FCC CFR47 PART 15 SUBPART C
INDUSTRY CANADA RSS-210 ISSUE 7
CERTIFICATION TEST REPORT

FOR

MILLIMETER WAVE RADAR SENSOR (76 GHz VEHICLE MOUNT)

MODEL NUMBER: DNMWR005

FCC ID: HYQDNMWR005

IC: 1551A-DNMWR005

REPORT NUMBER: 07J11348-1, Revision B1

ISSUE DATE: DECEMBER 21, 2007

Prepared for
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NVLAP LAB CODE 200065-0

Revision History

Rev.	Issue Date	Revisions	Revised By
--	12/17/2007	Initial Issue	M. Heckrotte
A	12/18/2007	Added 99% BW, added reference to OET 65, clarified environmental envelope for frequency stability tests, revised MPE calculations.	M. Heckrotte
B	12/20/2007	Added average measurements of fundamental.	M. Heckrotte
B1	12/21/2007	Revised duty cycle in MPE calculations.	M. Heckrotte

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1. ATTESTATION OF TEST RESULTS

COMPANY NAME: DENSO CORPORATION
1-1 SHOWA-CHO
KARIYA, AICHI 448-8661, JAPAN

EUT DESCRIPTION: MILLIMETER WAVE RADAR SENSOR (VEHICLE MOUNT)

MODEL: DNMWR004

MODEL TESTED: DNMWR005

SERIAL NUMBER: CCS2064

DATE TESTED: OCTOBER 17 TO DECEMBER 18, 2007

APPLICABLE STANDARDS

STANDARD	TEST RESULTS
CFR 47 Part 15 Subpart C	No Non-Compliance Noted
RSS-210 Issue 7 Annex 13 and RSS-GEN Issue 2	No Non-Compliance Noted

Compliance Certification 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.

Note: The results documented in this report apply only to the tested sample, under the conditions and modes of operation as described herein. This document may not be altered or revised in any way unless done so by Compliance Certification Services and all revisions are duly noted in the revisions section. Any alteration of this document not carried out by Compliance Certification Services will constitute fraud and shall nullify the document. No part of this report may be used to claim product certification, approval, or endorsement by NVLAP, NIST, or any government agency.

Approved & Released For CCS By: Tested By:

MICHAEL HECKROTTE
ENGINEERING MANAGER
COMPLIANCE CERTIFICATION SERVICES

VIEN TRAN
EMC ENGINEER
COMPLIANCE CERTIFICATION SERVICES

2. TEST METHODOLOGY

The tests and calculations documented in this report were performed in accordance with ANSI C63.4-2003, FCC CFR 47 Part 2, FCC CFR 47 Part 15, FCC OET Bulletin 65 Edition 97-01, RSS-GEN Issue 2, and RSS-210 Issue 7.

3. FACILITIES AND ACCREDITATION

The test sites and measurement facilities used to collect data are located at 47173 Benicia Street, Fremont, California, USA.

CCS is accredited by NVLAP, Laboratory Code 200065-0. The full scope of accreditation can be viewed at http://www.ccsemc.com.

4. CALIBRATION AND UNCERTAINTY

4.1. MEASURING INSTRUMENT CALIBRATION

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

4.2. MEASUREMENT UNCERTAINTY

Where relevant, the following measurement uncertainty levels have been estimated for tests performed on the apparatus:

PARAMETER	UNCERTAINTY
Radiated Emission, 30 to 200 MHz	+/- 3.3 dB
Radiated Emission, 200 to 1000 MHz	+4.5 / -2.9 dB
Radiated Emission, 1000 to 2000 MHz	+4.5 / -2.9 dB
Power Line Conducted Emission	+/- 2.9 dB

Uncertainty figures are valid to a confidence level of 95%.

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5. EQUIPMENT UNDER TEST

5.1. DESCRIPTION OF EUT

The EUT is a vehicle-mounted field disturbance sensor that is a millimeter wave frequency modulated continuous wave (FM-CW) radar operating at 76.0 GHz to 77.0 GHz (Nominal: 76.5 GHz). It adopts electronic scanning, which uses Digital Beam Forming (DBF) and Monopulse, to determine azimuth angle to objects.

The intended use is as a vehicle radar system, utilizing a serial bus interface.

The radio module is manufactured by Denso.

5.2. OUTPUT POWER

The EUT does not operate when the vehicle is stopped. The EUT has a single output power over all conditions when the vehicle is in motion.

5.3. DESCRIPTION OF AVAILABLE ANTENNAS

The radio utilizes an integral slotted waveguide array antenna, with a gain of 25 dBi.

5.4. AMBIENT OPERATING ENVIRONMENT

The radio is specified to operate from –30 to +70 deg C, and from 10 to 16 VDC.

5.5. DESCRIPTION OF MODEL DIFFERENCES

The radio circuitry is available in two models, with two interfaces. The transmitting and receiving circuitry are identical for both models. Model DNMWR004 utilizes a CAN bus interface. Model DNMWR005 utilizes an RS-232 serial interface.

Preliminary tests performed on both models confirmed that final tests on one model are representative of the RF characteristics of both models. Final tests were performed on model DNMWR004.

5.6. SOFTWARE AND FIRMWARE

MODEL DNMWR004

The firmware installed in the EUT during testing was mwr_tyt_585l_main_t145 and mwr_tyt_585l_sub_t165.

The EUT driver software installed in the support equipment during testing was CANcardXL WDM Drivers for WinXP Ver4.4.76.

The test software used during testing was Millimeterwave Radar Sensor control software for WinXP Ver1.21.

MODEL DNMWR005

The firmware installed in the EUT during testing was mwr_tyt_585l_main_t146 and mwr_tyt_585l_sub_t165.

The test software used during testing was Millimeterwave Radar Sensor control software for WinXP Ver1.0.

5.7. WORST-CASE CONDITION

The worst-case condition is when the transmitter is on. The transmitter emissions during the worst-case condition is compared to all three limits: “Vehicle Not In Motion”, “Vehicle In Motion, Forward-Looking Sensor” and “Vehicle In Motion, Side-Looking Sensor”.

5.8. DESCRIPTION OF TEST SETUP

SUPPORT EQUIPMENT

PERIPHERAL SUPPORT EQUIPMENT LIST				
Description	**Manufacturer**	**Model**	**Serial Number**	**FCC ID**
Laptop	Fujitsu	FMV-686NU	CP115994	DoC
Laptop	Fujitsu	FMV-680MC4	N/A	DoC
AC Adapter	Fujitsu	FMV-A312	01X37946A	N/A
DC power Supply	Xantrex	27519	N/A	N/A
DC Power Supply	HP	E3610A	N/A	N/A

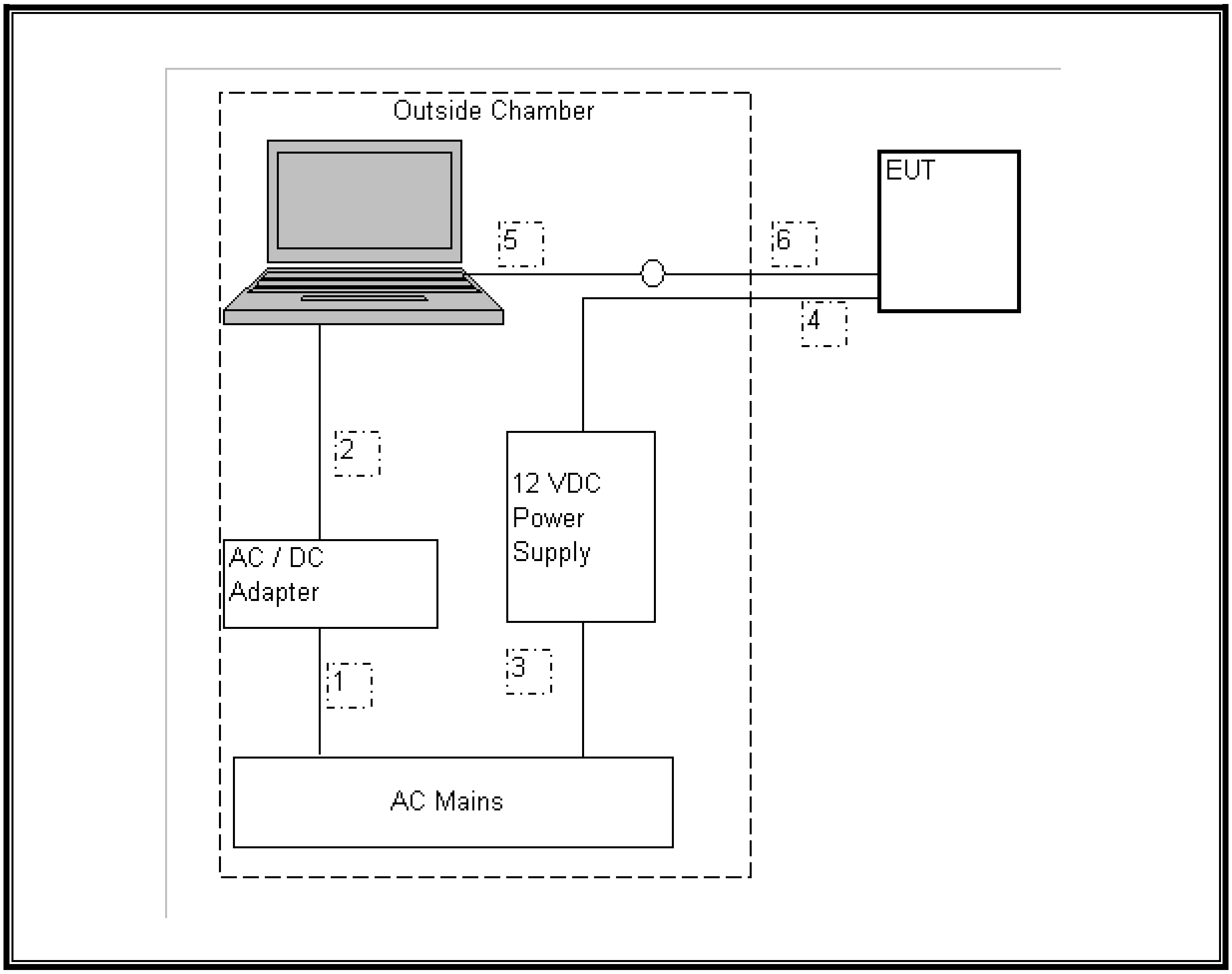
I/O CABLES

I/O CABLE LIST						
Cable No.	**Port**	**# of Identica Ports**	**Connector Type**	**Cable Type**	**Cable Length**	**Remarks**
1	AC	1	US115	Unshielded	2m	for laptop
2	DC	1	DC	Shielded	1.8m	for laptop
3	AC	1	US115	Unshielded	1.5m	Power supply
4	DC	1	DC	Unshielded	10.20m	12 VDC cable for EUT
5	RS-232	1	Serial	Shielded	.72m	PC card <=>D-sub 9 pin
6	RS-232	1	Serial	Shielded	10.20m	D-sub 9 pin <=>EUT cable

TEST SETUP

The EUT is connected to a support computer via a CAN bus PC Interface Card during the tests. The EUT was transmitting and receiving continuously during all tests.

SETUP DIAGRAM FOR TESTS



6. TEST AND MEASUREMENT EQUIPMENT

The following test and measurement equipment was utilized for the tests documented in this report:

TEST EQUIPMENT LIST					
Description	**Manufacturer**	**Model**	**Asset**	**Cal Date**	**Cal Due**
Quasi-Peak Adaptor	Agilent / HP	85650A	C00779	4/13/2006	1/21/2008
SA Display Section	Agilent / HP	85662A	N02480	5/4/2006	4/7/2008
SA RF Section, 1.5 GHz	Agilent / HP	85680B	N02455	4/4/2006	1/7/2008
Spectrum Analyzer, 40 GHz	Agilent / HP	8564E	C00951	9/5/2007	12/5/2008
Spectrum Analyzer, 40 GHz	Agilent / HP	E4446A	C00996	10/26/2007	10/26/2008
Spectrum Analyzer, 26.5 GHz	Agilent / HP	E4407B	C01784	8/9/2007	11/9/2008
Preamplifier, 1300 MHz	Agilent / HP	8447D	C00580	10/11/2007	10/11/2008
Preamplifier, 26.5 GHz	Agilent / HP	8449B	C00749	8/3/2007	9/27/2008
Preamplifier, 40 GHz	Miteq	NSP4000-SP2	C00990	10/11/2007	10/11/2008
Antenna, Bilog, 2 GHz	Sunol Sciences	JB1	C01011	9/10/2007	10/13/2008
Antenna, Horn, 18 GHz	EMCO	3115	C00872	4/15/2007	4/15/2008
Antenna, Horn, 26.5 GHz	ARA	SWH-28	C01015	10/6/2007	10/6/2008
Antenna, Horn, 40 GHz	ARA	MWH-2640/B	C00981	4/11/2007	4/11/2008
Harmonic Mixer, 40 GHz	Agilent / HP	11970Q	C00767	5/9/2007	5/9/2009
Harmonic Mixer, 50 GHz	Agilent / HP	11970Q	C00769	5/9/2007	5/9/2009
Harmonic Mixer, 75 GHz	Agilent / HP	11970V	C00768	12/1/2006	12/1/2008
Harmonic Mixer, 110 GHz	Agilent / HP	11970W	C00770	12/1/2006	12/1/2008
Harmonic Mixer, 140 GHz	OML	M08HWA	C00868	CNR	CNR
Harmonic Mixer, 220 GHz	OML	M05HWA	C00867	CNR	CNR
Harmonic Mixer, 385 GHz	OML	M03HWA	C01153	CNR	CNR
Environmental Chamber	Thermotron	SE600-10-10	C00930	4/16/2007	4/16/2008

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7. LIMITS AND RESULTS

7.1. 20 dB AND 99% BANDWIDTH

LIMIT

None; for reporting purposes only.

TEST PROCEDURE

The transmitter output is connected to a spectrum analyzer. The RBW is set to 1% to 3% of the measured bandwidth. The sweep time is coupled.

RESULTS

Frequency (GHz)	20 dB Bandwidth (MHz)	99% Bandwidth (MHz)
76.5	423	410

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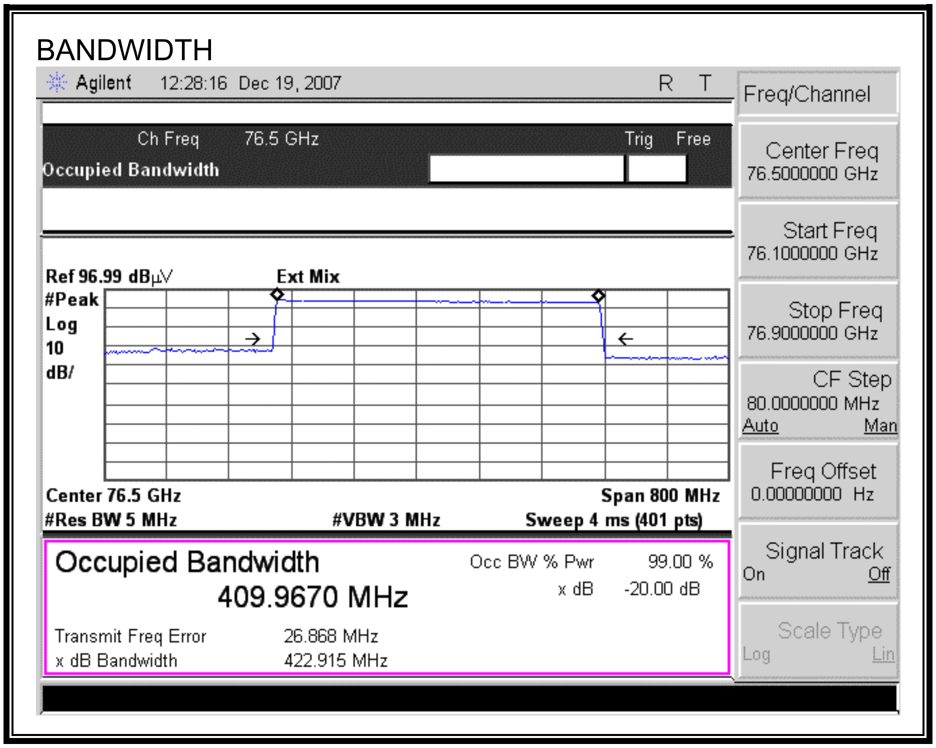
20 dB BANDWIDTH



7.2. IN BAND EMISSIONS

LIMIT

§15.253 (b)

RSS-210 Issue 7 Clause A13.1.2 (1)

Power Density Limit W/cm^2 at 3 m	EIRP Limit (W)	EIRP Limit (dBm)	Field Strength Limit dBuV/m at 3 m	Peak Field Strength Limit dBuV/m at 3 m
Vehicle Not In Motion				
2.00E-07	2.26E-01	23.5	118.7	138.7
Vehicle In Motion, Forward-Looking Sensor				
6.00E-05	6.78E+01	48.3	143.5	163.5
Vehicle In Motion, Side-Looking Sensor				
3.00E-05	3.39E+01	45.3	140.5	160.5

TEST PROCEDURE

The Field Strength is measured in the far field.

The most stringent limit is “Vehicle Not In Motion”. Since the transmitter has a single output power when it is on, if the EUT complies with the most stringent limit while transmitting it also complies with the remaining limits while transmitting.

The measurements are compared to the limits for the condition, “Vehicle Not In Motion”.

The EUT is placed on a non-conducting table 80 cm above the ground plane. The EUT is configured in accordance with ANSI C63.4. The EUT is set to transmit in a continuous mode.

The resolution bandwidth is set to 1 MHz. The video bandwidth is set to 1 MHz for peak measurements and 10 Hz for average measurements.

FAR FIELD BOUNDARY CALCULATIONS

The far-field boundary is given as:

R (far field) = (0.6 * D^2) / λ

Where:

D = Largest Antenna Dimension, including the reflector, in meters
λ = Wavelength in meters

The above equation predicts the boundary as follows:

Frequency (GHz)	Diameter (m)	Lambda (m)	R (Far Field) (m)
76.5	0.073	0.003922	0.82

The selected measurement distances of 3 meters for peak measurements and 1 meter for average measurements are in the far field.

PEAK RESULTS

12/17/07 High Frequency Measurement
Compliance Certification Services, Fremont 3m Chamber

Test Engr: Vien Tran
Project #: 07J11520
Company: Denso Corporation
EUT Descrip.: Millimeterwave Radar Sensor (76 GHz Vehicle Mount)
EUT M/N: DNMWR004
Test Target: FCC 15.253
Mode Oper: Tx 76.5 GHz

Test Equipment: External Harmonic mixers

Freq GHz	Dist (m)	Peak Reading dBuV	AF dB/m	Dist Corr dB	Peak dBuV/m	Peak Limit dBuV/m	Peak Margin dB	Notes (V/H)
76.46	3.00	71.9	47.9	0.0	119.8	138.7	-18.9	VERT
76.46	3.00	86.1	47.9	0.0	134.0	138.7	-4.7	HOR

Freq	Measurement Frequency	Peak	Peak Field Strength @ 3 m
Dist	Distance to Antenna	Peak Limit	Peak Field Strength Limit
Peak Reading	Analyzer Reading	Peak Margin	Margin vs. Peak Limit
AF	Antenna Factor		
Dist Corr	Distance Correct to 3 meters		

AVERAGE RESULTS

12/20/07 High Frequency Measurement
Compliance Certification Services, Fremont 3m Chamber

Test Engr: Vien Tran
Project #: 07J11520
Company: Denso Corporation
EUT Descrip.: Millimeterwave Radar Sensor (76 GHz Vehicle Mount)
EUT M/N: DNMWR004
Test Target: FCC 15.253
Mode Oper: Tx 76.5 GHz

Test Equipment: External Harmonic mixers

Freq GHz	Dist (m)	Avg Reading dBuV	AF dB/m	Dist Corr dB	Average dBuV/m	Avg Limit dBuV/m	Avg Margin dB	Notes (V/H)
76.46	1.00	50.5	47.9	-9.5	88.8	118.7	-29.9	VERT
76.46	1.00	62.5	47.9	-9.5	100.9	118.7	-17.8	HOR

Freq	Measurement Frequency	Average	Peak Field Strength @ 3 m
Dist	Distance to Antenna	Avg Limit	Peak Field Strength Limit
Avg Reading	Analyzer Reading	Avg Margin	Margin vs. Peak Limit
AF	Antenna Factor		
Dist Corr	Distance Correct to 3 meters		

7.3. OUT OF BAND EMISSIONS

LIMIT

§15.253 (c)

RSS-210 Issue 7 Clause A13.1.2 (2)

Radiated emissions below 40 GHz:

Frequency Range (MHz)	Field Strength Limit (uV/m) at 3 m	Field Strength Limit (dBuV/m) at 3 m
30 - 88	100	40
88 - 216	150	43.5
216 - 960	200	46
Above 960	500	54

Radiated emissions at and above 40 GHz, outside the operating band:

Power Density Limit W/cm^2 at 3 m	EIRP Limit (W)	EIRP Limit (dBm)	Field Strength Limit dBuV/m at 3 m	Peak Field Strength Limit dBuV/m at 3 m
40 to 200 GHz, Forward-Looking Sensor				
6.00E-10	6.78E-04	-1.7	93.5	113.5
40 to 200 GHz, Side-Looking Sensor				
3.00E-10	3.39E-04	-4.7	90.5	110.5
200 to 231 GHz				
1.00E-09	1.13E-03	0.5	95.7	115.7

TEST PROCEDURE

The EUT is placed on a non-conducting table 80 cm above the ground plane. The EUT is configured in accordance with ANSI C63.4. The EUT is set to transmit in a continuous mode.

For measurements below 1 GHz the resolution bandwidth is set to 100 kHz for peak detection measurements or 120 kHz for quasi-peak detection measurements. Peak detection is used unless otherwise noted as quasi-peak.

For measurements above 1 GHz the resolution bandwidth is set to 1 MHz, then the video bandwidth is set to 1 MHz for peak measurements. Should the peak measurement exceed the average limit, the video bandwidth is then set to 10 Hz for average measurements.

PROCEDURE FOR 30 MHz TO 40 GHz

The EUT is rotated through 360 degrees to maximize emissions received. The antenna is scanned from 1 to 4 meters above the ground plane to further maximize the emission. Measurements are made with the antenna polarized in both the vertical and the horizontal positions.

PROCEDURE FOR 40 TO 231 GHz

External harmonic mixers are utilized.

A pre-scan is performed first, as follows: The antenna is held close to the EUT and scanned around the entire perimeter surface of the EUT, in both horizontal and vertical polarizations.

A final scan using the procedure documented above for 30 MHz to 40 GHz, is made at any frequencies at which emissions are found in the pre-scan.

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SPURIOUS EMISSIONS ABOVE 1 GHz

No emissions from 1 GHz to 231 GHz, outside the operating band, were observed above the system noise floor.

SPURIOUS EMISSIONS 30 TO 1000 MHz

COMPLIANCE Certification Services

FCC, VCCI, CISPR, CE, AUSTEL, NZ
UL, CSA, TUV, BSMI, DHHS, NVLAP

Project #: 07U11426
Report #: 07U11426
Date& Time: 11/08/07 2:43 PM
Test Engr: Vien Tran

Company: Denso Corporation
EUT Description: Millimeter Wave Radar Sensor
Test Configuration : Transmitting and Receiving Continuously
Type of Test: Below 1 GHz
Mode of Operation: Tx

<< Main Sheet

Freq. (MHz)	Reading (dBuV)	AF (dB)	Closs (dB)	Pre-amp (dB)	Level (dBuV/m)	Limit FCC_B	Margin (dB)	Pol (H/V)	Az (Deg)	Height (Meter)	Mark (P/Q/A)
604.70	37.30	18.96	2.87	27.38	31.75	46.00	-14.25	3mV	0.00	1.00	P
675.10	35.08	19.57	3.08	27.10	30.63	46.00	-15.37	3mV	0.00	1.00	P
604.70	32.28	18.96	2.87	27.38	26.73	46.00	-19.27	3mH	0.00	1.00	P
Total data #: 3											
6 Worst Data											

7.4. FREQUENCY STABILITY

LIMIT

§15.253 (e)

RSS-210 Issue 7 Clause A13.1.5

Fundamental emissions must be contained within 76 to 77 GHz.

TEST PROCEDURE

The EUT is placed in an environmental chamber. The EUT antenna is inside the environmental chamber and the measurement antenna is outside the environmental chamber. These antennas face each other through a porthole of the chamber wall that is plugged with a thermal insulating foam insert. The low and high frequencies of the fundamental emission are measured over variations in temperature and voltage.

RESULTS

The environmental operating envelope (for both ambient temperature and supply voltage) of the EUT is greater than the environmental operating envelope specified by the rules. Testing was performed over the worst-case of these two envelopes.

Limit		76 Minimum	77 Maximum
Condition		F low	F high
Temperature deg C	Voltage VDC	(GHz)	(GHz)
25	12	76.33	76.73
-30	12	76.34	76.73
-20	12	76.34	76.74
-10	12	76.34	76.74
0	12	76.33	76.74
10	12	76.32	76.73
20	12	76.33	76.74
30	12	76.33	76.73
40	12	76.32	76.73
50	12	76.33	76.74
60	12	76.32	76.74
70	12	76.33	76.74
25	10	76.32	76.73
25	16	76.33	76.74

8. MAXIMUM PERMISSIBLE EXPOSURE

8.1. RULES

FCC RULES

§1.1310 The criteria listed in Table 1 shall be used to evaluate the environmental impact of human exposure to radio-frequency (RF) radiation as specified in §1.1307(b), except in the case of portable devices which shall be evaluated according to the provisions of §2.1093 of this chapter.

TABLE 1—LIMITS FOR MAXIMUM PERMISSIBLE EXPOSURE (MPE)

Frequency range (MHz)	Electric field strength (V/m)	Magnetic field strength (A/m)	Power density (mW/cm²)	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—LIMITS FOR MAXIMUM PERMISSIBLE EXPOSURE (MPE)—Continued

f = frequency in MHz
* = Plane-wave equivalent power density

NOTE 1 TO TABLE 1: Occupational/controlled limits apply in situations in which persons are exposed as a consequence of their employment provided those persons are fully aware of the potential for exposure and can exercise control over their exposure. Limits for occupational/controlled exposure also apply in situations when an individual is transient through a location where occupational/controlled limits apply provided he or she is made aware of the potential for exposure.

NOTE 2 TO TABLE 1: General population/uncontrolled exposures apply in situations in which the general public may be exposed, or in which persons that are exposed as a consequence of their employment may not be fully aware of the potential for exposure or can not exercise control over their exposure.

IC RULES

IC Safety Code 6, Section 2.2.1 (a) A person other than an RF and microwave exposed worker shall not be exposed to electromagnetic radiation in a frequency band listed in Column 1 of Table 5, if the field strength exceeds the value given in Column 2 or 3 of Table 5, when averaged spatially and over time, or if the power density exceeds the value given in Column 4 of Table 5, when averaged spatially and over time.

Table 5
Exposure Limits for Persons Not Classed As RF and Microwave Exposed Workers (Including the General Public)

1 Frequency (MHz)	2 Electric Field Strength; rms (V/m)	3 Magnetic Field Strength; rms (A/m)	4 Power Density (W/m^2)	5 Averaging Time (min)
0.003–1	280	2.19		6
1–10	$280/f$	$2.19/f$		6
10–30	28	$2.19/f$		6
30–300	28	0.073	2*	6
300–1 500	$1.585f^{0.5}$	$0.0042f^{0.5}$	$f/150$	6
1 500–15 000	61.4	0.163	10	6
15 000–150 000	61.4	0.163	10	$616\,000/f^{1.2}$
150 000–300 000	$0.158f^{0.5}$	$4.21 \times 10^{-4}f^{0.5}$	$6.67 \times 10^{-5}f$	$616\,000/f^{1.2}$

* Power density limit is applicable at frequencies greater than 100 MHz.

Notes:
1. Frequency, f, is in MHz.
2. A power density of 10 W/m^2 is equivalent to 1 mW/cm^2.
3. A magnetic field strength of 1 A/m corresponds to 1.257 microtesla (μT) or 12.57 milligauss (mG).

8.2. EQUATIONS FROM OET BULLETIN 65

NEAR-FIELD BOUNDARY

For the high-gain aperature antenna used with the EUT the extent of the near-field can be described by the following equation (D and λ in same units):

(OET 65 equation 12) Rnf = (D^2) / (4 * λ)

where

Rnf = extent of near-field
D = maximum dimension of antenna (diameter if circular)
λ = wavelength

MAXIMUM NEAR-FIELD POWER DENSITY

The magnitude of the on-axis (main beam) power density varies according to location in the near-field. However, the maximum value of the near-field, on-axis, power density can be expressed by the following equation:

(OET 65 equation 13) Snf = (16 * η * P) / (π * D^2)

where

Snf = maximum near-field power density
η = aperture efficiency
P = power fed to the antenna
D = antenna diameter

The antenna for the EUT is rectangular rather than circular. Substituting the formula for the area of a retangle in place of the area of a circle yields:

(modified equation 13) Snf = (4 * η * P) / (L * W)

where

Snf = maximum near-field power density
η = aperture efficiency
P = power fed to the antenna
L = antenna length
W = antenna width

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APERTURE EFFICIENCY

Aperture efficiency can be estimated, or a reasonable approximation for circular apertures can be obtained from the ratio of the effective aperture area to the physical area as follows:

(OET 65 equation 14) $\eta = ((G * \lambda^2) / (4 * \pi)) / ((\pi * D^2) / 4)$

where

η = aperture efficiency for circular apertures
G = power gain in the direction of interest relative to an isotropic radiator
λ = wavelength
D = antenna diameter

Substituting the formula for the area of a retangle in place of the area of a circle yields:

(modified equation 14) $\eta = ((G * \lambda^2) / (4 * \pi)) / (L * W)$

η = aperture efficiency for rectangular apertures
G = power gain in the direction of interest relative to an isotropic radiator
λ = wavelength
L = antenna length
W = antenna width

FAR-FIELD BOUNDARY

For purposes of evaluating RF exposure, the distance to the beginning of the far-field region (farthest extent of the transition region) can be approximated by the following equation:

(OET 65 equation 16) $Rff = (0.6 * (D^2)) / \lambda$

where

Rff = extent of near-field
D = antenna diameter
λ = wavelength

TRANSITION REGION

Power density in the transition region decreases inversely with distance from the antenna, while power density in the far-field (Fraunhofer region) of the antenna decreases inversely with the square of the distance.

The transition region will then be the region extending from Rnf, calculated from Equation (12), to Rff. If the location of interest falls within this transition region, the on axis power density can be determined from the following equation:

(OET 65 equation 17) St = Snf * Rnf / R

where

St = power density in the transition region
Snf = maximum power density for near-field calculated above
Rnf = extent of near-field calculated aboveS
R = distance to point of interest

FAR-FIELD REGION

The power density in the far-field or Fraunhofer region of the antenna pattern decreases inversely as the square of the distance. The power density in the far-field region of the radiation pattern can be estimated by the general equation discussed earlier:

(OET 65 equation 18) Sff = P * G / (4 * π * (R^2))

where

Sff = power density (on axis)
P = power fed to the antenna
G = power gain of the antenna in the direction of interest relative to an isotropic radiator
R = distance to the point of interest

8.3. CALCULATIONS

ANTENNA SPECIFICATIONS

The transmitting antenna specifications are as follows:
length = 0.07 m
width = 0.02 m
maximum dimension = .073 m
gain = 25 dBi

NEAR-FIELD BOUNDARY

Frequency (GHz)	Lambda (m)	Maximum Antenna Dimension (m)	Near-field Boundary (m)	Near-field Boundary (cm)
76.5	0.003922	0.073	0.34	34

FAR-FIELD BOUNDARY

Frequency (GHz)	Lambda (m)	Maximum Antenna Dimension (m)	Far-field Boundary (m)	Far-field Boundary (cm)
76.5	0.003922	0.073	0.82	82

APERTURE EFFICIENCY

Frequency (GHz)	Gain (dBi)	Gain (numeric)	Lambda (m)	Antenna Length (m)	Antenna Width (m)	Aperture Efficiency (η)
76.5	25	316	0.003922	0.070	0.020	0.277

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DUTY CYCLE

The total ON time is 13.6 msec within a 100 msec period. This yields a duty cycle of 13.6% and a correction factor of –8.66 dB.

POWER FED TO THE ANTENNA

Field Strength at 3 meters (dBuV/m)	F.S. to EIRP Conversion Factor	Peak EIRP (dBm)	Duty Cycle Factor (dB)	Average EIRP (dBm)
134	-95.2	38.8	-8.66	30.1

Antenna Gain (dBi)	Power Fed To Antenna (dBm)	Power Fed To Antenna (W)
25.00	5.1	0.003266

8.4. MAXIMUM POWER DENSITY AT A DISTANCE OF 20 cm

MAXIMUM NEAR-FIELD POWER DENSITY

The minimum allowable declared MPE distance for mobile devices is 20 cm, which is within the 34 cm boundary of the near-field Fresnel region of the antenna. Therefore the near-field power density is applicable to a separation distance of 20 cm.

MPE Distance (cm)	Aperture Efficiency (η)	Output Power (W)	Antenna Diameter (m)	FCC Power Density (mW/cm^2)	IC Power Density (W/m^2)
20.0	0.277	0.003266	0.073	0.087	0.865

From §1.1310 Table 1 (B), S = 1.0 mW/cm^2

From IC Safety Code 6, Section 2.2 Table 5 Column 4, S = 10 W/m^2

These calculations indicate that the power density at 20 cm is less than the applicable limits.

8.5. VALIDATION OF APPLICABILITY OF OET 65 EQUATIONS

The OET 65 equations cited above are based on parabolic aperture antennas with circular cross sections. The EUT antenna is a slotted waveguide array with a rectangular shape.

The modifications to the original equations to accomodate the actual antenna shape, as well as the applicability of the equations to the actual antenna design, can be validated by extrapolating the near-field power density through the transition region to the far-field boundary. This extrapolated value is compared to the direct calculation of the far-field power density at the far-field boundary.

EXTRAPOLATION OF NEAR-FIELD POWER DENSITY TO THE FAR-FIELD BOUNDARY

For the particular value of R = Rff, combining equations 12, 16 and 17 yields:

Sffboundary / Snf = Rnf / Rff = ((D^2) / (4 * λ)) / ((0.6 * (D^2)) / λ) = 1 / 2.4 = 0.417

Near-field Power Density (W/m^2)	Extrapolation Factor (linear)	Power Density at Far-field Boundary	
		FCC (mW/cm^2)	IC (W/m^2)
0.865	0.417	0.036	0.361

DIRECT CALCULATION OF POWER DENSITY AT THE FAR-FIELD BOUNDARY

Far-field Boundary (cm)	Output Power (dBm)	Antenna Gain (dBi)	Power Density at Far-field Boundary	
			FCC (mW/cm^2)	IC (W/m^2)
82.0	5.1	25.0	0.012	0.121

RESULTS

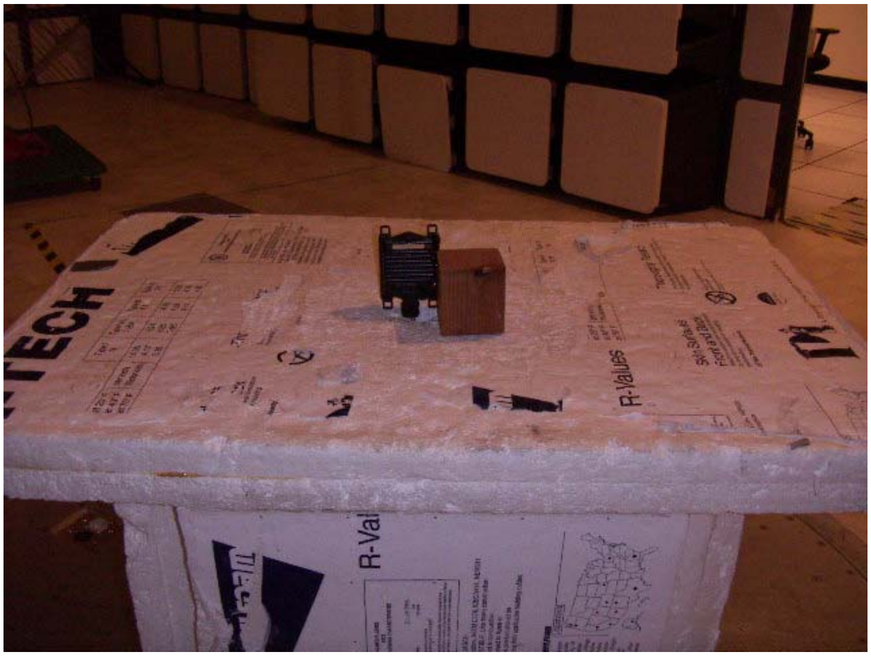
The extrapolated value of the near-field power density is greater than the direct calculation, therefore the near-field calculations provide a worst-case, upper bound of the actual maximum power density.

9. SETUP PHOTOS

RADIATED RF MEASUREMENT SETUP

RADIATED FRONT PHOTO

RADIATED BACK PHOTO



ENVIRONMENTAL CHAMBER SETUP

ENVIRONMENTAL CHAMBER PHOTO

END OF REPORT