RF EXPOSURE EVALUATION REPORT

FCC ID : MSQI001D

Equipment : ASUS Phone(Mobile Phone)

Model Name : ASUS_I001D, ASUS_I001DC

Applicant : ASUSTEK COMPUTER INC.

4F, No. 150, LI-TE RD., PEITOU, TAIPEI, TAIWAN

Manufacturer: Guangdong Enok Communication Co., Ltd.

No. 137, 139, Lixiang Road., Songmushan Village,

Report No.: FA931316B

Dalang Town, Dongguan City, Guangdong

Province, China

Standard : FCC 47 CFR Part 2 (2.1093)

We, SPORTON INTERNATIONAL INC have been evaluated in accordance with 47 CFR Part 2.1093 for the device and pass the limit.

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

Approved by: Cona Huang / Deputy Manager

Gua Guarg.

SPORTON INTERNATIONAL INC. EMC & Wireless Communications Laboratory

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TEL: 886-3-327-3456 Page 1 of 17
FAX: 886-3-328-4978 Issued Date: Jul. 22, 2019



Report No.: FA931316B

Table of Contents

1. Summary	4
1. Summary	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	
5.1 EUmmWave Probe / E-Field 5G Probe	8
5.2 Data Acquisition Electronics (DAE)	9
5.3 Scan configuration	9
6. Test Equipment List	
7. System Verification Source	10
8. Power Density System Verification	
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
10. 802.11ad Duty cycle	13
11. Test Positions	
12. RF Exposure Evaluation Results	
13. Simultaneous Transmission Analysis	15
14. Uncertainty Assessment	16
15 References	17

Appendix A. Plots of System Performance Check Appendix B. Plots of Power Density Measurement Appendix C. DASY Calibration Certificate Appendix D. Simultaneous Transmission analysis

Appendix E. Test Setup Photos

TEL: 886-3-327-3456 FAX: 886-3-328-4978 Form version: 180516

History of this test report

Report No.: FA931316B

Report No.	Version	Description	Issued Date
FA931316B	01	Initial issue of report	Jul. 22, 2019

TEL: 886-3-327-3456 Page 3 of 17
FAX: 886-3-328-4978 Issued Date: Jul. 22, 2019

1. Summary

The maximum measured average power density found during testing for ASUSTEK COMPUTER INC., ASUS Phone(Mobile Phone), are as follows.

Report No.: FA931316B

	Simultaneous transmission with other transmitters			
	Highest Total Power Density, averaging over 4cm ² Limit (FCC part 1.310) (mW/cm ²)			
5GNR n260	0.848	1	0.998	

2. Guidance Applied

The Power Density testing specification, method, and procedure for this device is in accordance with the following standards:

- 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 Draft TR 63170

TEL: 886-3-327-3456 Page 4 of 17
FAX: 886-3-328-4978 Issued Date: Jul. 22, 2019

3. Equipment Under Test (EUT) Information

3.1 General Information

	Product Feature & Specification					
Equipment Name	ASUS Phone(Mobile Phone)					
Model Name	ASUS_I001D, ASUS_I001DC					
FCC ID	MSQI001D					
Wireless Technology and Frequency Range	GSM850: 824.2 MHz ~ 848.8 MHz GSM1900: 1850.2 MHz ~ 1909.8 MHz WCDMA Band II: 1852.4 MHz ~ 1752.6 MHz WCDMA Band IV: 1712.4 MHz ~ 1752.6 MHz WCDMA Band V: 826.4 MHz ~ 846.6 MHz LTE Band 2: 1850.7 MHz ~ 1909.3 MHz LTE Band 4: 1710.7 MHz ~ 1754.3 MHz LTE Band 5: 824.7 MHz ~ 848.3 MHz LTE Band 7: 2502.5 MHz ~ 2567.5 MHz LTE Band 12: 699.7 MHz ~ 715.3 MHz LTE Band 13: 779.5 MHz ~ 784.5 MHz LTE Band 17: 706.5 MHz ~ 784.5 MHz LTE Band 26: 814.7 MHz ~ 848.3 MHz LTE Band 38: 2572.5 MHz ~ 2617.5 MHz LTE Band 41: 2498.5 MHz ~ 2687.5 MHz LTE Band 66: 1710.7 MHz ~ 1779.3 MHz WLAN 2.4GHz Band: 2412 MHz ~ 2462 MHz WLAN 5.3GHz Band: 5180 MHz ~ 5320 MHz WLAN 5.3GHz Band: 5500 MHz ~ 5320 MHz WLAN 5.5GHz Band: 5745 MHz ~ 5825 MHz Bluetooth: 2402 MHz ~ 2480 MHz NFC: 13.56 MHz 802.11ad					
Mode	GSM/GPRS/EGPRS RMC/AMR 12.2Kbps HSDPA HSUPA DC-HSDPA LTE: QPSK, 16QAM, 64QAM WLAN: 802.11a/b/g/n/ac HT20 / HT40 / VHT20 / VHT40 / VHT80 Bluetooth BR/EDR/LE NFC:ASK					
EUT Stage	Identical Prototype					

Report No.: FA931316B

Reviewed by: <u>Eric Huang</u> Report Producer: <u>Wan Liu</u>

TEL: 886-3-327-3456 Page 5 of 17
FAX: 886-3-328-4978 Issued Date: Jul. 22, 2019

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.

Report No.: FA931316B

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 $\text{mW/cm}^2 = 10 \text{W/m}^2$

Frequency range (MHz)	Electric field strength (V/m)	Magnetic field strength (A/m)	Power density (mW/cm ²)	Averaging time (minutes)
8.	(A) Limits for O	ccupational/Controlled Expos	sures	81
0.3-3.0	614	1.63	*(100)	6
3.0-30	1842/	f 4.89/1	*(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 Gene	ral Population/Uncontrolled I	Exposure	
0.3-1.34	614	1.63	*(100)	30
1.34-30	824/	f 2.19/1	*(180/f2)	30
30-300	27.5	0.073	0.2	30
300-1500			f/1500	30
1500-100,000	1		1.0	30

Table 1

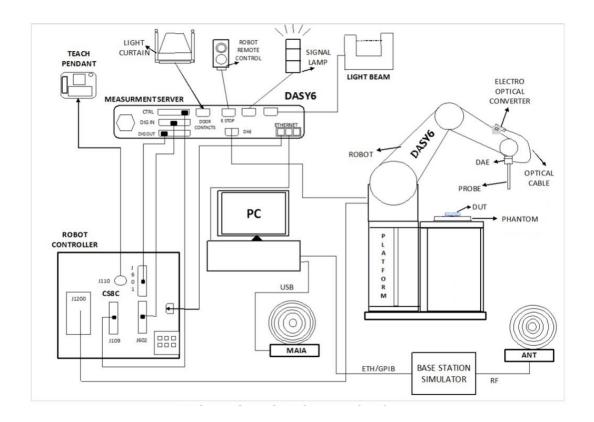
TEL: 886-3-327-3456 Page 6 of 17
FAX: 886-3-328-4978 Issued Date: Jul. 22, 2019

Report No.: FA931316B

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

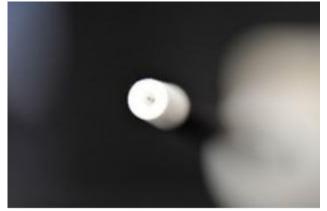


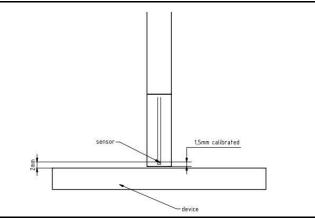
TEL: 886-3-327-3456 Page 7 of 17
FAX: 886-3-328-4978 Issued Date: Jul. 22, 2019

5.1 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			
	100			
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			





Report No.: FA931316B

TEL: 886-3-327-3456 Page 8 of 17
FAX: 886-3-328-4978 Issued Date: Jul. 22, 2019

RF EXPOSURE EVALUATION REPORT

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. 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.



Report No.: FA931316B

5.3 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		
Manufacturei	Name of Equipment	i ype/iviodei	Serial Nulliber	Last Cal.	Due Date	
SPEAG	5G Verification Source	60 GHz	1009	Apr. 24, 2019	Apr. 23, 2020	
SPEAG	SPEAG EUmmWV Probe Tip Protection		9413	Feb. 13, 2019	Feb. 12, 2020	
SPEAG	Data Acquisition Electronics	DAE4	918	Jun. 20, 2018	Jun. 19, 2019	
TESTO	Hygro meter	608-H1	34913631	Aug. 27, 2018	Aug. 26, 2019	
OML	Mixer	M15HW/A	V91113-1	Oct. 10, 2018	Oct. 09, 2019	
Agilent	Spectrum Analyzer	E4408B	MY44211028	Aug. 28, 2018	Aug. 27, 2019	
Custom Microwave	Standard Horn antenna	M15RH	V91113-A	NCR	NCR	

TEL: 886-3-327-3456 Page 9 of 17
FAX: 886-3-328-4978 Issued Date: Jul. 22, 2019

7. System Verification Source

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

Report No.: FA931316B

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				

 TEL: 886-3-327-3456
 Page 10 of 17

 FAX: 886-3-328-4978
 Issued Date : Jul. 22, 2019

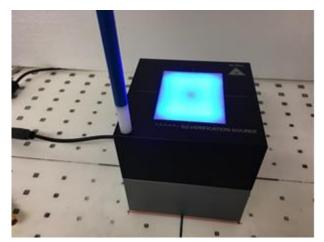
8. Power Density System Verification

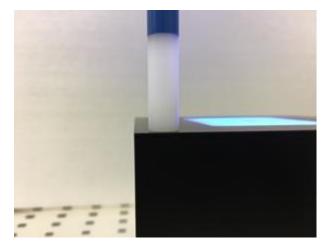
The system performance check verifies that the system operates within its specifications.

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 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	$0.25 \left(\frac{\tilde{\lambda}}{4}\right)$	60/60	24×24
60	$0.25 \left(\frac{\hat{\lambda}}{4}\right)$	32.5/32.5	26×26
90	$0.25 \left(\frac{\lambda}{4}\right)$	30/30	36×36

Settings for measurement of verification sources





Report No.: FA931316B

Verification Setup photo

9. System Verification Results

Date	Frequency (GHz)	5G Verification Source	Probe S/N	DAE S/N	Distance (mm)	Measured 4 cm² (W/m²)	Targeted 4 cm² (W/m²)	Deviation (%)
2019/6/1	60	60GHz_1009	9413	918	10	243	247	-1.62%

TEL: 886-3-327-3456 Page 11 of 17
FAX: 886-3-328-4978 Issued Date: Jul. 22, 2019

RF EXPOSURE EVALUATION REPORT

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 (\emptyset,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, \emptyset and θ) are sufficient for the description of the incident field.

Report No.: FA931316B

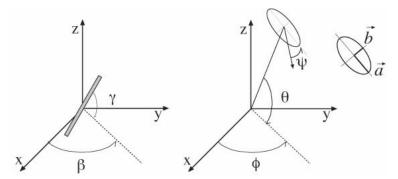


Illustration of the angles used for the numerical description of the sensor and the orientation of an ellipse in 3-D space.

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 (\emptyset , 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
- n · $Re\{S\}$ 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.

TEL: 886-3-327-3456 Page 12 of 17
FAX: 886-3-328-4978 Issued Date: Jul. 22, 2019

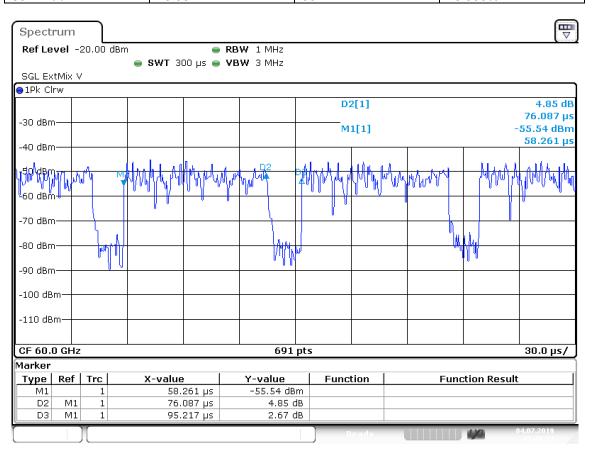
Report No.: FA931316B

10. 802.11ad Duty cycle

<Duty Cycle>

The actual 11ad RF signal is a wideband signal and is limited to transmit at 80% duty cycle.

Mode	On Time(us)	On+Off Time(us)	Duty Cycle (%)
802.11ad	76.087	95.217	79.909%



Date: 4.JUL.2019 15:46:31

TEL: 886-3-327-3456 Page 13 of 17
FAX: 886-3-328-4978 Issued Date: Jul. 22, 2019

11. Test Positions

902 11 ad	Measurement Plane						
802.11ad	Front	Back	Left	Right	Тор	Bottom	
Test Required	Yes	Yes	Yes	No	No	No	

Report No.: FA931316B

General Note:

1. According to appendix E antenna location, when the antenna to the edge is higher than 25mm, for that edge is not tested

12. RF Exposure Evaluation Results

General Note:

- 1. The 802.11ad PD test was performed of a 2mm separation between sensor and EUT surface (the probe tip is 0.5mm to the EUT surface).
- 2. The test position/separation and the area to scan for each test is selected and identified in the simulation report, details in illustrated in the simulation report exhibit and the operational description.
- 3. Using test software, the device under test was configured to transmit maximum power and at 100% duty cycle, at the center frequency of each desired channel. The actual 11ad RF signal is a wideband signal and is limited to transmit at 80% duty cycle. Therefore the measured maximum 4cm² average power density was scaled to account for the 80% duty factor.
- 4. According to TCBC Workshop in October 2018, 4 cm² averaging area may now be considered.
- Above 6 GHz, Maximum Permissible Exposure (MPE) limits apply to portable exposure conditions according to 47 CFR §2.1093.

Plot No.	Channel	Frequency (GHz)	Exposure Surface	Modulation	Gain Index	Test separation	Epeak [V/m]	Hpeak [A/m]	Measured results Savg inc 4cm^2 (W/m2)	Measured results Savg tot 4cm^2 (W/m2)	80% Duty cycle Reported Savg tot 4cm^2 (W/m2)	80% Duty cycle Reported Savg tot 4cm^2 (W/m2)
	1	58.32	Back	BPSK	1	2mm	110	0.287	3.740	4.980	2.992	3.984
	2	60.48	Back	BPSK	1	2mm	132	0.335	4.270	4.910	3.416	3.928
	3	62.64	Back	BPSK	1	2mm	113	0.324	3.730	5.950	2.984	4.760
	3	62.64	Back	BPSK	1	2mm	112	0.319	3.610	5.520	2.888	4.416
	1	58.32	Back	BPSK	1	2mm	115	0.376	3.110	4.660	2.488	3.728
	1	58.32	Back	BPSK	1	2mm	110	0.292	2.920	5.250	2.336	4.200
01	1	58.32	Back	BPSK	1	2mm	173	0.499	6.210	10.600	4.968	<mark>8.480</mark>
	2	60.48	Back	BPSK	1	2mm	92.5	0.283	3.220	5.040	2.576	4.032
	2	60.48	Back	BPSK	1	2mm	99.4	0.265	2.820	4.590	2.256	3.672
	2	60.48	Back	BPSK	1	2mm	136	0.382	3.260	4.380	2.608	3.504
	3	62.64	Back	BPSK	1	2mm	153	0.408	5.050	7.190	4.040	5.752
	3	62.64	Back	BPSK	1	2mm	183	0.454	4.950	6.110	3.960	4.888
	1	58.32	Left	BPSK	1	2mm	34.5	0.099	2.470	2.520	1.976	2.016
	2	60.48	Left	BPSK	1	2mm	36.4	0.098	1.420	1.520	1.136	1.216
	2	60.48	Front	BPSK	1	2mm	12.6	0.035	0.334	0.338	0.267	0.270

TEL: 886-3-327-3456 Page 14 of 17
FAX: 886-3-328-4978 Issued Date: Jul. 22, 2019



13. Simultaneous Transmission Analysis

Mode	Simultaneous Transmission Configurations	Head	Hotspot	Body-worn	Product Specific
	WWAN + WLAN 2.4GHz (WIFI 0/Chain0)	Yes	Yes	Yes	Yes
	WWAN + BT(WIFI 0/Chain0)	Yes	Yes	Yes	Yes
	WWAN + WLAN 5GHz (WIFI 3/Chain1)	Yes	Yes	Yes	Yes
Calling Mode	WWAN + WLAN 5GHz (WIFI 3/Chain1) + BT(WIFI 0/Chain0)	Yes	Yes	Yes	Yes
	WWAN + WLAN 2.4GHz MIMO	Yes	Yes	Yes	Yes
	WWAN + WLAN 5GHz MIMO	Yes	Yes	Yes	Yes
	WWAN + WLAN 2.4GHz (WIFI 0/Chain0)+ WLAN 5GHz (WIFI 3/Chain1)	Yes	Yes	Yes	Yes
	WWAN + WLAN 2.4GHz (WIFI 0/Chain0)		Yes	Yes	Yes
	WWAN + BT(WIFI 0/Chain0)		Yes	Yes	Yes
	WWAN + WLAN 5GHz (WIFI 3/Chain1)		Yes	Yes	Yes
Camera Mode	WWAN + WLAN 5GHz (WIFI 3/Chain1) + BT(WIFI 0/Chain0)		Yes	Yes	Yes
	WWAN + WLAN 2.4GHz MIMO		Yes	Yes	Yes
	WWAN + WLAN 5GHz MIMO		Yes	Yes	Yes
	WWAN + WLAN 2.4GHz (WIFI 0/Chain0)+ WLAN 5GHz (WIFI 3/Chain1)		Yes	Yes	Yes
	WWAN + WLAN 2.4GHz (WIFI 0/Chain0)		Yes	Yes	Yes
	WWAN + BT(WIFI 0/Chain0)		Yes	Yes	Yes
	WWAN + WLAN 5GHz (WIFI 3/Chain1)		Yes	Yes	Yes
Normal Mode	WWAN + WLAN 5GHz (WIFI 3/Chain1) + BT(WIFI 0/Chain0)		Yes	Yes	Yes
Nominal Mode	WWAN + WLAN 2.4GHz MIMO		Yes	Yes	Yes
	WWAN + WLAN 5GHz MIMO		Yes	Yes	Yes
	WWAN + WLAN 2.4GHz (WIFI 0/Chain0)+ WLAN 5GHz (WIFI 3/Chain1)		Yes	Yes	Yes
	WWAN + WLAN 2.4GHz (WIFI 0/Chain0)		Yes	Yes	Yes
	WWAN + BT(WIFI 0/Chain0)		Yes	Yes	Yes
	WWAN + WLAN 5GHz (WIFI 3/Chain1)		Yes	Yes	Yes
Gaming Mode	WWAN + WLAN 5GHz (WIFI 3/Chain1) + BT(WIFI 0/Chain0)		Yes	Yes	Yes
	WWAN + WLAN 2.4GHz MIMO		Yes	Yes	Yes
	WWAN + WLAN 5GHz MIMO		Yes	Yes	Yes
	WWAN + WLAN 2.4GHz (WIFI 0/Chain0)+ WLAN 5GHz (WIFI 3/Chain1)		Yes	Yes	Yes

Report No.: FA931316B

General Note:

- 1. The WWAN / WLAN and BT SAR test results were refer to sporton FCC SAR report, report no.: FA931316A
- 2. The 802.11ad PD test was performed of a 2mm separation between sensor and EUT surface, the test results are conservatively used in simultaneous transmission analysis in body exposure conditions.
- 3. Considering 802.11ad with WWAN / WLAN and Bluetooth can transmit simultaneously, the basic restrictions are on SAR and power density, and summation of these quantities should follow below formula and the simultaneous transmission analysis was following below step:
 - i) Use the standalone SAR according original report to collocate with 802.11ad power density at each exposure positions, if the result < 1, additional analysis is not necessary.
 - ii) If this ratio is larger than 1, use surface single point SAR measurements and treat as 1-gram measurements with 1.6 W/kg for 1g, 4.0W/kg for 10g as the limit. Use these measurement for the point by point summation and confirm the ratio summation does not exceed 1

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

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

Test Engineer: Aaron Chen, Steven Chang, Thomas Wang, and Nick Yu

TEL: 886-3-327-3456 Page 15 of 17
FAX: 886-3-328-4978 Issued Date: Jul. 22, 2019

14. Uncertainty Assessment

The budget is valid for evaluation distances > $\lambda/2\pi$. For specific tests and configurations, the Uncertainty could be considerably smaller.

Report No.: FA931316B

		dule mmWave L stances to the A				
Error Description	Uncertainty Value (± dB)	Probability	Divisor	(Ci)	Standard Uncertainty (±dB)	(Vi) Veff
Measurement System						
Probe Calibration	0.49	N	1	1	0.49	∞
Hemispherical Isotropy	0.50	R	1.732	1	0.29	∞
Linearity	0.20	R	1.732	0	0.12	∞
System Detection Limits	0.04	R	1.732	1	0.02	∞
Modulation Response	0.40	R	1.732	1	0.23	∞
Readout Electronics	0.03	N	1	1	0.03	∞
Response Time	0.00	R	1.732	1	0.00	∞
Integration Time	0.00	R	1.732	1	0.00	∞
RF Ambient Noise	0.2	R	1.732	1	0.12	∞
RF Ambient Reflections	0.21	R	1.732	1	0.12	∞
Probe Positioner	0.04	R	1.732	1	0.02	∞
Probe Positioning	0.30	R	1.732	1	0.17	∞
Savg Reconstruction	0.60	R	1.732	1	0.35	∞
Test Sample Related						
Power Drift	0.2	R	1.732	1	0.12	∞
Input Power	0	N	1	0	0.00	∞
	0.76 dB	∞				
	K=2					
	1.52 dB					

TEL: 886-3-327-3456 Page 16 of 17
FAX: 886-3-328-4978 Issued Date: Jul. 22, 2019



15. References

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Report No.: FA931316B

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- [3] FCC KDB 865664 D02 v01r02, "RF Exposure Compliance Reporting and Documentation Considerations" Oct 2015.
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TEL: 886-3-327-3456 Page 17 of 17
FAX: 886-3-328-4978 Issued Date: Jul. 22, 2019