POWER DENSITY EVALUATION REPORT

FCC 47 CFR § 2.1093

For
60GHz RF/BB Module with USB3.0 interface

FCC ID: 2AVCWMWC434M
Model Name: MWC-434x

Report Number: 14757552-S1V3
Issue Date: 11/8/2023

Prepared for
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ACCREDITED
CERT #0751.05

REVISION HISTORY

Rev.	Date	Revisions	Revised By
V1	6/20/2023	Initial Issue	--
V2	6/29/2023	Added Appendix E	Dave Weaver
V3	11/8/2023	Table 9.2 – updated units	Dave Weaver

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1. Attestation of Test Results

Applicant Name	X-Com	
FCC ID	2AVCWMWC434M	
Model Name	MWC-434x	
Applicable Standards	FCC 47 CFR § 2.1093	
Exposure Category	Radiofrequency (RF) Radiation Exposure (above 6GHz)	
	Uncontrol (mW/cm^2 over 4 cm^2) 30 min average	Occupational/controlled (mW/cm^2 over 4 cm^2) 6 min average
	1.0	5
Applicable limit	☒ Uncontrolled / ☐ Occupational/controlled	
PD Result (mW/cm^2 over $4cm^2$)	0.0794	
Date Tested	4/10/2023	
Test Results	Pass	

UL Verification Services Inc. tested the above equipment in accordance with the requirements set forth in the above standards. The test results show that the equipment tested is capable of demonstrating compliance with the requirements as documented in this report.

This report contains data provided by the customer which can impact the validity of results. UL Verification Services Inc. is only responsible for the validity of results after the integration of the data provided by the customer.

The results documented in this report apply only to the tested sample, under the conditions and modes of operation as described herein. It is the manufacturer's responsibility to assure that additional production units of this model are manufactured with identical electrical and mechanical components. All samples tested were in good operating condition throughout the entire test program. Measurement Uncertainties are published for informational purposes only and were not taken into account unless noted otherwise.

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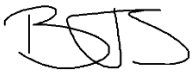
Approved & Released By:	Prepared By:
	
Dave Weaver Operations Leader UL Verification Services Inc.	Brandon Sousa Senior Laboratory Technician UL Verification Services Inc.

2. Test Specification, Methods and Procedures

The tests documented in this report were performed in accordance with FCC 47 CFR § 2.1093, the following FCC Published RF exposure KDB procedures:

- 447498 D01 General RF Exposure Guidance v06
- 865664 D01 SAR measurement 100 MHz to 6 GHz v01r04
- 865664 D02 RF Exposure Reporting v01r02
- SPEAG DASY 6 System Handbook; part 4 cDASY6 Module mmWave
- IEC TR 63170: 2018

In addition to the above, TCB workshop information was used.

- TCB workshop November, 2017; RF Exposure Procedures (Power Density Evaluation)
- TCB workshop October, 2018; RF Exposure Procedures (Millimeter Wave Assessment)
- TCB workshop April, 2019; RF Exposure Procedures (Millimeter Wave RF Exposure Evaluation)
- TCB workshop November, 2019; RF Exposure Procedures (Millimeter Wave Scan Requirements)
- TCB workshop October 2020; RF Exposure Procedures (U NII 6-7 GHz RF Exposure)

3. Facilities and Accreditation

The test sites and measurement facilities used to collect data are located at

47266 Benicia Street
SAR Lab 6

UL Verification Services Inc. is accredited by A2LA, Certificate Number 0751.05

The Test Lab Conformity Assessment Body Identifier (CABID)

Location	CABID	Company Number
47173 Benicia Street, Fremont, CA, 94538 UNITED STATES	US0104	2324A
47266 Benicia Street, Fremont, CA, 94538 UNITED STATES		

4. Measurement System & Test Equipment

4.1. EUmmWVx / E-Field 5G Probe

E-Field mm-Wave Probe for General Near-Field Measurements

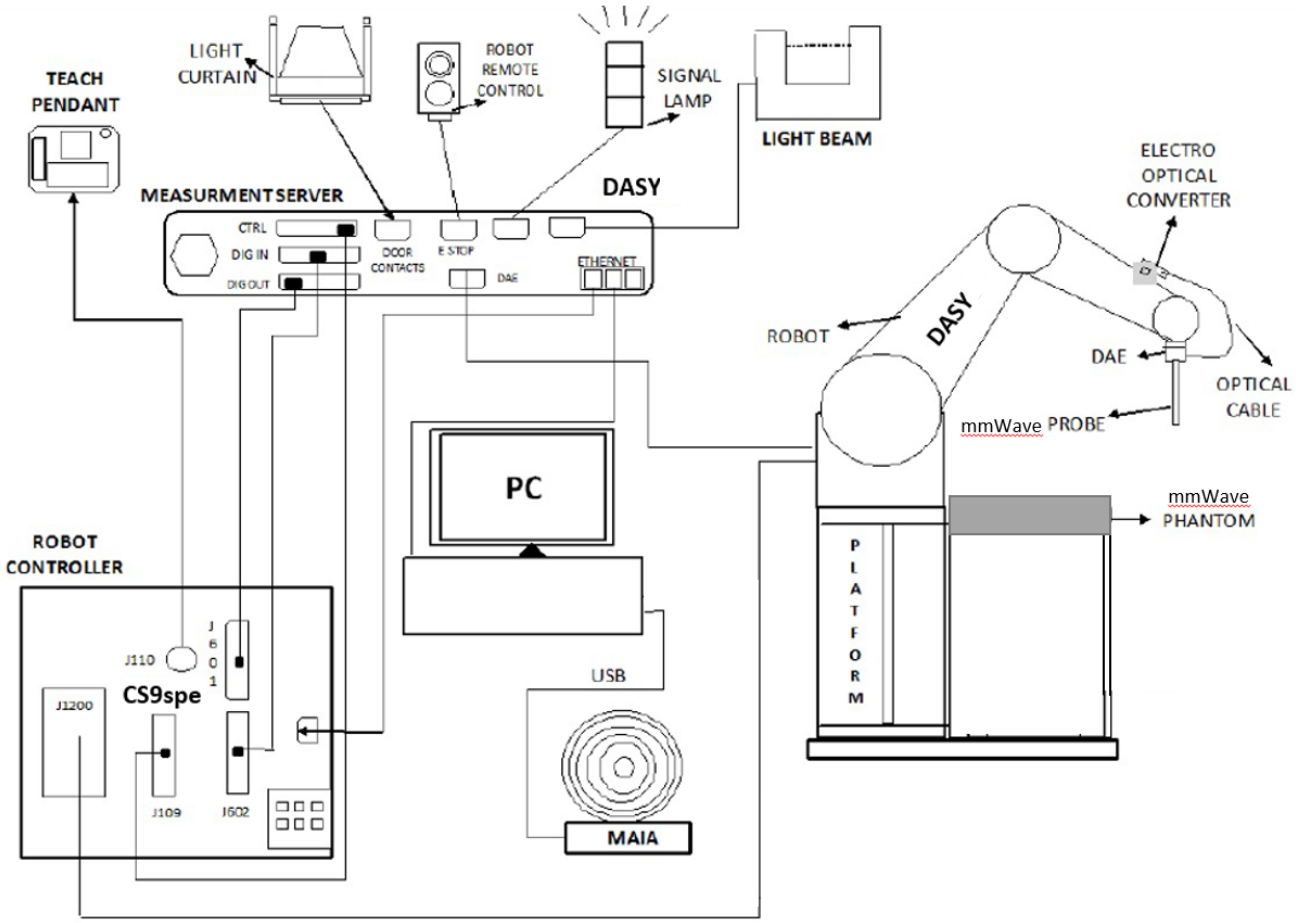
	Two dipoles optimally arranged to obtain pseudo-vector information Minimum 3 measurements/point, 120º rotated around probe axis Sensors (0.8mm length) printed on glass substrate protected by high density foam Low perturbation of the measured field Requires positioner which can do accurate probe rotation
Frequency Range	750 MHz – 110 GHz (EUmmWV4)
Dynamic Range	< 20 V/m - 10'000 V/m with PRE-10 (min < 50 V/m - 3000 V/m)
Position Precision	< 0.2 mm
Dimensions	Overall length: 337 mm (tip: 20 mm) Tip diameter: encapsulation 8 mm (internal sensor < 1mm) Distance from probe tip to dipole centers: < 2 mm Sensor displacement to probe's calibration point: < 0.3 mm
Applications	E-field measurements of 5G devices and other mm-wave transmitters operating above 6GHz in < 2 mm distance from device (free-space) Power density, H-field and far-field analysis using total field reconstruction (DASY8 Module mmWave)
Compatibility	DASY8 Module mmWave V3.2.0.1840

4.2. Data Acquisition Electronics(DAE)

	Serial optical link for communication with DASY embedded system (fully remote controlled) Two-step probe touch detector for mechanical surface detection and emergency robsot stop
Measurement Range	–100 – +300 mV (16 bit resolution and two range settings: 4 mV, 400 mV)
Input Offset Voltage	<5 µV (with auto zero)
Input Resistance	200 Mohm
Input Bias Current	<50 fA
Battery Power	>10 hours of operation (with two 9.6 V NiMH batteries)
Dimensions (L × W × H)	60 × 60 × 68 mm

4.3. Measurement System

The DASY6 system used for performing compliance tests consists of the following items:



- A standard high precision 6-axis robot with controller, teach pendant and software. An arm extension for accommodating the data acquisition electronics (DAE).
- The EUmmWV2 probe is based on the pseudo-vector probe design, which not only measures the field magnitude but also derives its polarization ellipse.
- A data acquisition electronics (DAE) which performs the signal amplification, signal multiplexing, AD-conversion, offset measurements, mechanical surface detection, collision detection, etc. The unit is battery powered with standard or rechargeable batteries. The signal is optically transmitted to the EOC.
- The Electro-optical converter (EOC) performs the conversion from optical to electrical signals for the digital communication to the DAE. To use optical surface detection, a special version of the EOC is required. The EOC signal is transmitted to the measurement server.
- The function of the measurement server is to perform the time critical tasks such as signal filtering, control of the robot operation and fast movement interrupts.
- The Light Beam used is for probe alignment. This improves the (absolute) accuracy of the probe positioning.
- A computer running Win10 and the DASY8[1] software.
- Remote control and teach pendant as well as additional circuitry for robot safety such as warning lamps, etc.
- The phantom which is specialized for 5G other accessories according to the targeted measurement.

[1] DASY8 software used: DASY 8 mmWave V3.2.0.1840 and older generations.

4.4. Measurement Procedures

4.2.1. System Verification Scan Procedures

DASY8_Module mmWave supports “5G Scan”, a fine resolution scan performed on two different planes which is used to reconstruct the E- and H-fields as well as the power density; the average power density is derived from this measurement.

Step 1: Power Reference Measurement
The Power Reference Measurement and Power Drift Measurements are for monitoring the power drift of the device under test in the batch process. The minimum distance of probe sensors to surface determines the closest measurement point to devise under test.

Step 2: 5G Scan
The steps in the X, Y, and Z directions are specified in terms of fractions of the signal wavelength ,lambda. Area Scan Parameters extracted from SPEAG DASY 8 System Handbook; part 4 DASY8 Module mmWave.

Recommended settings for measurement of verification sources

Frequency [GHz]	Grid step	Grid extent X/Y [mm]	Measurement points
10	$0.125\left(\frac{\lambda}{8}\right)$	60/60	18×18
30	$0.25\left(\frac{\lambda}{4}\right)$	60/60	26×26
45	$0.25\left(\frac{\lambda}{4}\right)$	42/42	28×28
60	$0.25\left(\frac{\lambda}{4}\right)$	32.5/32.5	28×28
90	$0.25\left(\frac{\lambda}{4}\right)$	30/30	38×38

The minimum distance of probe sensors to the verification source surface, horn antenna, is 10 mm for 10 GHz and 5.55mm for 30 GHz and above.

Step 3: Power drift measurement

The Power Drift Measurement measures the field at the same location as the most recent power reference measurement within the same procedure, and with the same settings. The Power Drift Measurement gives the field difference in dB from the reading conducted within the last Power Reference Measurement. This allows a user to monitor the power drift of the device under test within a batch process. The measurement procedure is the same as Step 1.
When the drift is larger than ± 5 %, test is repeated from step1.

4.2.2. Scan Procedures

Step 1: Power Reference Measurement
Same as System Verification Scan Procedures step 1.

Step 2: 5G Scan
Same as System Verification Scan Procedures step 2. But measurement area is defined based on TCB work shop April 2019, “A sufficiently large measurement region and proper measurement spatial resolution are required to maintain field reconstruction accuracy”.
–Fields at the measurement region boundary should be ~20-30 dB below the peaks

Step 3: Power drift measurement
Same as System Verification Scan Procedures step 3.
When the drift is smaller than ± 5 %, it is considered in the uncertainty budget if drifts larger than 5%, uncertainty is re-calculate.

4.5. Test Equipment

The measuring equipment used to perform the tests documented in this report has been calibrated in accordance with the manufacturers' recommendations, and is traceable to recognized national standards.

System Check

Name of Equipment	Manufacturer	Type/Model	Serial No.	Cal. Due Date
5G Verification Source	SPEAG	60 GHz	1003	9/19/2023

Lab Equipment

Name of Equipment	Manufacturer	Type/Model	Serial No.	Cal. Due Date
E-Field Probe (SAR Lab 6)	SPEAG	EUmmWV2	9496	2/20/2024
Data Acquisition Electronics	SPEAG	DAE4	1540	1/23/2024

5. Measurement Uncertainty

a		b	c	d f(d,k)	e	f = b×*e/d*	g
Error Description		Unc.Value (±dB)	Probab. Distri.	Div.	*ci*	Std. Unc. (±dB)	vi
Uncertainty terms dependent on the measurement system							
CAL	Calibration Repeatability	0.49	Normal	1	1	0.49	∞
COR	Probe correction	0	Rectangular	1.732	1	0.00	∞
FRS	Frequency response (BW 1 GHz)	0.20	Rectangular	1.732	1	0.12	∞
SCC	Sensor cross coupling	0	Rectangular	1.732	1	0.00	∞
ISO	Isotropy	0.50	Rectangular	1.732	1	0.29	∞
LIN	Linearity	0.20	Rectangular	1.732	1	0.12	∞
PSC	Probe scattering	0	Rectangular	1.732	1	0.00	∞
PPO	Probe positioning o set	0.30	Rectangular	1.732	1	0.17	∞
PPR	Probe positioning repeatability	0.04	Rectangular	1.732	1	0.02	∞
SMO	Sensor mechanical o set	0	Rectangular	1.732	1	0.00	∞
PSR	Probe spatial resolution	0	Rectangular	1.732	1	0.00	∞
FLD	Field impedance dependance	0	Rectangular	1.732	1	0.00	∞
APD	Amplitude and phase drift	0	Rectangular	1.732	1	0.00	∞
APN	Amplitude and phase noise	0.04	Rectangular	1.732	1	0.02	∞
TR	Measurement area truncation	0	Rectangular	1.732	1	0.00	∞
DAQ	Data acquisition	0.03	Normal	1	1	0.03	∞
SMP	Sampling	0	Rectangular	1.732	1	0.00	∞
REC	Field reconstruction	0.60	Rectangular	1.732	1	0.35	∞
TRA	Forward transformation	0	Rectangular	1.732	1	0.00	∞
SCA	Power density scaling	-	Rectangular	1.732	1	-	∞
SAV	Spatial averaging	0.10	Rectangular	1.732	1	0.06	∞
SDL	System detection limit	0.04	Rectangular	1.732	1	0.02	∞
Uncertainty terms dependent on the DUT and environmental factors							
PC	Probe coupling with DUT	0	Rectangular	1.732	1	0	∞
MOD	Modulation response	0.40	Rectangular	1.732	1	0.23	∞
IT	Integration time	0	Rectangular	1.732	1	0	∞
RT	Response time	0	Rectangular	1.732	1	0	∞
DH	Device holder influence	0.10	Rectangular	1.732	1	0.06	∞
DAQ	DUT alignment	0	Rectangular	1.732	1	0	∞
AC	RF ambient conditions	0.04	Rectangular	1.732	1	0.02	∞
AR	Ambient reflections	0.04	Rectangular	1.732	1	0.02	∞
MSI	Immunity / secondary reception	0	Rectangular	1.732	1	0	∞
DRI	Drift of the DUT	0.21	Rectangular	1.732	1	0.12	∞
Combined Standard Uncertainty Uc(f) =			RSS			0.76	∞
Expanded Uncertainty U, Coverage Factor = 2, > 95 % Confidence =						1.52	

6. Device Under Test (DUT) Information

6.1. DUT Description

Device Dimension	Overall (Length x Width x Height): 46.5 x 55.0 x 29.0 mm		
Test sample information	**S/N**	**IMEI**	**Notes**
	2241000860	NA	
Hardware Version	R1.0		
Software Version	R1.0		

6.2. Wireless Technologies

Wireless technologies	Frequency bands	Operating modes	Duty Cycle used for PD testing
802.11ad	60GHz	BPSK,QPSK,16QAM	100%

6.3. Test Rationale

The DUT is a 60 GHz, 802.11ad device that is mounted onto a VR/AR headset (see figure 1). The mounting will provide more than 5 mm separation distance between the user and the side of the device. Power density testing at the side of the device facing the user's head was performed as this is the normal use case. Additional testing directly above the device was performed for information purposes only. Refer to section 7 for details of the test setups.

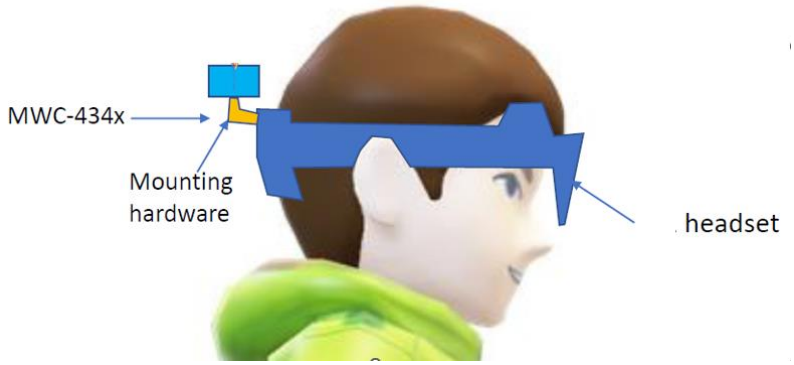


Figure 1

7. RF Exposure Conditions (Test Configurations)

Field strength measurements using the DASY fast scan were performed to determine the worst case beam IDs (See section 9.1). Full PD measurements were then performed on the highest three beam IDs for each position and polarity (See section 9.2)

A test separation distance of 5 mm was used for the measurements above the top of the device and 2 mm for the side. The device and mounting was removed from the headset for side testing as the probe/DAE would have been obstructed by the headset.

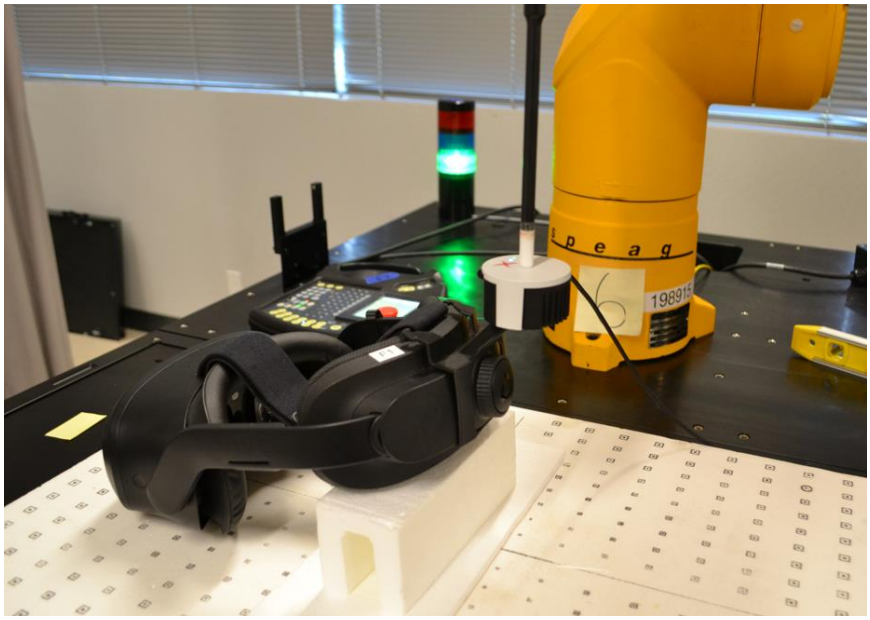


Figure 2 – Top Measurements

Side measurements directly above the heatsink (probe position A in figure 3) yielded negligible results so measurements were performed in the plane offset above the side of device (Probe position B). In normal use this plane will be a considerable distance from the user so this is a very conservative measurement position.

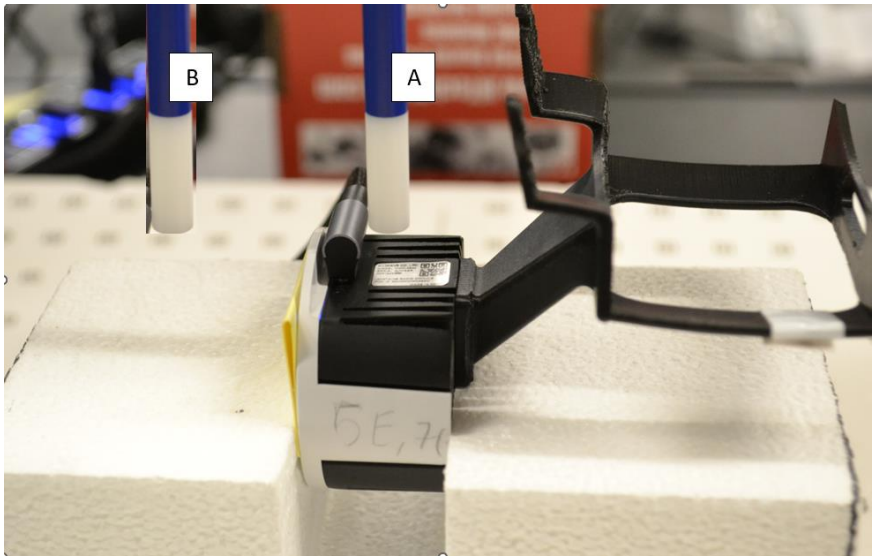


Figure 3 – Side measurements

8. System Performance Check

Per Nov 2017,TCB Workshop

System validation is required before a system is deployed for measurement.

System check is also required before each series of continuous measurement and, as applicable, repeated at least weekly.

Peak and spatially averaged power density at the peak location(s) must be compared to calibrated results according to the defined test conditions

- the same spatial resolution and measurement region used in the waveguide calibration should be applied to system validation and system check.
- 1 cm^2 and 4 cm^2 spatial averaging have been recommended in the AHG10 draft TR with reference targets available for specific waveguide.
- power density distribution should also be verified, both spatially (shape) and numerically (level) through visual inspection for noticeable differences.
- the measured results should be within 10% of the calibrated targets.

The system components, software settings and other system parameters shall be the same as those used for the compliance tests. The system check shall be performed at closest probe calibration frequency point as in the compliance tests, e.g., if the EUT operates at 35 GHz, it is recommended to perform the validation at 30 GHz.

SAR Lab	Test Date	Frequency (GHz)	5G Verification Source SN	Measured psPDn (W/m^2) over 4cm^2	Target psPDn (W/m^2) over 4cm^2	Deviation (dB)	Delta ±10 %	Measured psPDtot (W/m^2) over 4cm^2	Target psPDtot (W/m^2) over 4cm^2	Deviation (dB)	Delta ±10 %	Plot
SAR 6	4/10/2023	60	1003	227	227.9	-0.02	0%	231	231.4	-0.01	0%	1

9. Measured and Reported (Scaled) Results

Per TCB workshop October 2018, 4 cm^2 averaging area is considered.

9.1. Fast Scan Results

Signal Type	Band	Distance (mm)	Test Position	Freq. (MHz)	Beam ID	Duty Cycle	Max field strength	Plot No.
CW	60 GHz	5	Top	60480	Beam 0	100%	306	1
CW	60 GHz	5	Top	60480	Beam 7	100%	305	2
CW	60 GHz	5	Top	60480	Beam 8	100%	332	3
CW	60 GHz	5	Top	60480	Beam 9	100%	302	4
CW	60 GHz	5	Top	60480	Beam 10	100%	384	5
CW	60 GHz	5	Top	60480	Beam 11	100%	290	6
CW	60 GHz	5	Top	60480	Beam 12	100%	373	7
CW	60 GHz	2	Side	60480	Beam 0	100%	41.5	8
CW	60 GHz	2	Side	60480	Beam 7	100%	75.6	9
CW	60 GHz	2	Side	60480	Beam 8	100%	78.4	10
CW	60 GHz	2	Side	60480	Beam 9	100%	77	11
CW	60 GHz	2	Side	60480	Beam 10	100%	76.2	12
CW	60 GHz	2	Side	60480	Beam 11	100%	53.6	13
CW	60 GHz	2	Side	60480	Beam 12	100%	46.3	14

Note(s):

9.2. Measured Power Density

Signal Type	Band	Distance (mm)	Test Position	Freq. (MHz)	Beam ID	Duty Cycle	Normal psPD (W/m^2)	TotalpsPD (W/m^2)	Plot No.
CW	60 GHz	5	Top	60480	Beam 8	100%	35.1	41.3	15
CW	60 GHz	5	Top	60480	Beam 10	100%	43	49.5	16
CW	60 GHz	5	Top	60480	Beam 12	100%	46.8	50	17
CW	60 GHz	2	Side	60480	Beam 8	100%	6.58	7.58	18
CW	60 GHz	2	Side	60480	Beam 9	100%	6.9	7.94	19
CW	60 GHz	2	Side	60480	Beam 12	100%	1.64	1.77	20

Note(s):

1. Test results for the Top test position are included for information only

9.3. Duty Cycle Corrected Power Density

Signal Type	Band	Distance (mm)	Test Position	Freq. (MHz)	Beam ID	Duty Cycle	Normal psPD (mW/cm^2)	TotalpsPD (mW/cm^2)
CW	60 GHz	2	Side	60480	Beam 8	10%	0.0658	0.0758
CW	60 GHz	2	Side	60480	Beam 9	10%	0.069	0.0794
CW	60 GHz	2	Side	60480	Beam 12	10%	0.0164	0.0177

Appendixes

Refer to separated files for the following appendixes.

Appendix A: System Check Plot

Appendix B: Test Plots

Appendix C: Probe Certificate

Appendix D: Verification source Certificate

Appendix E: Test Setup Photos

END OF REPORT