RADIO TEST REPORT

Test Report No.: 14326176H-A-R1

Customer	**DENSO CORPORATION**
Description of EUT	**Millimeter Wave Radar Sensor**
Model Number of EUT	**DNMWR015**
FCC ID	**HYQDNMWR015**
Test Regulation	**FCC Part 95 Subpart M**
Test Result	**Complied (Refer to SECTION 3)**
Issue Date	**November 7, 2022**
Remarks	**-**

Representative Test Engineer

Yuichiro Yamazaki
Engineer

Approved By

Ryota Yamanaka
Engineer

CERTIFICATE 5107.02

☐ The testing in which "Non-accreditation" is displayed is outside the accreditation scopes in UL Japan, Inc.
☒ There is no testing item of "Non-accreditation".

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- The information provided from the applicant for this report is identified in Section 1.
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REVISION HISTORY

Original Test Report No.: 14326176H-A

This report is a revised version of 14326176H-A. 14326176H-A is replaced with this report.

Revision	Test Report No.	Date	Page Revised Contents
- (Original)	14326176H-A	July 25, 2022	-
1	14326176H-A-R1	November 7, 2022	Correction of the following date; - Receipt Date From June 13 to 24, 2022 to May 31, 2022 - Test Date From June 1 and 2, 2022 to June 13 to 24, 2022
1	14326176H-A-R1	November 7, 2022	Correction of the Declared value for Tx On 1 time of Modulation characteristics test; From 13.315 ms to 13.360 ms

Reference: Abbreviations (Including words undescribed in this report)

A2LA	The American Association for Laboratory Accreditation	ICES	Interference-Causing Equipment Standard
AC	Alternating Current	IEC	International Electrotechnical Commission
AFH	Adaptive Frequency Hopping	IEEE	Institute of Electrical and Electronics Engineers
AM	Amplitude Modulation	IF	Intermediate Frequency
Amp, AMP	Amplifier	ILAC	International Laboratory Accreditation Conference
ANSI	American National Standards Institute	ISED	Innovation, Science and Economic Development Canada
Ant, ANT	Antenna	ISO	International Organization for Standardization
AP	Access Point	JAB	Japan Accreditation Board
ASK	Amplitude Shift Keying	LAN	Local Area Network
Atten., ATT	Attenuator	LIMS	Laboratory Information Management System
AV	Average	MCS	Modulation and Coding Scheme
BPSK	Binary Phase-Shift Keying	MRA	Mutual Recognition Arrangement
BR	Bluetooth Basic Rate	N/A	Not Applicable
BT	Bluetooth	NIST	National Institute of Standards and Technology
BT LE	Bluetooth Low Energy	NS	No signal detect.
BW	BandWidth	NSA	Normalized Site Attenuation
Cal Int	Calibration Interval	NVLAP	National Voluntary Laboratory Accreditation Program
CCK	Complementary Code Keying	OBW	Occupied Band Width
Ch., CH	Channel	OFDM	Orthogonal Frequency Division Multiplexing
CISPR	Comite International Special des Perturbations Radioelectriques	P/M	Power meter
CW	Continuous Wave	PCB	Printed Circuit Board
DBPSK	Differential BPSK	PER	Packet Error Rate
DC	Direct Current	PHY	Physical Layer
D-factor	Distance factor	PK	Peak
DFS	Dynamic Frequency Selection	PN	Pseudo random Noise
DQPSK	Differential QPSK	PRBS	Pseudo-Random Bit Sequence
DSSS	Direct Sequence Spread Spectrum	PSD	Power Spectral Density
EDR	Enhanced Data Rate	QAM	Quadrature Amplitude Modulation
EIRP, e.i.r.p.	Equivalent Isotropically Radiated Power	QP	Quasi-Peak
EMC	ElectroMagnetic Compatibility	QPSK	Quadri-Phase Shift Keying
EMI	ElectroMagnetic Interference	RBW	Resolution Band Width
EN	European Norm	RDS	Radio Data System
ERP, e.r.p.	Effective Radiated Power	RE	Radio Equipment
EU	European Union	RF	Radio Frequency
EUT	Equipment Under Test	RMS	Root Mean Square
Fac.	Factor	RSS	Radio Standards Specifications
FCC	Federal Communications Commission	Rx	Receiving
FHSS	Frequency Hopping Spread Spectrum	SA, S/A	Spectrum Analyzer
FM	Frequency Modulation	SG	Signal Generator
Freq.	Frequency	SVSWR	Site-Voltage Standing Wave Ratio
FSK	Frequency Shift Keying	TR	Test Receiver
GFSK	Gaussian Frequency-Shift Keying	Tx	Transmitting
GNSS	Global Navigation Satellite System	VBW	Video BandWidth
GPS	Global Positioning System	Vert.	Vertical
Hori.	Horizontal	WLAN	Wireless LAN

CONTENTS **PAGE**

SECTION 1: Customer Information

Company Name	DENSO CORPORATION
Address	1-1, Showa-cho, Kariya-shi, Aichi-ken, 448-8661 Japan
Telephone Number	+81-78-682-2674
Contact Person	Shozo Taniguchi

The information provided from the customer is as follows;
- Customer, Description of EUT, Model Number of EUT, FCC ID on the cover and other relevant pages
- Operating/Test Mode(s) (Mode(s)) on all the relevant pages
- SECTION 1: Customer Information
- SECTION 2: Equipment Under Test (EUT) other than the Receipt Date and Test Date
- SECTION 4: Operation of EUT during testing

* The laboratory is exempted from liability of any test results affected from the above information in SECTION 2 and 4.

SECTION 2: Equipment Under Test (EUT)

2.1 Identification of EUT

Description	Millimeter Wave Radar Sensor
Model Number	DNMWR015
Serial Number	Refer to SECTION 4.2
Condition	Pre-production (Not for Sale: This sample is equivalent to production version.)
Modification	No Modification by the test lab
Receipt Date	May 31, 2022
Test Date	June 13 to 24, 2022

2.2 Product Description

General Specification

Rating	DC 12 V (Car battery), DC 9 V to 16 V (Operating range)
Operating temperature	-30 deg. C to +85 deg. C

Radio Specification

Equipment Type	Transceiver
Frequency of Operation	76.5 GHz
Bandwidth	500 MHz (Max.), 450 MHz (Typ.)
Type of Modulation	FM-CW
Antenna Gain	21.5 dBi
Steerable Antenna	Electronically (Receiving Part only)
Usage location	Forward-looking, vehicle-mounted

SECTION 3: Test specification, procedures & results

3.1 Test Specification

Test Specification	FCC Part 95 Subpart M FCC Part 95 final revised on October 20, 2021
Title	FCC 47CFR Part95 – PERSONAL RADIO SERVICES Subpart M – The 76-81 GHz Band Radar Service

* Also the EUT complies with FCC Part 15 Subpart B.

3.2 Procedures and results

Item	Test Procedure	Specification	Worst margin	Results	Remarks
Conducted emission	**FCC:** N/A	**FCC:** N/A	N/A	N/A	*1)
Occupied bandwidth	**FCC:** ANSI C63.26-2015 5.4 Occupied bandwidth	**FCC:** Section 2.1049	See data.	Complied a)	Radiated
Radiated Power Modulation characteristics	**FCC:** ANSI C63.26-2015 5.5 Radiated emissions testing ANSI C63.10-2013 6. Standard test methods 9. Procedures for testing millimeter-wave systems	**FCC:** Section 95.3367 Section 2.1046 Section 2.1047		Complied b)	Radiated
Field strength of spurious radiation	**FCC:** ANSI C63.26-2015 5.5 Radiated emissions testing	**FCC:** Section 95.3379 (a) Section 2.1053 Section 2.1057	19.1 dB 801.0 MHz, QP, Horizontal	Complied c)	Radiated
Frequency stability	**FCC:** ANSI C63.26-2015 5.6 Frequency stability testing	**FCC:** Section 95.3379 (b) Section 2.1055	See data.	Complied d)	Radiated

Note: UL Japan, Inc.'s EMI Work Procedures: Work Instructions-ULID-003591 and Work Instructions-ULID-003593.
*1) The test is not applicable since the EUT is not the device that is designed to be connected to the public utility (AC) power line.

a) Refer to APPENDIX 1 (data of Occupied bandwidth)
b) Refer to APPENDIX 1 (data of Radiated Power and Modulation characteristics)
c) Refer to APPENDIX 1 (data of Field strength of spurious radiation)
d) Refer to APPENDIX 1 (data of Frequency Stability)

Symbols:
Complied The data of this test item has enough margin, more than the measurement uncertainty.
Complied# The data of this test item meets the limits unless the measurement uncertainty is taken into consideration

* In case any questions arise about test procedure, ANSI C63.26-2015 and KDB653005 are also referred.

Supplied Voltage Information
This EUT provides stable voltage constantly to RF Module regardless of input voltage.

Antenna Information
The antenna is not removable from the EUT.

3.3 Addition to standard

No addition, exclusion nor deviation has been made from the standard.

3.4 Uncertainty

EMI

There is no applicable rule of uncertainty in this applied standard. Therefore, the results are derived depending on whether or not laboratory uncertainty is applied.

The following uncertainties have been calculated to provide a confidence level of 95 % using a coverage factor $k = 2$.

Radiated emission

Measurement distance	Frequency range		Uncertainty (+/-)
3 m	9 kHz to 30 MHz		3.2 dB
10 m			3.0 dB
3 m	30 MHz to 200 MHz	Horizontal	4.8 dB
		Vertical	5.0 dB
	200 MHz to 1000 MHz	Horizontal	5.1 dB
		Vertical	6.2 dB
10 m	30 MHz to 200 MHz	Horizontal	4.8 dB
		Vertical	4.8 dB
	200 MHz to 1000 MHz	Horizontal	5.0 dB
		Vertical	5.0 dB
3 m	1 GHz to 6 GHz		4.9 dB
	6 GHz to 18 GHz		5.2 dB
1 m	10 GHz to 26.5 GHz		5.4 dB
	26.5 GHz to 40 GHz		5.4 dB
0.5 m	26.5 GHz to 40 GHz		5.4 dB
10 m	1 GHz to 18 GHz		5.4 dB
>= 0.5 m	40 GHz to 50 GHz		4.1 dB
>= 0.5 m	50 GHz to 75 GHz		5.1 dB
>= 0.5 m	75 GHz to 110 GHz		5.4 dB
>= 3.8 cm*	110 GHz to 170 GHz		5.2 dB
>= 2.5 cm*	170 GHz to 260 GHz		5.0 dB

*under consideration about Uncertainty for testing at 1 cm distance

Radiated emission (with Block downconverter)

Measurement distance	Frequency range	Uncertainty (+/-)
>= 0.5 m	75 GHz - 83 GHz	4.4 dB*

*This value was used for 75 GHz - 83 GHz in this report.

3.5 Test Location

UL Japan, Inc. Ise EMC Lab.
*A2LA Certificate Number: 5107.02 / FCC Test Firm Registration Number: 884919
ISED Lab Company Number: 2973C / CAB identifier: JP0002
4383-326 Asama-cho, Ise-shi, Mie-ken 516-0021 Japan
Telephone: +81-596-24-8999

Test site	Width x Depth x Height (m)	Size of reference ground plane (m) / horizontal conducting plane	Other rooms	Maximum measurement distance
No.1 semi-anechoic chamber	19.2 x 11.2 x 7.7	7.0 x 6.0	No.1 Power source room	10 m
No.2 semi-anechoic chamber	7.5 x 5.8 x 5.2	4.0 x 4.0	-	3 m
No.3 semi-anechoic chamber	12.0 x 8.5 x 5.9	6.8 x 5.75	No.3 Preparation room	3 m
No.3 shielded room	4.0 x 6.0 x 2.7	N/A	-	-
No.4 semi-anechoic chamber	12.0 x 8.5 x 5.9	6.8 x 5.75	No.4 Preparation room	3 m
No.4 shielded room	4.0 x 6.0 x 2.7	N/A	-	-
No.5 semi-anechoic chamber	6.0 x 6.0 x 3.9	6.0 x 6.0	-	-
No.5 measurement room	6.4 x 6.4 x 3.0	6.4 x 6.4	-	-
No.6 shielded room	4.0 x 4.5 x 2.7	4.0 x 4.5	-	-
No.6 measurement room	4.75 x 5.4 x 3.0	4.75 x 4.15	-	-
No.7 shielded room	4.7 x 7.5 x 2.7	4.7 x 7.5	-	-
No.8 measurement room	3.1 x 5.0 x 2.7	3.1 x 5.0	-	-
No.9 measurement room	8.8 x 4.6 x 2.8	2.4 x 2.4	-	-
No.10 shielded room	3.8 x 2.8 x 2.8	3.8 x 2.8	-	-
No.11 measurement room	4.0 x 3.4 x 2.5	N/A	-	-
No.12 measurement room	2.6 x 3.4 x 2.5	N/A	-	-

* Size of vertical conducting plane (for Conducted Emission test) : 2.0 x 2.0 m for No.1, No.2, No.3, and No.4 semi-anechoic chambers and No.3 and No.4 shielded rooms.

3.6 Test data, Test instruments, and Test set up

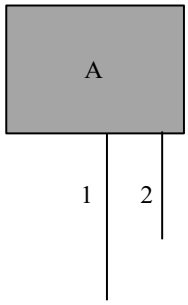
Refer to APPENDIX.

SECTION 4: Operation of EUT during testing

4.1 Operating Mode(s)

Mode	Test Item
Normal operating mode	Occupied bandwidth, Radiated Power, Modulation characteristics, Field strength of spurious radiation, Frequency Stability
*Power of the EUT was set by the software as follows; Power Setting: 38.0 dBm Software: mwr_gen4_0061_p05 Version: - (Date: 2022.06.01, Storage location: EUT memory)	
*This setting of software is the worst case. Any conditions under the normal use do not exceed the condition of setting. In addition, end users cannot change the settings of the output power of the product.	

4.2 Configuration and peripherals



* Cabling and setup(s) were taken into consideration and test data was taken under worse case conditions.

Description of EUT

No.	Item	Model number	Serial number	Manufacturer	Remarks
A	Millimeter Wave Radar Sensor	DNMWR015	0140932335	DENSO CORPORATION	EUT

List of cables used

No.	Name	Length (m)	Shield		Remarks
			Cable	Connector	
1	DC Cable	3.0	Unshielded	Unshielded	-
2	Signal Cable	2.0	Unshielded	Unshielded	-

SECTION 5: Radiated Spurious Emission

Test Procedure

[For below 30 MHz]
The EUT was placed on a urethane platform of nominal size, 1.0 m by 1.5 m, raised 0.8 m above the conducting ground plane.
The EUT was rotated a full revolution in order to obtain the maximum value of the electric field intensity.
The measurements were performed for vertical polarization (antenna angle: 0 deg., 45 deg., 90 deg., 135 deg., and 180 deg.) and horizontal polarization.
*Refer to Figure 1 about Direction of the Loop Antenna.

[For above 30 MHz, up to 1 GHz]
The EUT was placed on a urethane platform of nominal size, 1.0 m by 1.5 m, raised 0.8 m above the conducting ground plane. The Radiated Electric Field Strength has been measured in a Semi Anechoic Chamber with a ground plane.

[For above 1 GHz, up to 40 GHz]
The EUT was placed on a urethane platform of nominal size, 0.5 m by 0.5 m, raised 1.5 m above the conducting ground plane.
The Radiated Electric Field Strength has been measured in a Semi Anechoic Chamber with absorbent materials lined on a ground plane.

The height of the measuring antenna varied between 1 m and 4 m (frequency range 9 kHz to 30 MHz: loop antenna was fixed height at 1.0 m) and EUT was rotated a full revolution in order to obtain the maximum value of the electric field strength.

Test antenna was aimed at the EUT for receiving the maximum signal and always kept within the illumination area of the 3 dB beamwidth of the antenna.

The measurements were performed for both vertical and horizontal antenna polarization with the Test Receiver, or the Spectrum Analyzer.
The measurements were made with the following detector function of the test receiver and the Spectrum analyzer.
The test was made with the detector (RBW/VBW) in the following table.

Test Antennas are used as below;

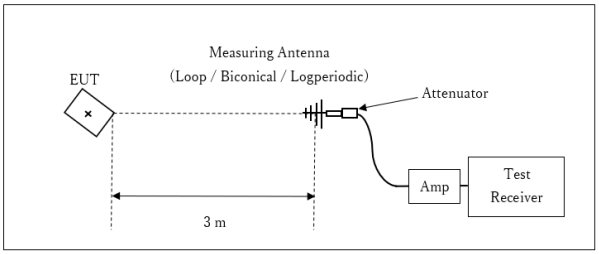
Frequency	Below 30 MHz	30 MHz to 200 MHz	200 MHz to 1 GHz	Above 1 GHz
Antenna Type	Loop	Biconical	Logperiodic	Horn

Frequency	9 kHz to 150 kHz	150 kHz to 30 MHz	30 MHz to 1 GHz	1 GHz to 40 GHz
Instrument used	Test Receiver	Test Receiver	Test Receiver	Spectrum Analyzer
Detector	CISPR QP, Average	CISPR QP, Average	CISPR QP	Average *1)
IF Bandwidth	200 Hz	9 kHz	120 kHz	RBW: 1 MHz VBW: 3 MHz

*1) A RMS average mode was applied according to KDB653005 4 (b) and 5.4 (f).

[Test setup]

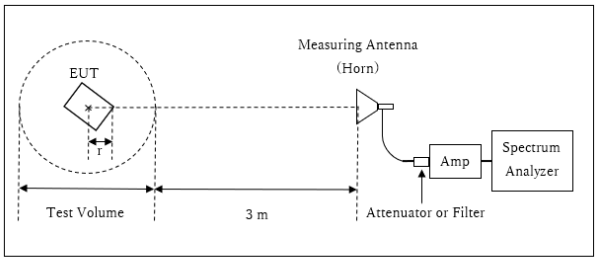
Below 1 GHz



× : Center of turn table

Test Distance: 3 m

1 GHz to 10 GHz



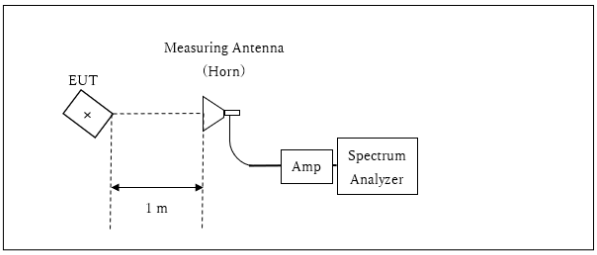
r : Radius of an outer periphery of EUT
× : Center of turn table

Distance Factor: 20 x log (4.0 m*/3.0 m) = 2.5 dB
* Test Distance: (3 + Test Volume /2) - r = 4.0 m

Test Volume: 2 m
(Test Volume has been calibrated based on CISPR 16-1-4.)
r = 0.0 m

* The test was performed with r = 0.0 m since that yielded the worst emission levels from the EUT.

10 GHz to 40 GHz

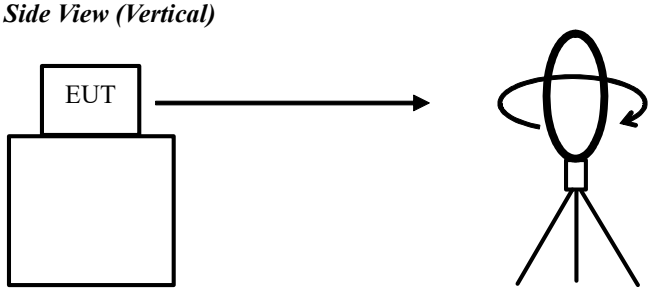


× : Center of turn table

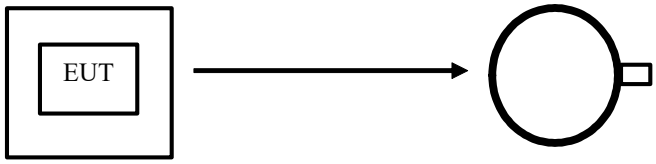
Distance Factor: 20 x log (1.0 m* / 3.0 m) = -9.5 dB
*Test Distance: 1 m

Figure 1: Direction of the Loop Antenna

Side View (Vertical)

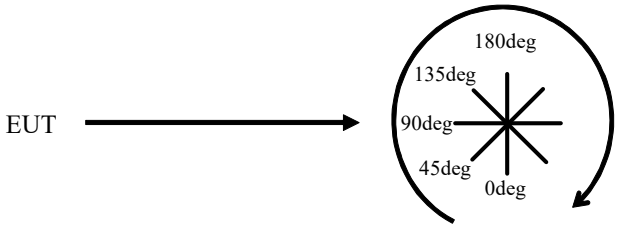


Top View (Horizontal)



Antenna was not rotated.

Top View (Vertical)



Front side: 0 deg.
Forward direction: clockwise

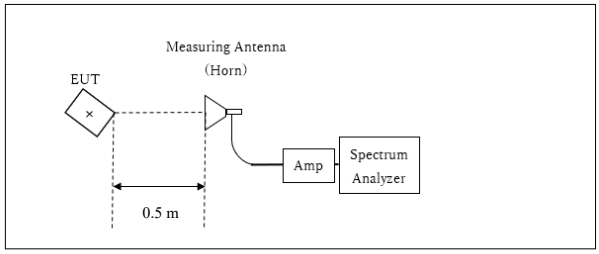
[Above 40 GHz]
The test was performed based on "Procedures for testing millimeter-wave systems" of ANSI C63.10-2013.
The EUT was placed on a urethane platform, raised 1.5 m above the conducting ground plane. The measurements were performed on handheld method.

Set spectrum analyzer RBW, VBW, span, etc., to the proper values. Note these values. Enable two traces—one set to "clear write," and the other set to "max hold." Begin hand-held measurements with the test antenna (horn) at a distance of 1 m from the EUT in a horizontally polarized position. Slowly adjust its position, entirely covering the plane 1 m from the EUT. Observation of the two active traces on the spectrum analyzer will allow refined horn positioning at the point(s) of maximum field intensity. Repeat with the horn in a vertically polarized position. If the emission cannot be detected at 1 m, reduce the RBW to increase system sensitivity. Note the value. If the emission still cannot be detected, move the horn closer to the EUT, noting the distance at which a measurement is made.

Note the maximum level indicated on the spectrum analyzer. Adjust this level, if necessary, by the antenna gain, filter loss, conversion loss of the external mixer and gain of LNA used, at the frequency under investigation. Calculate the field strength of the emission at the measurement distance from the Friis' transmission equation.

Frequency	40 GHz to 50 GHz	50 GHz to 83 GHz (except for 76 GHz to 81 GHz)	83 GHz to 110 GHz	110 GHz to 231 GHz
Final measurement distance with 1 MHz RMS detector	0.5 m	1.0 m	0.5 m	0.01 m

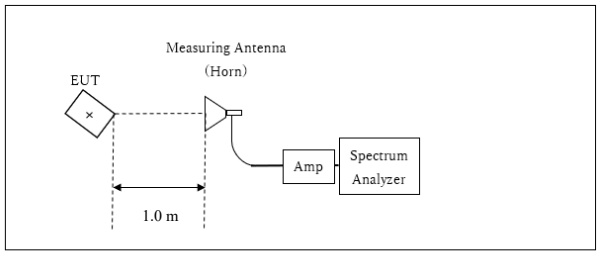
[Test setup]
40 GHz to 50 GHz, 83 GHz to 110 GHz



× : Center of turn table

*Test Distance: 0.5 m

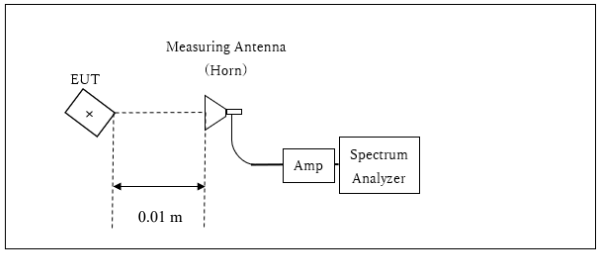
50 GHz to 83 GHz (except for 76 GHz to 81 GHz)



× : Center of turn table

*Test Distance: 1.0 m

110 GHz to 231 GHz



× : Center of turn table

*Test Distance: 0.01 m

The noise levels were confirmed at each position of X, Y and Z axes of EUT to see the position of maximum noise, and the test was made at the position that has the maximum noise.

[About fundamental measurement]
The carrier levels were confirmed at maximum direction of transmission. The maximum direction was searched under carefully since beam-widths are extremely narrow.

The carrier levels were measured in the far field. The distance of the far field was calculated from follow equation.

$$r = \frac{2D^2}{\lambda}$$

where

r is the distance from the radiating element of the EUT to the edge of the far field, in m
D is the largest dimension of both the radiating element and the test antenna (horn), in m
(The antenna aperture size of test antenna was used for this caluculation.)
Lambda is the wavelength of the emission under investigation [300/f (MHz)], in m

Frequency	Wavelength	Maximum Dimention			Far Field Boundary	Tested Distance
		EUT	Test Antenna	Maximum		
	Lambda			*D*	*r*	
[GHz]	[mm]	[m]	[m]	[m]	[m]	[m]
77	3.9	0.057000	0.025150	0.057000	1.668	1.8

The Radiated power test was performed with the EUT that was attached on the jig,
since the antenna array was mounted on angularly-tilted.

The test results and limit are rounded off to one decimal place, so some differences might be observed.

The Peak Power results was applied to the desensitization correction factor by KDB653005 4 (c) and 5.4 (d).
The derivation of the FMCW Desensitization Factor is given in Keysight Application Note 5952 1039 Appendix B.

Desensitization factor was calculated from follow equation.

$$\alpha = \frac{1}{\sqrt[4]{1 + \left(\frac{2In(2)}{\pi}\right)^2 \left(\frac{Fs}{Ts\,B^2}\right)^2}}$$

And
FMCW Desensitization factor = 20 Log (α)

Where
*F*s is FMCW Sweep Width or Chirp Width
*T*s is FMCW Sweep Time
B is -3dB Bandwidth of Gaussian RBW Filter

F_s	T_s	*B*	α	FMCW Desensitization factor
[MHz]	[us]	[MHz]		[dB]
402.0325	412.0	1.0	0.958	-0.37

*F*s and *B* were used the actual measurement value
*T*s was referred to the values in the specifications.
(Considering the worst case, the shortest characteristic value was applied.)

Measurement range : 9 kHz to 231 GHz
Test data : APPENDIX
Test result : Pass

SECTION 6: Frequency Stability

Test Procedure
The block downconverter was placed in side of the temperature chamber's drain hole.

The power supply was set to nominal operating voltage (110 %), and the spectrum mask was measured at 20 deg. C.

After that, EUT power supply was varied between 85 % and 115 % of nominal voltage and the frequency excursion of the EUT emission mask was recorded.

The EUT operating temperature was raised to 50 deg. C, and the frequency excursion of the EUT emission mask was recorded. Measurements were repeated at each 10 deg. C decrement down to -20 deg. C.

In addition, additional tests were performed with some temperatures according to the customer's request.

Both lower and upper frequencies of the -20 dB Bandwidth were recorded.

Test data : APPENDIX
Test result : Pass

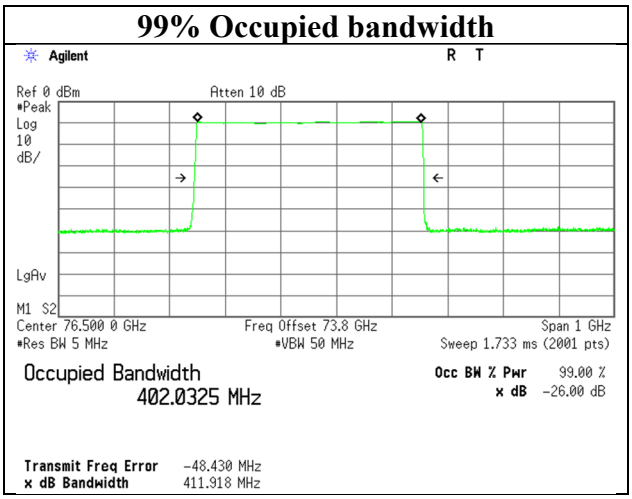
APPENDIX 1: Test data

Occupied bandwidth

Test place	Ise EMC Lab.
Semi Anechoic Chamber	No. 3
Date	June 15, 2022
Temperature / Humidity	21 deg. C / 54 % RH
Engineer	Yuichiro Yamazaki
Mode	Normal operating mode

99 % Occupied bandwidth [MHz]
402.0325

[Data]



The measurement was performed with Peak detector and Max Hold since the duty cycle was not 100 %.

Radiated Power

Test place	Ise EMC Lab.
Semi Anechoic Chamber	No. 3
Date	June 15, 2022
Temperature / Humidity	21 deg. C / 54 % RH
Engineer	Yuichiro Yamazaki
Mode	Normal operating mode

Power	Freq.	Measured Power	Rx Ant. Gain	Down Converter Gain	IF Cable Loss	Tested Distance	FSL	Duty Factor	FMCW desensitization Factor	EIRP		Lmit	Margin
	[GHz]	[dBm]	[dBi]	[dB]	[dB]	[m]	[dB]	[dB]	[dB]	[dBm]	[mW]	[dBm]	[dB]
Average	76.5	-14.17	23.06	14.92	1.43	1.8	75.22	7.91	-	32.41	1741.81	50	17.59
Peak	76.5	-4.62	23.06	14.92	1.43	1.8	75.22	-	-0.37	34.42	2766.94	55	20.58

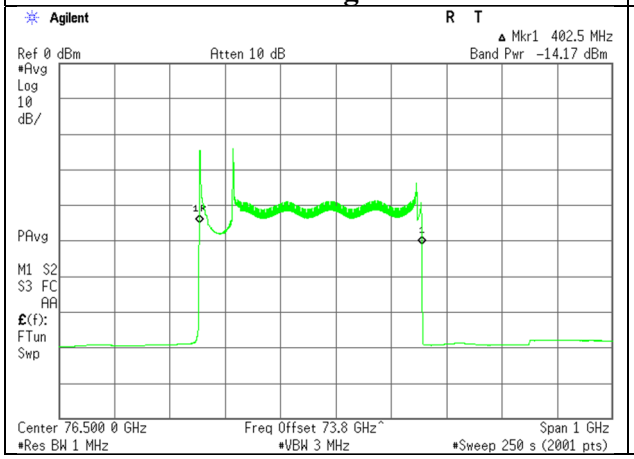
Calculating formula:

FSL (Free Space path Loss) = 10 * log10((4 * Pi * Tested Distance / Lambda) ^2)
Average EIRP = Measured Power - Rx Ant. Gain - Down Converter Gain + IF Cable Loss + FSL + Duty Factor
Peak EIRP = Measured Power - Rx Ant. Gain - Down Converter Gain + IF Cable Loss + FSL - FMCW desensitization factor

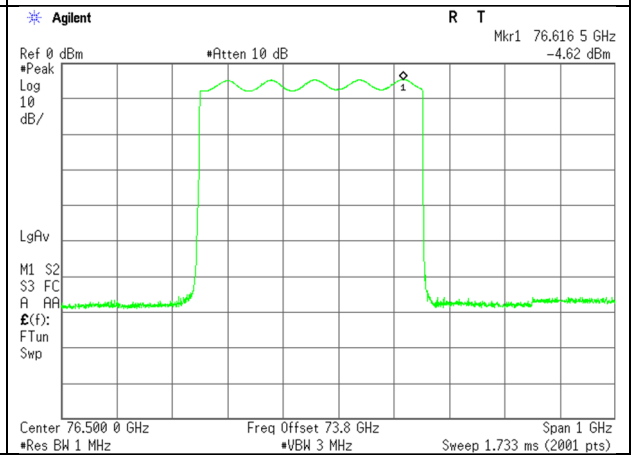
The test method referred to KDB653005 4 and 5.4.
The derivation of the Duty Factor is given in next page (Modulation characteristics).
The derivation of the FMCW Desensitization Factor is given in Keysight Application Note 5952 1039 Appendix B.
(Refer Section 5)

[Data]

Average



Peak



Modulation characteristics

Test place	Ise EMC Lab.
Semi Anechoic Chamber	No. 3
Date	June 15, 2022
Temperature / Humidity	21 deg. C / 54 % RH
Engineer	Yuichiro Yamazaki
Mode	Normal operating mode

	Tx On 1 time [ms]	Tx On 2 time [ms]	Total Tx On time [ms]	Tx On + Tx Off time (1cycle) [ms]	Duty Factor [dB]
Measured	12.957	3.210	16.167	100.000	-7.91
Declared *	13.360	3.700	17.060	100.000	-7.68

Calculating formula:

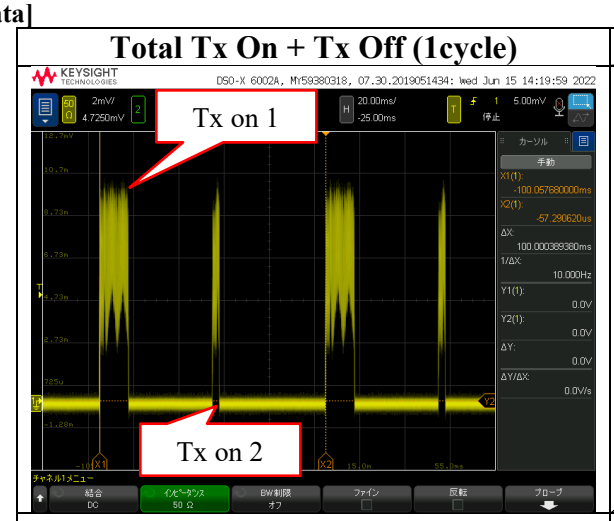
Total Tx On time =Tx On 1 time + Tx On 2 time

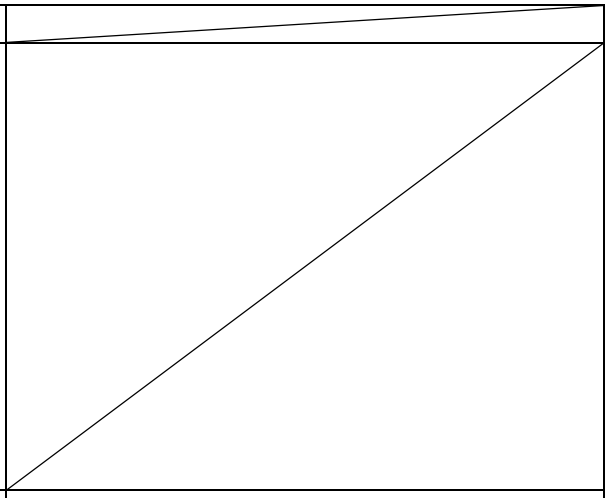
Duty factor = 10 * log (Total Tx On time / Tx On + Tx Off time)

* See the application document.

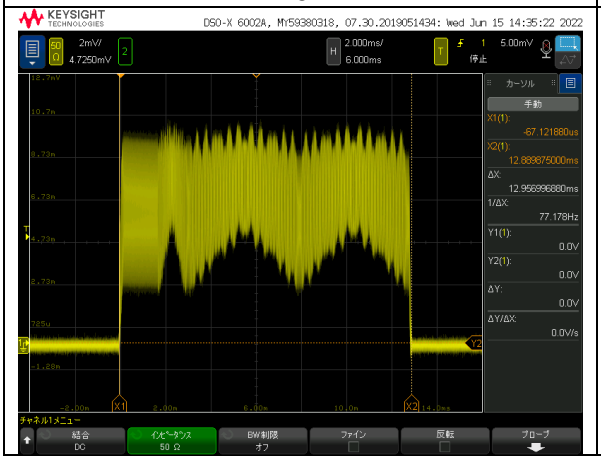
[Data]

Total Tx On + Tx Off (1cycle)

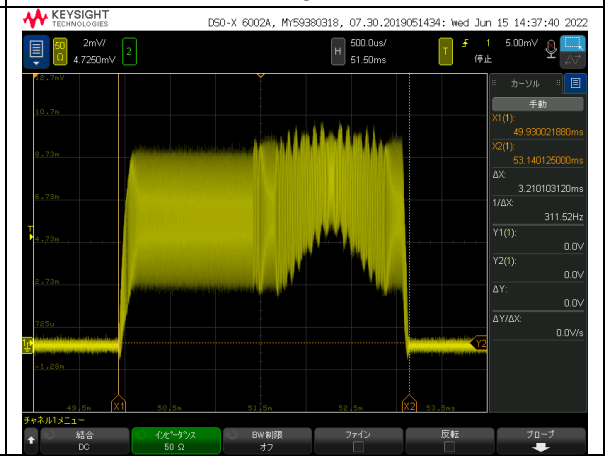




Tx on 1



Tx on 2



Field strength of spurious radiation
(Below 40 GHz)

Test place	Ise EMC Lab.	
Semi Anechoic Chamber	No. 3	No. 3
Date	June 21, 2022	June 24, 2022
Temperature / Humidity	22 deg. C / 55 % RH	22 deg. C / 50 % RH
Engineer	Yuichiro Yamazaki	Yuichiro Yamazaki
	(30 MHz - 40 GHz)	(9 kHz - 30 MHz)
Mode	Normal operating mode	

Polarity	Frequency	Reading (QP / PK)	Reading (AV)	Ant. Factor	Loss	Gain	Result (QP / PK)	Result (AV)	Limit (QP / PK)	Limit (AV)	Margin (QP / PK)	Margin (AV)	Remark
[Hori/Vert]	[MHz]	[dBuV]	[dBuV]	[dB/m]	[dB]	[dB]	[dBuV/m]	[dBuV/m]	[dBuV/m]	[dBuV/m]	[dB]	[dB]	
Hori.	37.0	25.4	-	15.9	7.2	32.2	16.3	-	40.0	-	23.7	-	
Hori.	163.7	25.2	-	15.7	8.8	32.1	17.6	-	43.5	-	25.9	-	
Hori.	181.9	26.3	-	16.4	9.0	32.1	19.6	-	43.5	-	23.9	-	
Hori.	324.9	26.2	-	14.8	10.2	32.0	19.2	-	46.0	-	26.9	-	
Hori.	494.3	25.3	-	17.9	11.3	32.0	22.6	-	46.0	-	23.4	-	
Hori.	801.0	24.3	-	21.0	13.1	31.5	26.9	-	46.0	-	19.1	-	
Vert.	37.0	22.1	-	15.9	7.2	32.2	13.0	-	40.0	-	27.0	-	
Vert.	163.7	28.7	-	15.7	8.8	32.1	21.1	-	43.5	-	22.4	-	
Vert.	181.9	25.4	-	16.4	9.0	32.1	18.7	-	43.5	-	24.8	-	
Vert.	324.9	25.6	-	14.8	10.2	32.0	18.6	-	46.0	-	27.5	-	
Vert.	494.3	25.2	-	17.9	11.3	32.0	22.5	-	46.0	-	23.5	-	
Vert.	801.0	23.5	-	21.0	13.1	31.5	26.1	-	46.0	-	19.9	-	

Result = Reading + Ant Factor + Loss (Cable+Attenuator+Filter+Distance factor(above 1 GHz)) - Gain(Amplifier)

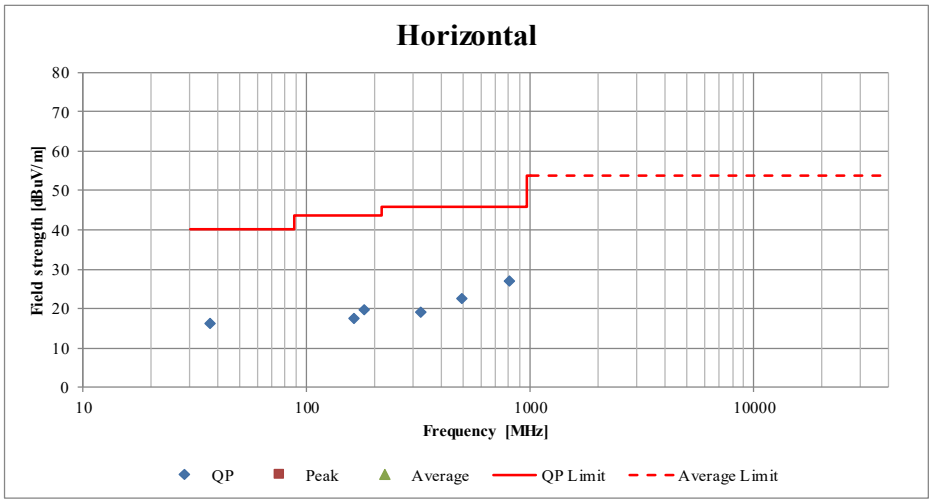
*Other frequency noises omitted in this report were not seen or had enough margin (more than 20 dB).

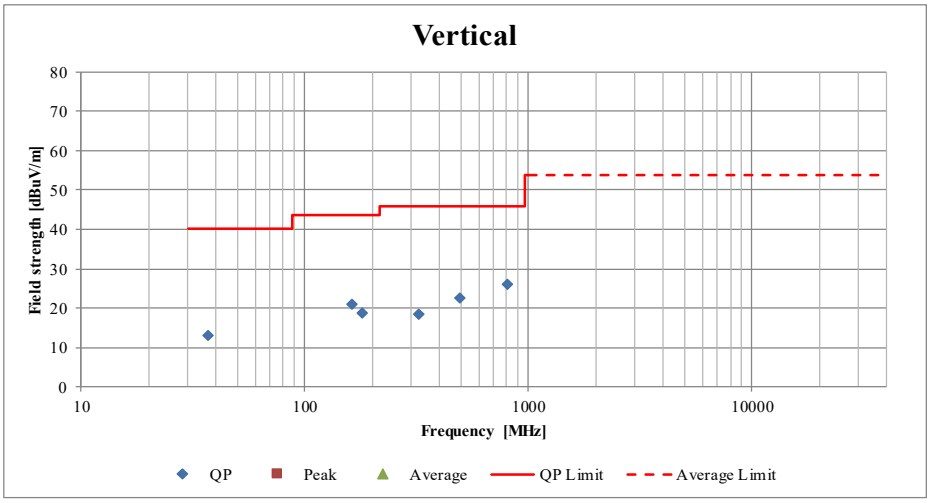
*QP detector was used up to 1GHz.

Distance factor: 1 GHz - 10 GHz 20log (4.0 m / 3.0 m) = 2.5 dB
10 GHz - 40 GHz 20log (1.0 m / 3.0 m) = -9.5 dB

Field strength of spurious radiation
(Below 40 GHz)
(Plot data, Worst case)

Test place	Ise EMC Lab.	
Semi Anechoic Chamber	No. 3	No. 3
Date	June 21, 2022	June 24, 2022
Temperature / Humidity	22 deg. C / 55 % RH	22 deg. C / 50 % RH
Engineer	Yuichiro Yamazaki (30 MHz - 40 GHz)	Yuichiro Yamazaki (9 kHz - 30 MHz)
Mode	Normal operating mode	





*These plots data contains sufficient number to show the trend of characteristic features for EUT.

Field strength of spurious radiation
(Above 40 GHz)

Test place	Ise EMC Lab.	
Semi Anechoic Chamber	No. 3	No. 3
Date	June 13, 2022	June 15, 2022
Temperature / Humidity	22 deg. C / 48 % RH	21 deg. C / 54 % RH
Engineer	Yuichiro Yamazaki (40 GHz - 75 GHz, Above 83 GHz)	Yuichiro Yamazaki (75 GHz - 76 GHz, 81 GHz - 83 GHz)
Mode	Normal operating mode	

Freq.	Reading	Rx Ant. gain	Filter loss	LNA gain	Mixer loss	IF cable loss	Meas. range D	FSL	EIRP		Power density at 3 m			Remarks
											Result	Limit	Margin	
[GHz]	[dBm]	[dBi]	[dB]	[dB]	[dB]	[dB]	[m]	[dB]	[dBm]	[mW]	[pW/cm^2]	[pW/cm^2]	[dB]	
48.705	-58.10	22.18	0.00	32.52	0.00	8.92	0.5	60.17	-43.70	0.000043	0.04	600	42.02	NS
54.333	-68.99	23.26	0.21	26.57	0.00	0.00	1.0	67.14	-51.47	0.000007	0.01	600	49.78	NS
68.996	-66.96	24.34	0.44	21.98	0.00	0.00	1.0	69.22	-43.62	0.000043	0.04	600	41.93	NS
74.710	-64.99	24.49	1.45	21.38	0.00	0.00	1.0	69.91	-39.50	0.000112	0.10	600	37.82	NS
75.805	-74.47	23.02	0.00	0.00	-14.89	1.21	1.0	70.04	-41.14	0.000077	0.07	600	39.45	NS
82.491	-76.62	23.50	0.65	0.00	-12.52	2.60	1.0	70.77	-38.62	0.000137	0.12	600	36.94	NS
89.821	-56.60	23.88	0.59	33.56	0.00	0.00	0.5	65.49	-47.96	0.000016	0.01	600	46.28	NS
99.932	-49.03	24.50	0.43	33.23	0.00	0.00	0.5	66.42	-39.91	0.000102	0.09	600	38.23	NS
102.217	-47.00	24.52	0.37	32.30	0.00	0.00	0.5	66.61	-36.84	0.000207	0.18	600	35.15	NS
117.113	-87.48	22.54	0.00	18.23	55.65	0.00	0.01	33.81	-38.79	0.000132	0.12	600	37.10	NS
120.152	-87.69	22.65	0.00	19.25	53.54	0.00	0.01	34.04	-42.02	0.000063	0.06	600	40.33	NS
127.753	-88.15	22.88	0.00	20.88	53.48	0.00	0.01	34.57	-43.86	0.000041	0.04	600	42.18	NS
139.170	-89.50	23.17	0.00	18.95	53.68	0.00	0.01	35.31	-42.62	0.000055	0.05	600	40.94	NS
142.074	-90.45	23.22	0.00	18.97	55.23	0.00	0.01	35.49	-41.91	0.000064	0.06	600	40.23	NS
153.480	-91.51	23.36	0.00	17.74	58.49	0.00	0.01	36.16	-37.95	0.000160	0.14	600	36.27	NS
160.551	-92.20	23.40	0.00	16.26	60.28	0.00	0.01	36.55	-35.02	0.000315	0.28	600	33.34	NS
167.921	-93.42	23.41	0.00	13.64	61.79	0.00	0.01	36.94	-31.73	0.000671	0.59	600	30.05	NS
171.152	-87.19	22.42	0.00	0.00	59.14	0.00	0.01	37.11	-13.36	0.046147	40.80	600	11.67	NS
178.772	-88.53	22.60	0.00	0.00	57.61	0.00	0.01	37.49	-16.03	0.024939	22.05	600	14.35	NS
187.087	-88.40	22.78	0.00	0.00	55.79	0.00	0.01	37.88	-17.51	0.017753	15.70	600	15.82	NS
197.433	-90.04	22.98	0.00	0.00	57.45	0.00	0.01	38.35	-17.22	0.018972	16.78	600	15.53	NS
207.184	-89.40	23.13	0.00	0.00	58.52	0.00	0.01	38.77	-15.24	0.029901	26.44	1000	15.78	NS
213.343	-91.35	23.20	0.00	0.00	57.38	0.00	0.01	39.02	-18.14	0.015337	13.56	1000	18.68	NS
221.766	-91.02	23.29	0.00	0.00	61.32	0.00	0.01	39.36	-13.63	0.043328	38.31	1000	14.17	NS
229.856	-92.37	23.35	0.00	0.00	61.62	0.00	0.01	39.67	-14.43	0.036057	31.88	1000	14.96	NS

Calculation:

FSL (Free Space path Loss) = 10 * log ((4 * Pi * D / λ) ^{2})
EIRP = Reading - Rx Ant. gain + Filter loss - LNA gain + Mixer loss + IF cable loss + FSL
Power density Result at 3 m = EIRP / (4 * Pi * 300 ^{2})

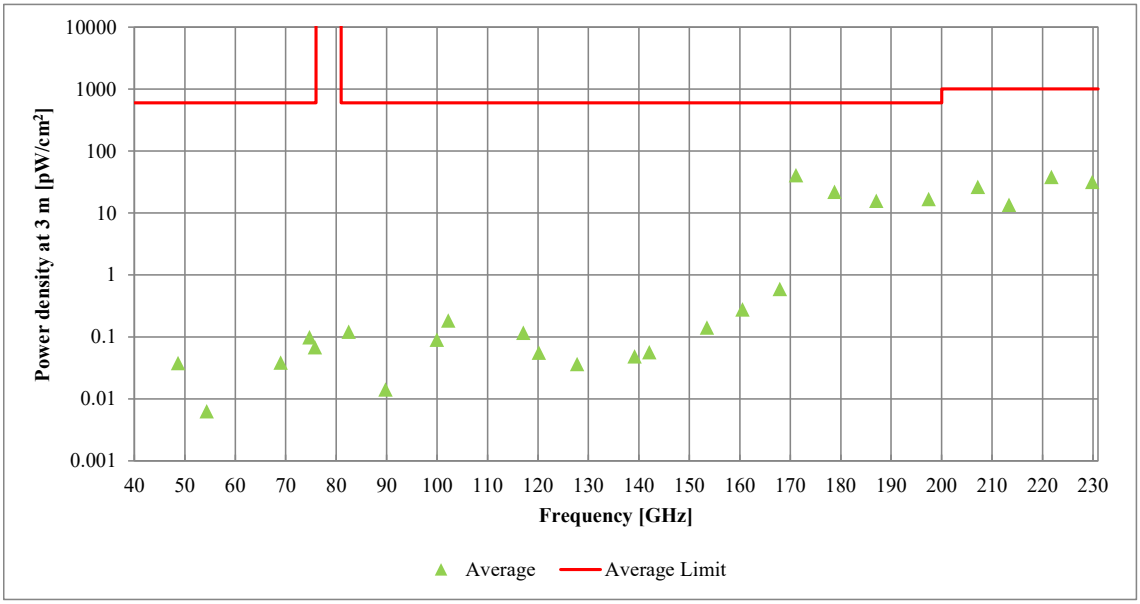
These calculation results are same as results which were calculated with formulas described in the Section 9 of ANSI C63.10-2013.
The equipment were not used for factor 0 dB of the data sheets.
The converion loss is automatically corrected in the mixer, so the factor of data sheet were 0 dB.

NS: No signal detected.

There is no spurious emission from 40 GHz to 231 GHz except for operating band (76 GHz to 81 GHz).
The values in the table are Floor Noise in each measurement frequency band.

Field strength of spurious radiation
(Above 40 GHz)
(Plot data, Worst case)

Test place	Ise EMC Lab.	
Semi Anechoic Chamber	No. 3	No. 3
Date	June 13, 2022	June 15, 2022
Temperature / Humidity	22 deg. C / 48 % RH	21 deg. C / 54 % RH
Engineer	Yuichiro Yamazaki (40 GHz - 75 GHz, Above 83 GHz)	Yuichiro Yamazaki (75 GHz - 76 GHz, 81 GHz - 83 GHz)
Mode	Normal operating mode	



*These plots data contains sufficient number to show the trend of characteristic features for EUT.

Frequency Stability

Test place	Ise EMC Lab.
Measurement Room	No. 6
Date	June 17, 2022
Temperature / Humidity	23 deg. C / 45 % RH
Engineer	Yuichiro Yamazaki
Mode	Normal operating mode

Test Condition		Measured -20 dBc Frequency		Remarks
Temperature [deg. C]	Power Supply [V]	Lower Result [GHz]	Upper Result [GHz]	
50	13.2	76.201	76.615	
40	13.2	76.213	76.625	
30	13.2	76.226	76.645	
20	13.2	76.248	76.660	
20	10.2	76.249	76.661	85 % of the minimum operating voltage, DC 12 V * 0.85
20	13.8	76.249	76.660	115 % of the maximum operating voltage, DC 12 V * 1.15
10	13.2	76.293	76.701	
0	13.2	76.291	76.702	
-10	13.2	76.291	76.699	
-20	13.2	76.294	76.701	

Fundamental emissions were contained within the frequency band 76 GHz - 81 GHz during all conditions of operation.

APPENDIX 2: Test instruments

Test equipment (1/2)

Test Item	Local ID	LIMS ID	Description	Manufacturer	Model	Serial	Last Calibration Date	Cal Int
RE	APANT08	146613	Loop Antenna	Rohde & Schwarz	HFH2-Z2	842906/011	10/06/2021	12
RE	MAEC-03	142008	AC3_Semi Anechoic Chamber(NSA)	TDK	Semi Anechoic Chamber 3m	DA-10005	05/23/2022	24
RE	MAEC-03-SVSWR	142013	AC3_Semi Anechoic Chamber(SVSWR)	TDK	Semi Anechoic Chamber 3m	DA-10005	04/01/2021	24
RE	MAT-95	142314	Attenuator	Pasternack Enterprises	PE7390-6	D/C 1504	06/13/2022	12
RE	MBA-03	141424	Biconical Antenna	Schwarzbeck Mess-Elektronik OHG	VHA9103+ BBA9106	1915	08/21/2021	12
RE	MCC-112	141216	Coaxial cable	Fujikura/Suhner/TSJ	5D-2W/SFM14/ sucoform141-PE/ 421-010/ RFM-E321(SW)	-/00640	07/19/2021	12
RE	MCC-135	142032	Microwave Cable	Huber+Suhner	SUCOFLEX102	37511/2	09/18/2021	12
RE	MCC-219	159670	Coaxial Cable	UL Japan	-	-	11/19/2021	12
RE	MCC-220	151897	Microwave Cable	Huber+Suhner	SF101EA/11PC24/ 11PC24/2.5M	SN MY1726/ 1EA	04/25/2022	12
RE	MCC-231	177964	Microwave Cable	Junkosha INC.	MMX221	1901S329(1m)/ 1902S579(5m)	03/15/2022	12
RE	MCC-242	196409	Microwave Cable	Huber+Suhner	SF101EA/11PC24/ 11PC24/2500MM	SN 800093/ 1EA	01/20/2022	12
RE	MCC-51	141323	Coaxial cable	UL Japan	-	-	07/19/2021	12
RE	MCC-66	141328	Microwave Cable 1G-40GHz	Suhner	SUCOFLEX102	28636/2	04/01/2022	12
RE	MCH-04	141429	Temperature and Humidity Chamber	Espec	PL-2KP	14015723	08/05/2021	12
RE	MDO-10	211944	Digital Storage Oscilloscope	Keysight Technologies Inc	DSOX6002A	MY59380318	10/07/2021	12
RE	MDPLX-01	142026	Diplexer	OML INC.	DPL26	-	11/25/2021	12
RE	MDT-05	142529	Detector	HEROTEK, INC.	DT1840P	484823	-	-
RE	MHA-02	141503	Horn Antenna 18-26.5GHz	EMCO	3160-09	1265	06/22/2022	12
RE	MHA-16	141513	Horn Antenna 15-40GHz	Schwarzbeck Mess-Elektronik OHG	BBHA9170	BBHA9170306	06/07/2021	12
RE	MHA-20	141507	Horn Antenna 1-18GHz	Schwarzbeck Mess-Elektronik OHG	BBHA9120D	258	11/09/2021	12
RE	MHA-24	142036	Horn Antenna	Custom Microwave Inc.	HO6R	-	09/30/2021	12
RE	MHA-27	142039	Horn Antenna	Custom Microwave Inc.	HO4R	-	09/30/2021	12
RE	MHA-31	142041	Horn Antenna	Oshima Prototype Engineering Co.	A16-187	1	09/30/2021	12
RE	MHA-33	180634	Horn Antenna	SAGE Millimeter, Inc.	SAZ-2410-15-S1	17343-01	06/09/2022	12
RE	MHA-35	180544	Horn Antenna	SAGE Millimeter, Inc.	SAZ-2410-10-S1	17343-01	06/27/2022	12
RE	MHA-36	180545	Horn Antenna	SAGE Millimeter, Inc.	SAZ-2410-10-S1	17343-02	06/27/2022	12
RE	MHF-29	154635	High Pass Filter 83 GHz - 110 GHz	Oshima Prototype Engineering Co.	A17-016	1	05/26/2022	12
RE	MHF-30	183867	WR-10 HighPass Filter	Oshima Prototype Engineering Co.	A19-206	001	03/04/2022	12
RE	MJM-16	142183	Measure	KOMELON	KMC-36	-	-	-
RE	MJM-24	142225	Measure	ASKUL	-	-	-	-
RE	MLA-22	141266	Logperiodic Antenna (200-1000MHz)	Schwarzbeck Mess-Elektronik OHG	VUSLP9111B	9111B-191	08/21/2021	12
RE	MLF-01	201432	WR-15 Low Pass Filter	Oshima Prototype Engineering Co.	2020-0142-02	001	09/29/2021	12
RE	MMM-08	141532	DIGITAL HiTESTER	HIOKI E.E. CORPORATION	3805	51201197	01/16/2022	12
RE	MMM-18	141558	Digital Tester(TRUE RMS MULTIMETER)	Fluke Corporation	115	17930030	05/17/2022	12
RE	MMX-03	142049	Harmonic Mixer	OML INC.	M06HWD	D100709-1	11/17/2021	12
RE	MMX-04	142053	Harmonic Mixer	OML INC.	M04HWD	Y100709-1	12/07/2021	12
RE	MMX-05	142050	Block Downconverter	Keysight Technologies Inc	PS-X30-W10117A	13715	03/03/2022	12

Test equipment (2/2)

Test Item	Local ID	LIMS ID	Description	Manufacturer	Model	Serial	Last Calibration Date	Cal Int
RE	MMX-07	186076	Wave guide Harmonic Mixer	Keysight Technologies Inc	M1971V	MY56390208	05/25/2022	12
RE	MMX-08	186077	Wave guide Harmonic Mixer	Keysight Technologies Inc	M1971W	MY56390146	05/25/2022	12
RE	MOS-13	141554	Thermo-Hygrometer	CUSTOM. Inc	CTH-201	1301	01/10/2022	12
RE	MOS-14	141561	Thermo-Hygrometer	CUSTOM. Inc	CTH-201	1401	01/10/2022	12
RE	MPA-11	141580	MicroWave System Amplifier	Keysight Technologies Inc	83017A	MY39500779	03/17/2022	12
RE	MPA-13	141582	Pre Amplifier	SONOMA INSTRUMENT	310	260834	02/25/2022	12
RE	MPA-23	142055	Power Amplifier	SAGE Millimeter, Inc.	SBP-5037532015-1515-N1	11599-01	03/04/2022	12
RE	MPA-25	159919	Power Amplifier	SAGE Millimeter, Inc.	SBP-4035033018-2F2F-S1	12559-01	06/10/2022	12
RE	MPA-29	176027	D-Band Low Noise Amplifier	SAGE Millimeter, Inc.	SBL-1141741860-0606-EI	15235-01	07/08/2021	12
RE	MPA-31	180607	Power Amplifier	SAGE Millimeter, Inc.	SBP-7531142515-1010-E1	17343-01	10/18/2021	12
RE	MSA-03	141884	Spectrum Analyzer	Keysight Technologies Inc	E4448A	MY44020357	03/31/2022	12
RE	MSA-04	141885	Spectrum Analyzer	Keysight Technologies Inc	E4448A	US44300523	11/10/2021	12
RE	MSA-19	182484	Signal Analyzer	Keysight Technologies Inc	N9030B	MY57143159	06/10/2022	12
RE	MSA-22	141978	Spectrum Analyzer	Keysight Technologies Inc	E4448A	MY46180899	03/24/2022	12
RE	MTR-08	141949	Test Receiver	Rohde & Schwarz	ESCI	100767	08/05/2021	12

***Hyphens for Last Calibration Date and Cal Int (month) are instruments that Calibration is not required (e.g. software), or instruments checked in advance before use.**

The expiration date of the calibration is the end of the expired month.
As for some calibrations performed after the tested dates, those test equipment have been controlled by means of an unbroken chains of calibrations.

All equipment is calibrated with valid calibrations. Each measurement data is traceable to the national or international standards.

Test Item: RE: Radiated Emission