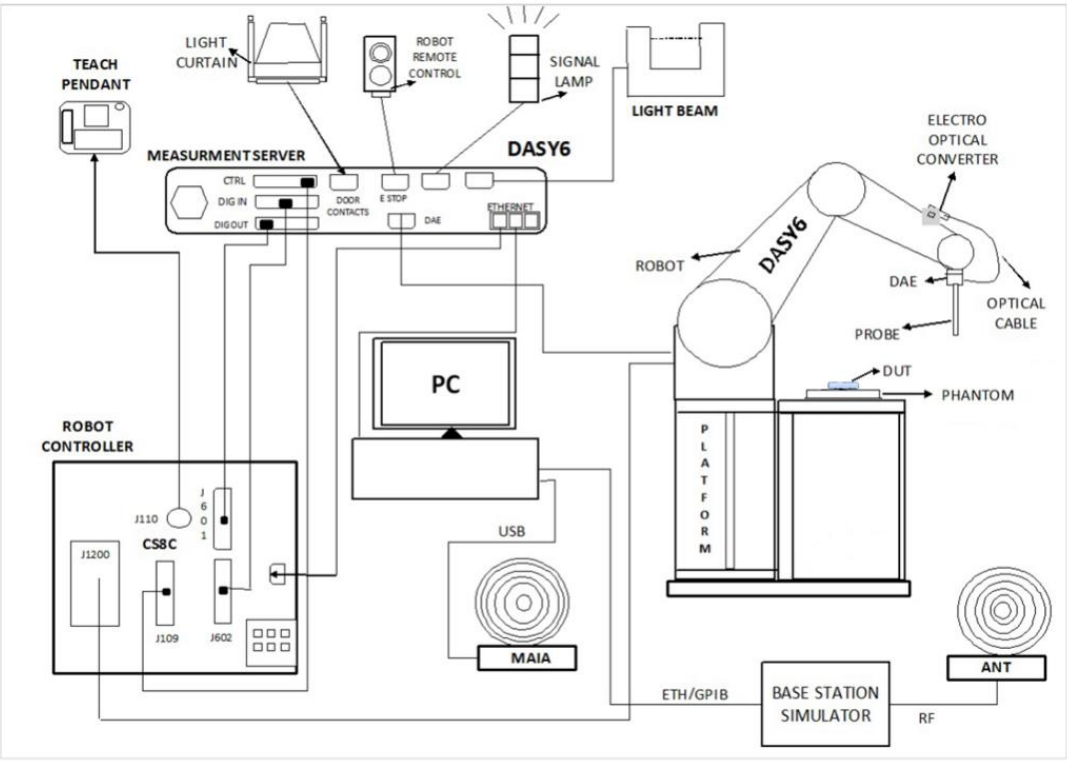
Frequency range (MHz)	Electric field strength (V/m)	Magnetic field strength (A/m)	Power density (mW/cm^2)	Averaging time (minutes)
(A) Limits for Occupational/Controlled Exposures				
0.3-3.0	614	1.63	*(100)	6
3.0-30	1842/f	4.89/f	*(900/f2)	6
30-300	61.4	0.163	1.0	6
300-1500			f/300	6
1500-100,000			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/f2)	30
30-300	27.5	0.073	0.2	30
300-1500			f/1500	30
1500-100,000			1.0	30

Table 1

5. System Description and Setup

The system to be used for the near field power density measurement

- SPEAG DASY6 system
- SPEAG cDASY6 5G module software
- EUmmWVx probe
- 5G Phantom cover



5.1 Test Site Location

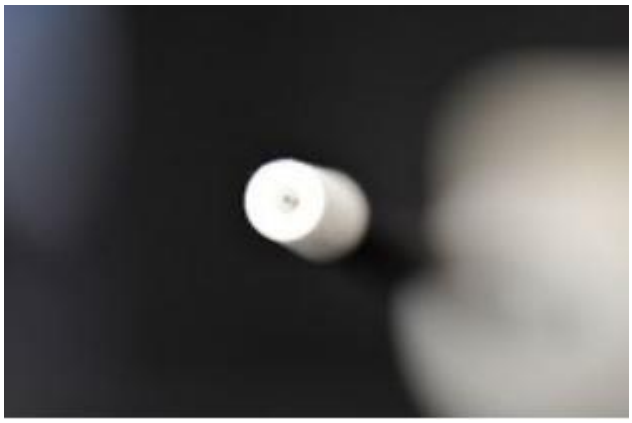
Sporton Lab and below test site location are accredited to ISO 17025 by Taiwan Accreditation Foundation (TAF code: 1190) and the FCC designation No. TW1190 under the FCC 2.948(e) by Mutual Recognition Agreement (MRA) in FCC test.

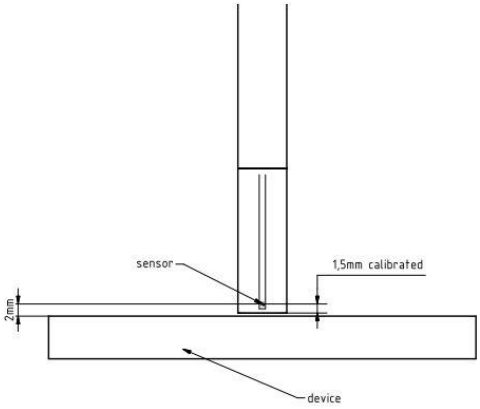
Test Site	SPORTON INTERNATIONAL INC. EMC & Wireless Communications Laboratory
Test Site Location	TW1190 No. 52, Huaya 1st Rd., Guishan Dist., Taoyuan City 333, CHINESE TAIPEI
Test Site No.	SAR06-HY

5.2 EUmmWave Probe / E-Field 5G Probe

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.

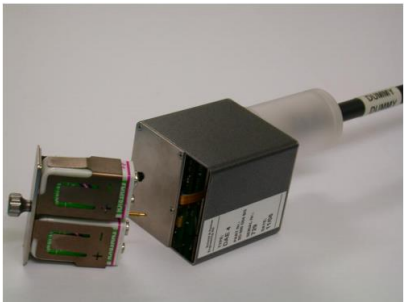
Frequency	750 MHz – 110 GHz
Probe Overall Length	320 mm
Probe Body Diameter	8.0 mm
Tip Length	23.0 mm
Tip Diameter	8.0 mm
Probe's two dipoles length	0.9 mm – Diode loaded
Dynamic Range	< 20 V/m - 10000 V/m with PRE-10 (min < 50 V/m - 3000 V/m)
Position Precision	< 0.2 mm
Distance between diode sensors and probe's tip	1.5 mm
Minimum Mechanical separation between probe tip and a Surface	0.5 mm
Applications	E-field measurements of 5G devices and other mm-wave transmitters operating above 10GHz in < 2 mm distance from device (free-space) Power density, H-field and far-field analysis using total field reconstruction.
Compatibility	cDASY6 + 5G-Module SW1.0 and higher





5.3 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. 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 200 MOhm; the inputs are symmetrical and floating. Common mode rejection is above 80 dB.



5.4 Scan configuration

Fine-resolution scans on 2 different planes are performed to reconstruct the E- and H-fields as well as the power density; the z-distance between the 2 planes is set to $\lambda/4$.
The (x, y) grid step is also set $\lambda/4$, the grid extent is set to sufficiently large to identify the field pattern and the peak.

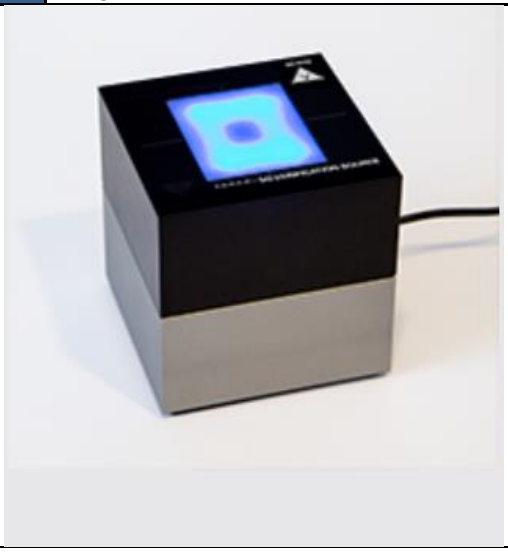
6. Test Equipment List

Manufacturer	Name of Equipment	Type/Model	Serial Number	Calibration	
				Last Cal.	Due Date
SPEAG	5G Verification Source	30GHz	1009	May. 24, 2022	May. 23, 2023
SPEAG	EUmmWV Probe Tip Protection	EUmmWV3	9424	Apr. 06, 2022	Apr. 05, 2023
SPEAG	Data Acquisition Electronics	DAE4	316	Jan. 26, 2022	Jan. 25, 2023
TESTO	Hygro meter	608-H1	45256952	Nov. 02, 2022	Nov. 01, 2023
Aglient	Spectrum Analyzer	E4408B	MY44211028	Aug. 19, 2021	Aug. 17, 2023
Custom Microwave	Standard Horn antenna	M15RH	V91113-A	NCR	NCR

7. System Verification Source

The System Verification sources at 30 GHz and above comprise horn-antennas and very stable signal generators.

Model	Ka-band horn antenna
Calibrated frequency:	30 GHz at 10mm from the case surface
Frequency accuracy	± 100 MHz
E-field polarization	linear
Harmonics	-20 dBc
Total radiated power	14 dBm
Power stability	0.05 dB
Power consumption	5 W
Size	00 x 100 x 100 mm
Weight	1 kg



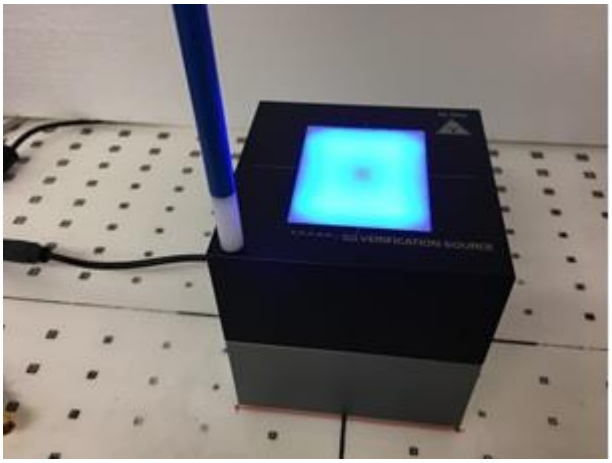
8. Power Density System Verification

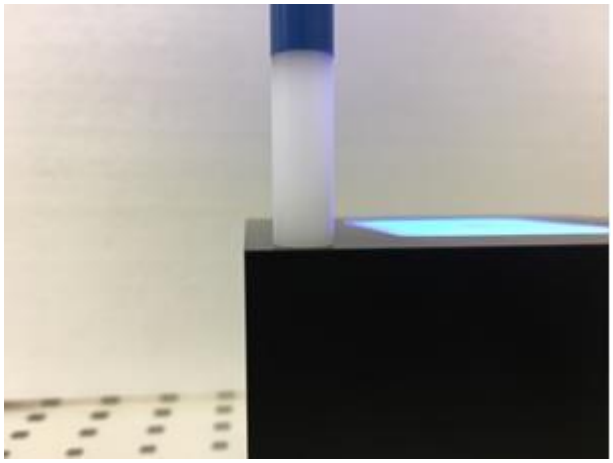
The system performance check verifies that the system operates within its specifications.

The EUT is replaced by a calibrated source, the same spatial resolution, measurement region and the test separation used in the calibration was applied to system check. Through visual inspection into the measured power density distribution, both spatially (shape) and numerically (level) have no noticeable difference. The measured results should be within 0.66dB of the calibrated targets.

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

Settings for measurement of verification sources





Verification Setup photo

9. System Verification Results

Test Site	Frequency (GHz)	5G Verification Source	Probe S/N	DAE S/N	Distance (mm)	Measured 4 cm^2 (W/m^2)	Targeted 4 cm^2 (W/m^2)	Deviation (dB)	Date
SAR06-HY	30G	30GHz_1009	9424	316	5.5mm	30.4	29.8	0.09	2022/9/12

9.1 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 (∅, 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, ∅ and θ) are sufficient for the description of the incident field.

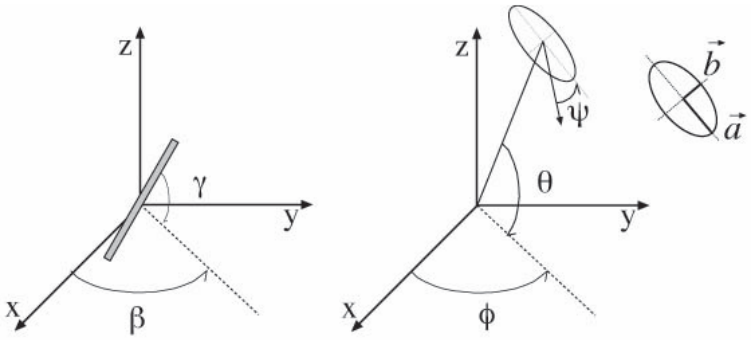


Illustration of the angles used for the numerical description of the sensor and the orientation of an ellipse in 3-D space.

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 (∅, 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 to use a probe consisting of two sensors angled by r_1 and r_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 degree ($r_2 = r_1 + 90$ degree), and to simplify, the first rotation angle of the probe (β_1) can be set to 0 degree.

9.2 Total Field and Power Flux 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
- $\mathrm{n} \cdot Re\{S\}$ 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.

9.3 Test Positions

Band	Antenna Module	Measurement Plane					
		S1(Front) 2mm	S2(Back) 2mm	S3(Left) 2mm	S4(Right) 2mm	S5(Top) 2mm	S6(Bottom) 2mm
5G NR Band 260/261	Plane A sub-module	v	v	v	v	v	✗
	Plane B sub-module	v	v	v	v	v	✗

From the Part 0 and simulation report, beam IDs with highest PD and corresponding Plimit were selected to be tested for each antenna module and for each frequency band.

10. RF Exposure Evaluation Results

1. The PD test was performed of a 2mm separation between sensor and EUT surface (the probe tip is 0.5mm to the EUT surface), 2 mm separation distance PD testing.
2. According to TCBC Workshop in October 2018, 4 cm^2 averaging area are used.
3. This device is enabled with Samsung S.LSI TAS feature, S.LSI TAS will manage and ensure LTE and 5G simultaneous transmission is compliant. The validation of the time-averaging algorithm and compliance under the Tx varying transmission scenario for WWAN technologies are reported in Part 2 report.
4. Pimit parameter for 5G mmW NR radio was calculated in RF Exposure Part 0 test report.
5. According the KDB inquiry guidance, the back surface was measured on the camera bump 2 mm surface, and reporting simulation PD at 2 mm from antenna-adjacent housing.
6. TAS algorithm makes use of the target power per slot in determining consumed SAR. The EIRP control can maintain the required amount of power for either CW tone or actual waveform to ensure the accuracy of actual transmit power. Plimit derived from CW tone signals can be confirmed to apply irrespective of the waveform, therefore the device was configured to transmit CW wave signal for testing.
7. Run PD test, from the beam ID with the highest simulated for selected side
   a. Horizontal polarization (H-only), CW tone signal.
   b. Vertical polarization (V-only), CW tone signal.
   c. Horizontal + Vertical polarization (H+V) , CW tone signal
   d. If step b to c result > 50% limit, then repeat for 2nd highest beam ID. If 2nd beam ID result is also > 50% limit, then repeat for 3rd beam ID
   e. For Maximum among 2)–3), test low and high channel
   f. For Maximum among 2)–4), test other sides, which is within 2.5 cm from the mmwave antenna module
   g. Apply the ratio from simulation to scale PD values@2 mm separation distance to PD values@10 mm separation distance.
   Repeat steps a)-f) for the rest of the bands and plane
8. It's illustrated in Part 0 report that, 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 device uncertainty of 2.3 dB, as well as PD design target of 4.42 W/m2. Therefore, 5G mmW NR RF exposure for this DUT is evaluated by reported PD calculated as:

Reported PD= PD design target +2.3 dB =7.5 W/m2 = 0.75 mW/cm^2

Test Number	Antenna Module	H	V	Band	Frequency (GHz)	Exposure Surface	Input Power limit	Test Separation	Modulation	Epeak [V/m]	Hpeak [A/m]	Measured results Savg inc 4cm^2 (W/m2)	Measured results Savg tot 4cm^2 (W/m2)
	1= A-Plane	0	-	n261	27.925	S5_Top	11	2mm	CW	59.5	0.141	1.72	2.04
	1= A-Plane	-	4	n261	27.925	S5_Top	11	2mm	CW	67.3	0.173	1.56	1.82
	1= A-Plane	3	3	n261	27.925	S5_Top	11	2mm	CW	81.3	0.237	2.33	2.84
01	1= A-Plane	3	3	n261	27.5	S5_Top	11	2mm	CW	78.3	0.267	3.43	4.11
	1= A-Plane	3	3	n261	28.35	S5_Top	11	2mm	CW	70.7	0.212	2.26	2.64
	1= A-Plane	3	3	n261	27.5	S1_Front	11	2mm	CW	44.2	0.114	2.19	2.60
	1= A-Plane	3	3	n261	27.5	S2_Back	11	2mm	CW	33.5	0.078	0.787	0.907
	1= A-Plane	6	6	n261	27.5	S3_Left	11	2mm	CW	23.2	0.066	0.568	0.684
	1= A-Plane	0	0	n261	27.5	S4_Right	11	2mm	CW	25.5	0.068	1.07	1.22
	0=B-Plane	3	-	n261	27.925	S2_Back	9.41	2mm	CW	38.8	0.097	0.996	1.08
	0=B-Plane	-	4	n261	27.925	S2_Back	9.41	2mm	CW	46.3	0.119	2.30	2.48
	0=B-Plane	4	4	n261	27.925	S2_Back	9.41	2mm	CW	59.2	0.175	3.71	4.04
	0=B-Plane	4	4	n261	27.5	S2_Back	9.41	2mm	CW	54.9	0.150	2.74	2.97
	0=B-Plane	4	4	n261	28.35	S2_Back	9.41	2mm	CW	64	0.155	2.73	2.99
	0=B-Plane	0	0	n261	27.925	S1_Front	9.41	2mm	CW	13.2	0.037	0.197	0.206
	0=B-Plane	6	6	n261	27.925	S3_Left	9.41	2mm	CW	11.3	0.029	0.186	0.201
	0=B-Plane	0	0	n261	27.925	S4_Right	9.41	2mm	CW	25.5	0.061	0.811	0.911
	0=B-Plane	3	3	n261	27.925	S5_Top	9.41	2mm	CW	25.7	0.066	0.577	0.725
	1= A-Plane	0	-	n260	38.5	S5_Top	13.24	2mm	CW	74.6	0.221	1.59	2.14
	1= A-Plane	-	4	n260	38.5	S5_Top	13.24	2mm	CW	74	0.184	2.68	2.97
	1= A-Plane	2	2	n260	38.5	S5_Top	13.24	2mm	CW	73.8	0.227	3.38	3.83
	1= A-Plane	0	0	n260	37	S5_Top	13.24	2mm	CW	115	0.252	3.63	4.52
02	1= A-Plane	2	2	n260	40	S5_Top	13.24	2mm	CW	98.5	0.269	4.49	4.90
	1= A-Plane	2	2	n260	40	S1_Front	13.24	2mm	CW	44.2	0.114	1.01	1.61
	1= A-Plane	4	4	n260	40	S2_Back	13.24	2mm	CW	32.1	0.087	1.04	1.16
	1= A-Plane	1	1	n260	40	S3_Left	13.24	2mm	CW	25	0.083	0.834	0.871
	1= A-Plane	0	0	n260	40	S4_Right	13.24	2mm	CW	25.1	0.081	0.644	0.757
	0=B-Plane	0	-	n260	38.5	S2_Back	13.63	2mm	CW	60.7	0.138	1.66	2.00
	0=B-Plane	-	6	n260	38.5	S2_Back	13.63	2mm	CW	57.1	0.132	1.69	1.89
	0=B-Plane	3	3	n260	38.5	S2_Back	13.63	2mm	CW	63.6	0.153	3.21	3.47
	0=B-Plane	3	3	n260	37	S2_Back	13.63	2mm	CW	57.4	0.155	2.95	3.20
	0=B-Plane	6	6	n260	40	S2_Back	13.63	2mm	CW	75	0.211	2.39	2.83
	0=B-Plane	5	5	n260	38.5	S1_Front	13.63	2mm	CW	8.93	0.028	0.065	0.072
	0=B-Plane	1	1	n260	38.5	S3_Left	13.63	2mm	CW	22.8	0.087	0.838	0.87
	0=B-Plane	1	1	n260	38.5	S4_Right	13.63	2mm	CW	22.4	0.064	0.890	0.935
	0=B-Plane	3	3	n260	38.5	S5_Top	13.63	2mm	CW	35.4	0.075	0.703	0.963

11. 5G NR + LTE + WLAN + BT Sim-Tx analysis

In 5G NR + LTE + WLAN + BT simultaneous transmission, 5G NR FR2 and LTE transmission are managed and controlled by Samsung S.LSI TAS feature, while the RF exposure from WLAN and BT radios is managed using legacy approach, i.e., through a fixed power back-off if needed.

Since WLAN and BT do not employ time-averaging, 1gSAR and 10gSAR measurement for WLAN and BT need to be conducted at their corresponding rated power following current FCC test procedures to determine reported SAR values.

TAS managed and controlled for Multi-RATs (5GNR + LTE)

The power ratio factors are g_1 and g_2 for LTE and FR2 respectively. The main purpose of these power ratio factors is to split the available SAR budget among different RATs, so $g_1 + g_2 \leq 1$. The value of g_1 is computed based on the need of the LTE anchor and can be changed if the anchor changes its power request. Based on the SAR Budget portion allocated to the anchor, the value of g_2 will be computed. At steady state (where all RATs are being on for a while), the allocated power ratio factors will guarantee that the total exposure ratio never exceeds the highest exposure of either one.

The reported time-averaged PD is applicable for the worst-surface of the device, and for other surfaces the reported PD is determined as below

1. Calculate ratio of simulated PD for desired surface to simulated PD of worst surface for a given beam

2. Repeat 1 to obtain ratios for all supported beams, and determine maximum ratio

3. Repeat 1~2 to obtain the corresponding worst-case PD for other surfaces which are needed for TER analysis.

- *For body-worn and hotspot scenario, if SAR was measured at 15mm and 10mm, respectively, then the worst-case PD at 15mm and 10mm separation distance should be determined per surface as*
  - *15mm_worst-case_PD = PD_ratio_15mm_to_2mm * reported* time-averaged PD
  - *10mm_worst-case_PD = PD_ratio_10mm_to_2mm * reported time-averaged PD*

12. Standalone and Simultaneous-Tx combination

Exposure Condition	Tx mode	Capable TX Configurations	WWAN Power(1)	WiFi Power	BT Power
Head	WWAN standalone	WWAN	Index 2		
	WiFi standalone	WiFi 2.4G MIMO/CDD (Ant4+3)		Index 2	
		WiFi 5G MIMO (Ant4+3)			
		WiFi 6E MIMO (Ant4+3)			
	WiFi +BT	WiFi 5G MIMO (Ant4+3) + Bluetooth (Ant4)		Index 2	Index 1
		WiFi 5G MIMO (Ant4+3) + Bluetooth (Ant3)			
		WiFi 6E MIMO (Ant4+3) + Bluetooth (Ant4)			
		WiFi 6E MIMO (Ant4+3) + Bluetooth (Ant3)			
	WWAN + WiFi	WWAN + WiFi 2.4G MIMO/CDD (Ant4+3)	Index 3	Index 1	
		WWAN + WiFi 5G MIMO (Ant4+3)			
		WWAN + WiFi 6E MIMO (Ant4+3)			
	WWAN + BT	WWAN + Bluetooth (Ant4)			Index 1
		WWAN + Bluetooth (Ant3)			
	WWAN + WiFi +BT	WWAN + WiFi 5G MIMO (Ant4+3) + Bluetooth (Ant4)		Index 1	Index 1
		WWAN + WiFi 5G MIMO (Ant4+3) + Bluetooth (Ant3)			
		WWAN + WiFi 6E MIMO (Ant4+3) + Bluetooth (Ant4)			
		WWAN + WiFi 6E MIMO (Ant4+3) + Bluetooth (Ant3)			
Body	WWAN standalone	WWAN	Index 5		
	WiFi standalone	WiFi 2.4G MIMO/CDD (Ant4+3)		Index 6	
		WiFi 5G MIMO (Ant4+3)			
		WiFi 6E MIMO (Ant4+3)			
	BT standalone	Bluetooth (Ant4)			Index 2
		Bluetooth (Ant3)			
	WiFi +BT	WiFi 5G MIMO (Ant4+3) + Bluetooth (Ant4)		Index 6	Index 3
		WiFi 5G MIMO (Ant4+3) + Bluetooth (Ant3)			
		WiFi 6E MIMO (Ant4+3) + Bluetooth (Ant4)			
		WiFi 6E MIMO (Ant4+3) + Bluetooth (Ant3)			
	WWAN + WiFi	WWAN + WiFi 2.4G MIMO/CDD (Ant4+3)	Index 6 / Index 4 (Hotspot)	Index 4	
		WWAN + WiFi 5G MIMO (Ant4+3)			
		WWAN + WiFi 6E MIMO (Ant4+3)			
	WWAN + BT	WWAN + Bluetooth (Ant4)	Index 6		Index 3
		WWAN + Bluetooth (Ant3)			
	WWAN + WiFi +BT	WWAN + WiFi 5G MIMO (Ant4+3) + Bluetooth (Ant4)	Index 6 / Index 4 (Hotspot)	Index 5 / Index 3 (Hotspot)	Index 4
		WWAN + WiFi 5G MIMO (Ant4+3) + Bluetooth (Ant3)			
		WWAN + WiFi 6E MIMO (Ant4+3) + Bluetooth (Ant4)			
		WWAN + WiFi 6E MIMO (Ant4+3) + Bluetooth (Ant3)			

General Note:

1. The FR2 output power is fixed power level regardless of use cases.
2. Simultaneous operation at maximum power levels when the device is neither against the body nor the head (i.e. in a mobile RF exposure condition) is addressed in Sporton's RF Exposure report FA241215-02A
3. The WLAN and Bluetooth SAR test results, referenced from the report of FCC ID: A4RG0DZQ (Sporton SAR Report No. FA241215-02D).
4. The Sim-Tx configuration combination include in operation description will be match the title in the below Sum-Tx evaluation table
5. For LTE+5GNR+WiFi+BT, due to the TAS control, simultaneous transmission compliance can be assessed on LTE+WiFi/BT and 5GNR +WiFi/BT, and the validation of the time-averaging algorithm and compliance under the Tx varying transmission scenario for WWAN technologies are reported in Part 2 report. For 5GNR FR2 with WiFi, total exposure ratio is calculated as below formula, LTE/FR1 + WIFI simultaneous transmission analysis referring from the report of FCC ID: A4RG0DZQ (Sporton SAR Report No. FA241215-02D).

The [∑ of (the highest measured or estimated SAR for each standalone antenna configuration, adjusted for maximum tune-up tolerance) / 1.6 or 4.0 W/kg] + [∑ of MPE ratios] is ≤ 1.0.

12.1 Simultaneous transmission analysis for WiFi/BT + 5G NR

*Ratio is highest ratio of (PD on desired exposure plane) / (PD on worst-surface) out of all beams and out of all channels illustrated in Power Density Simulation Report.

NR Band	Antenna Module	Exposure condition	Surface	Evaluation Distance (mm)	Ratio*	PD_Design Target +Total uncertainty (W/m^2)	PD_Design Target +Total uncertainty)*Ratio (W/m^2)
n261	Plane A sub-module	Extremity	Front Surface	2 mm	0.591	7.5	4.432
			Back Surface	2 mm	0.435	7.5	3.264
			Left side	2 mm	0.044	7.5	0.327
			Right side	2 mm	0.225	7.5	1.686
			Top side	2 mm	1.000	7.5	7.500
			Bottom side	2 mm			
n261	Plane B sub-module		Front Surface	2 mm	0.069	7.5	0.518
			Back Surface	2 mm	1.000	7.5	7.500
			Left side	2 mm	0.043	7.5	0.323
			Right side	2 mm	0.368	7.5	2.759
			Top side	2 mm	0.564	7.5	4.228
			Bottom side	2 mm			
n260	Plane A sub-module		Front Surface	2 mm	0.765	7.5	5.738
			Back Surface	2 mm	0.572	7.5	4.293
			Left side	2 mm	0.050	7.5	0.377
			Right side	2 mm	0.256	7.5	1.917
			Top side	2 mm	1.000	7.5	7.500
			Bottom side	2 mm			
n260	Plane B sub-module		Front Surface	2 mm	0.038	7.5	0.285
			Back Surface	2 mm	1.000	7.5	7.500
			Left side	2 mm	0.080	7.5	0.599
			Right side	2 mm	0.251	7.5	1.882
			Top side	2 mm	0.430	7.5	3.225
			Bottom side	2 mm			

NR Band	Antenna Module	Exposure condition	Surface	Evaluation Distance (mm)	Ratio*	PD_Design Target +Total uncertainty (W/m^2)	PD_Design Target +Total uncertainty)*Ratio (W/m^2)
n261	Plane A sub-module	Head	Front Surface	2 mm	0.591	7.5	4.432
n261	Plane B sub-module		Front Surface	2 mm	0.069	7.5	0.518
n260	Plane A sub-module		Front Surface	2 mm	0.765	7.5	5.738
n260	Plane B sub-module		Front Surface	2 mm	0.038	7.5	0.285

NR Band	Antenna Module	Exposure condition	Surface	Evaluation Distance (mm)	Ratio*	PD_Design Target +Total uncertainty (W/m^2)	PD_Design Target +Total uncertainty)*Ratio (W/m^2)
n261	Plane A sub-module	Body Worn/Hotspot	worst-surface	10 mm	0.565	7.5	4.237
n261	Plane B sub-module		worst-surface	10 mm	0.454	7.5	3.402
n260	Plane A sub-module		worst-surface	10 mm	0.746	7.5	5.592
n260	Plane B sub-module		worst-surface	10 mm	0.569	7.5	4.268

<Head Exposure Condition>

<5GNR FR2, WLAN Index 1, BT Index 1>

NR Band	Antenna Module	Exposure Position	1	2	3	4	5	Reported SAR/1.6 + PD/10 Summation Total Exposure ratio			
			WLAN2.4GHz Ant 4+3	WLAN5/6GHz Ant 4+3	Bluetooth Ant 4	Bluetooth Ant 3	PD	1+5 Summed Ratio	2+5 Summed Ratio	2+3+5 Summed Ratio	2+4+5 Summed Ratio
			1g SAR (W/kg)	1g SAR (W/kg)	1g SAR (W/kg)	1g SAR (W/kg)	4cm^2(W/m^2)				
n261	Plane A sub-module	Right Cheek	0.523	0.269	0.093	0.314	4.430	**0.770**	**0.611**	**0.669**	**0.807**
		Right Tilted	0.114	0.228	0.100	0.034	4.430	**0.514**	**0.586**	**0.648**	**0.607**
		Left Cheek	0.380	0.303	0.286	0.134	4.430	**0.681**	**0.632**	**0.811**	**0.716**
		Left Tilted	0.360	0.268	0.399	0.009	4.430	**0.668**	**0.611**	**0.860**	**0.616**
n261	Plane B sub-module	Right Cheek	0.523	0.269	0.093	0.314	0.520	**0.379**	**0.220**	**0.278**	**0.416**
		Right Tilted	0.114	0.228	0.100	0.034	0.520	**0.123**	**0.195**	**0.257**	**0.216**
		Left Cheek	0.380	0.303	0.286	0.134	0.520	**0.290**	**0.241**	**0.420**	**0.325**
		Left Tilted	0.360	0.268	0.399	0.009	0.520	**0.277**	**0.220**	**0.469**	**0.225**
n260	Plane A sub-module	Right Cheek	0.523	0.269	0.093	0.314	5.740	**0.901**	**0.742**	**0.800**	**0.938**
		Right Tilted	0.114	0.228	0.100	0.034	5.740	**0.645**	**0.717**	**0.779**	**0.738**
		Left Cheek	0.380	0.303	0.286	0.134	5.740	**0.812**	**0.763**	**0.942**	**0.847**
		Left Tilted	0.360	0.268	0.399	0.009	5.740	**0.799**	**0.742**	**0.991**	**0.747**
n260	Plane B sub-module	Right Cheek	0.523	0.269	0.093	0.314	0.280	**0.355**	**0.196**	**0.254**	**0.392**
		Right Tilted	0.114	0.228	0.100	0.034	0.280	**0.099**	**0.171**	**0.233**	**0.192**
		Left Cheek	0.380	0.303	0.286	0.134	0.280	**0.266**	**0.217**	**0.396**	**0.301**
		Left Tilted	0.360	0.268	0.399	0.009	0.280	**0.253**	**0.196**	**0.445**	**0.201**

<Hotspot Exposure Condition>

<5GNR FR2, WLAN Index 3, BT Index 4>

WWAN Band	FR1 Band	Exposure Position	1	2	3	4	5	Reported SAR/1.6 + PD/10 Summation Total Exposure ratio			
			WLAN2.4GHz Ant 4+3	WLAN5/6GHz Ant 4+3	Bluetooth Ant 4	Bluetooth Ant 3	PD	1+5 Summed	2+5 Summed	2+3+5 Summed	2+4+5 Summed
			1g SAR (W/kg)	1g SAR (W/kg)	1g SAR (W/kg)	1g SAR (W/kg)	4cm^2(W/m^2)				
n261	Plane A sub-module	Front	0.377	0.207	0.070	0.124	4.237	**0.659**	**0.553**	**0.597**	**0.631**
		Back	0.321	0.295	0.075	0.097	4.237	**0.624**	**0.608**	**0.655**	**0.669**
		Left side	0.507	0.223	0.001	0.255	4.237	**0.741**	**0.563**	**0.564**	**0.722**
		Right side	0.427	0.189	0.099	0.001	4.237	**0.691**	**0.542**	**0.604**	**0.542**
		Top side	0.427	0.388	0.214	0.017	4.237	**0.691**	**0.666**	**0.800**	**0.677**
n261	Plane B sub-module	Front	0.377	0.207	0.070	0.124	3.402	**0.576**	**0.470**	**0.513**	**0.547**
		Back	0.321	0.295	0.075	0.097	3.402	**0.541**	**0.525**	**0.571**	**0.585**
		Left side	0.507	0.223	0.001	0.255	3.402	**0.657**	**0.480**	**0.480**	**0.639**
		Right side	0.427	0.189	0.099	0.001	3.402	**0.607**	**0.458**	**0.520**	**0.459**
		Top side	0.427	0.388	0.214	0.017	3.402	**0.607**	**0.583**	**0.716**	**0.593**
n260	Plane A sub-module	Front	0.377	0.207	0.070	0.124	5.592	**0.795**	**0.689**	**0.732**	**0.766**
		Back	0.321	0.295	0.075	0.097	5.592	**0.760**	**0.744**	**0.790**	**0.804**
		Left side	0.507	0.223	0.001	0.255	5.592	**0.876**	**0.699**	**0.699**	**0.858**
		Right side	0.427	0.189	0.099	0.001	5.592	**0.826**	**0.677**	**0.739**	**0.678**
		Top side	0.427	0.388	0.214	0.017	5.592	**0.826**	**0.802**	**0.935**	**0.812**
n260	Plane B sub-module	Front	0.377	0.207	0.070	0.124	4.268	**0.662**	**0.556**	**0.600**	**0.634**
		Back	0.321	0.295	0.075	0.097	4.268	**0.627**	**0.611**	**0.658**	**0.672**
		Left side	0.507	0.223	0.001	0.255	4.268	**0.744**	**0.566**	**0.567**	**0.726**
		Right side	0.427	0.189	0.099	0.001	4.268	**0.694**	**0.545**	**0.607**	**0.546**
		Top side	0.427	0.388	0.214	0.017	4.268	**0.694**	**0.669**	**0.803**	**0.680**

<Body-Worn Exposure Condition>

<5GNR FR2, WLAN Index 5, BT Index 4>

WWAN Band	FR1 Band	Exposure Position	1	2	3	4	5	Reported SAR/1.6 + PD/10 Summation Total Exposure ratio			
			WLAN2.4GHz Ant 4+3	WLAN5/6GHz Ant 4+3	Bluetooth Ant 4	Bluetooth Ant 3	PD	1+5 Summed Ratio	2+5 Summed Ratio	2+3+5 Summed Ratio	2+4+5 Summed Ratio
			1g SAR (W/kg)	1g SAR (W/kg)	1g SAR (W/kg)	1g SAR (W/kg)	4cm^2(W/m^2)				
n261	Plane A sub-module	Front	0.484	0.183	0.070	0.141	4.237	**0.726**	**0.538**	**0.582**	**0.626**
		Back	0.548	0.487	0.098	0.097	4.237	**0.766**	**0.728**	**0.789**	**0.789**
n261	Plane B sub-module	Front	0.484	0.183	0.070	0.141	3.402	**0.643**	**0.455**	**0.498**	**0.543**
		Back	0.548	0.487	0.098	0.097	3.402	**0.683**	**0.645**	**0.706**	**0.705**
n260	Plane A sub-module	Front	0.484	0.183	0.070	0.141	5.592	**0.862**	**0.674**	**0.717**	**0.762**
		Back	0.548	0.487	0.098	0.097	5.592	**0.902**	**0.864**	**0.925**	**0.924**
n260	Plane B sub-module	Front	0.484	0.183	0.070	0.141	4.268	**0.729**	**0.541**	**0.585**	**0.629**
		Back	0.548	0.487	0.098	0.097	4.268	**0.769**	**0.731**	**0.792**	**0.792**

<5GNR FR2, BT Index 3>

WWAN Band	FR1 Band	Exposure Position	1	2	3	Reported SAR/1.6 + PD/10 Summation Total Exposure ratio	
			Bluetooth Ant 4	Bluetooth Ant 3	PD	1+3 Summed Ratio	2+3 Summed Ratio
			1g SAR (W/kg)	1g SAR (W/kg)	4cm^2(W/m^2)		
n261	Plane A sub-module	Front	0.249	0.306	4.237	**0.579**	**0.615**
		Back	0.329	0.338	4.237	**0.629**	**0.635**
n261	Plane B sub-module	Front	0.249	0.306	3.402	**0.496**	**0.531**
		Back	0.329	0.338	3.402	**0.546**	**0.551**
n260	Plane A sub-module	Front	0.249	0.306	5.592	**0.715**	**0.750**
		Back	0.329	0.338	5.592	**0.765**	**0.770**
n260	Plane B sub-module	Front	0.249	0.306	4.268	**0.582**	**0.618**
		Back	0.329	0.338	4.268	**0.632**	**0.638**

<Product Specific Exposure Condition>

<5GNR FR2 with WLAN Index 4>

WWAN Band	FR1 Band	Exposure Position	1	2	Reported SAR/4.0 + PD/10 Summation Total Exposure ratio
			WLAN5/6GHz Ant 4+3	PD	1+2 Summed Ratio
			10g SAR (W/kg)	4cm^2(W/m^2)	
n261	Plane A sub-module	Front	0.973	4.432	**0.686**
		Back	0.646	3.264	**0.488**
		Left side	1.623	0.327	**0.438**
		Right side	0.657	1.686	**0.333**
		Top side	0.934	7.500	**0.984**
		Bottom side			**0.000**
n261	Plane B sub-module	Front	0.973	0.518	**0.295**
		Back	0.646	7.500	**0.912**
		Left side	1.623	0.323	**0.438**
		Right side	0.657	2.759	**0.440**
		Top side	0.934	4.228	**0.656**
		Bottom side			**0.000**
n260	Plane A sub-module	Front	0.973	5.738	**0.817**
		Back	0.646	4.293	**0.591**
		Left side	1.623	0.377	**0.443**
		Right side	0.657	1.917	**0.356**
		Top side	0.934	7.500	**0.984**
		Bottom side			**0.000**
n260	Plane B sub-module	Front	0.973	0.285	**0.272**
		Back	0.646	7.500	**0.912**
		Left side	1.623	0.599	**0.466**
		Right side	0.657	1.882	**0.352**
		Top side	0.934	3.225	**0.556**
		Bottom side			**0.000**

Test Engineer：White Huang, Jerry Hsu and Charles Shen

13. Uncertainty Assessment

The budget is valid for evaluation distances > λ/2π. For specific tests and configurations, the Uncertainty could be considerably smaller.

cDASY6 Mo dule mmWave Uncertainty Budget Evaluation Distances to the Antennas > λ/2π					
Error Description	Uncertainty Value (±dB)	Probability	Divisor	(Ci)	Standard Uncertainty (±dB)
Uncertainty terms dependent on the measurement system					
Probe Calibration	0.49	N	1	1	0.49
Probe correction	0.00	R	1.732	1	0.00
Frequency response (BW ≤ 1 GHz)	0.20	R	1.732	1	0.12
Sensor cross coupling	0.00	R	1.732	1	0.00
Isotropy	0.50	R	1.732	1	0.29
Linearity	0.20	R	1.732	1	0.12
Probe scattering	0.00	R	1.732	1	0.00
Probe positioning offset	0.30	R	1.732	1	0.17
Probe positioning repeatability	0.04	R	1.732	1	0.02
Sensor mechanical offset	0.00	R	1.732	1	0.00
Probe spatial resolution	0.00	R	1.732	1	0.00
Field impedance dependence	0.00	R	1.732	1	0.00
Amplitude and phase drift	0.00	R	1.732	1	0.00
Amplitude and phase noise	0.04	R	1.732	1	0.02
Measurement area truncation	0.00	R	1.732	1	0.00
Data acquisition	0.03	N	1	1	0.03
Sampling	0.00	R	1.732	1	0.00
Field reconstruction	0.60	R	1.732	1	0.35
Forward transformation	0.00	R	1.732	1	0.00
Power density scaling	0.00	R	1.732	1	0.00
Spatial averaging	0.10	R	1.732	1	0.06
System detection limit	0.04	R	1.732	1	0.02
Uncertainty terms dependent on the DUT and environmental factors					
Probe coupling with DUT	0.00	R	1.732	1	0.0
Modulation response	0.40	R	1.732	1	0.2
Integration time	0.00	R	1.732	1	0.0
Response time	0.00	R	1.732	1	0.0
Device holder influence	0.10	R	1.732	1	0.1
DUT alignment	0.00	R	1.732	1	0.0
RF ambient conditions	0.04	R	1.732	1	0.0
Ambient reflections	0.04	R	1.732	1	0.0
Immunity / secondary reception	0.00	R	1.732	1	0.0
Drift of the DUT		R	1.732	1	
Combined Std. Uncertainty					0.76 dB
Expanded STD Uncertainty (95%)					1.52 dB

Declaration of Conformity:
The test results with all measurement uncertainty excluded is presented in accordance with the regulation limits or requirements declared by manufacturers.

Comments and Explanations:
The declared of product specification for EUT presented in the report are provided by the manufacturer, and the manufacturer takes all the responsibilities for the accuracy of product specification.

14. References

[1] FCC 47 CFR Part 2 “Frequency Allocations and Radio Treaty Matters; General Rules and Regulations”

[2] FCC KDB 447498 D01 v06, “Mobile and Portable Device RF Exposure Procedures and Equipment Authorization Policies”, Oct 2015

[3] FCC KDB 865664 D02 v01r02, “RF Exposure Compliance Reporting and Documentation Considerations” Oct 2015.

[4] FCC KDB 648474 D04 v01r03, “SAR Evaluation Considerations for Wireless Handsets”, Oct 2015.