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Measured Radio Frequency Emissions
From

Delphi 76.7 GHz Radar
FCC ID: L2C0051TR
IC: 3432A-0051TR

Report No. 417124-641
September 12, 2012

For:
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Test Report Prepared by:	Valdis V. Liepa		

Summary

Testing for compliance with FCC Regulations Part 15, Subpart C, Section 253 and Industry Canada RSS-210 was performed on Delphi 76.7 GHz Radar model L2C0051TR. This device is subject to the Rules and Regulations as a Field Disturbance Device.

In testing completed on September 9, 2012, we determined that the L2C0051TR meets FCC/IC regulations for average power density at 3 meters by 35.6 dB in the worst case. Spurious emissions meet out of band emissions regulations by more than 11.9 dB.

1. Introduction

This Delphi 76.7 GHz Radar was tested for compliance with FCC Regulations, Part 15, adopted under Docket 87-389, April 18, 1989 as subsequently amended, and with Industry Canada RSS-210/Gen, Issue 8, December 2010. The tests were performed at the University of Michigan Radiation Laboratory following the procedures described in the FCC MM-Wave Test Procedures. Test site description and attenuation characteristics are on file with FCC Laboratory, Columbia, Maryland (FCC Reg. No: 91050) and with Industry Canada, Ottawa, ON (File Ref. No: IC 2057A-1).

2. Test Procedure and Equipment Used

The pertinent test equipment commonly used in our facility for measurements is listed in Table 2.1 below. The middle column identifies the specific equipment used in these tests.

Table 2.1 Test Equipment.

Test Instrument	Eqpt. Used	Manufacturer/Model
Spectrum Analyzer (9kHz-22GHz)		Hewlett-Packard 8593A SN: 3107A01358
Spectrum Analyzer (9kHz-26GHz)		Hewlett-Packard 8593E, SN: 3412A01131
Spectrum Analyzer (9kHz-26GHz)	X	Hewlett-Packard 8563E, SN: 3310A01174
Spectrum Analyzer (9kHz-40GHz)	X	Hewlett-Packard 8564E, SN: 3745A01031
Power Meter		Hewlett-Packard, 432A
Power Meter		Anritsu, ML4803A/MP
Harmonic Mixer (26-40 GHz)	X	Hewlett-Packard 11970A, SN: 3003A08327
Harmonic Mixer (40-60 GHz)	X	Hewlett-Packard 11970U, SN: 2332A00500
Harmonic Mixer (50-90 GHz)	X	Hewlett-Packard 11970V, SN: 2521A00179
Harmonic Mixer (75-110 GHz)	X	Hewlett-Packard 11970W, SN: 2521A00179
Harmonic Mixer (140-220 GHz)	X	Pacific Millimeter Prod., GMA, SN: 26
S-Band Std. Gain Horn		S/A, Model SGH-2.6
C-Band Std. Gain Horn	X	University of Michigan, NRL design
XN-Band Std. Gain Horn	X	University of Michigan, NRL design
X-Band Std. Gain Horn	X	S/A, Model 12-8.2
X-band horn (8.2- 12.4 GHz)		Narda 640
X-band horn (8.2- 12.4 GHz)		Scientific Atlanta , 12-8.2, SN: 730
K-band horn (18-26.5 GHz)		FXR, Inc., K638KF
Ka-band horn (26.5-40 GHz)	X	FXR, Inc., U638A
U-band horn (40-60 GHz)	X	Custom Microwave, HO19
W-band horn(75-110 GHz)	X	Custom Microwave, HO10
G-band horn (140-220 GHz)	X	Custom Microwave, HO5R
Bicone Antenna (30-250 MHz)		University of Michigan, RLBC-1
Bicone Antenna (200-1000 MHz)		University of Michigan, RLBC-2
Dipole Antenna Set (30-1000 MHz)		University of Michigan, RLDP-1,-2,-3
Dipole Antenna Set (30-1000 MHz)		EMCO 2131C, SN: 992
Active Rod Antenna (30 Hz-50 MHz)		EMCO 3301B, SN: 3223
Active Loop Antenna (30 Hz-50 MHz)		EMCO 6502, SN:2855
Ridge-horn Antenna (300-5000 MHz)	X	University of Michigan
Amplifier (5-1000 MHz)		Avantak, A11-1, A25-1S
Amplifier (5-4500 MHz)	X	Avantak
Amplifier (4.5-13 GHz)	X	Avantek, AFT-12665
Amplifier (6-16 GHz)	X	Trek
Amplifier (16-26 GHz)	X	Avantek
LISN Box		University of Michigan
Signal Generator		Hewlett-Packard 8657B

3. Device Under Test

3.1 Identification

The Device Under Test (DUT) is a 76-77 GHz vehicular radar employing two distinct chirps (one for Short Range and Long Range detection) using two distinct transmit chains (planar arrays). The DUT is approximately 18 x 10 x 3.5 cm in dimension and is designed for use as a forward looking radar on a 24 VDC vehicle.

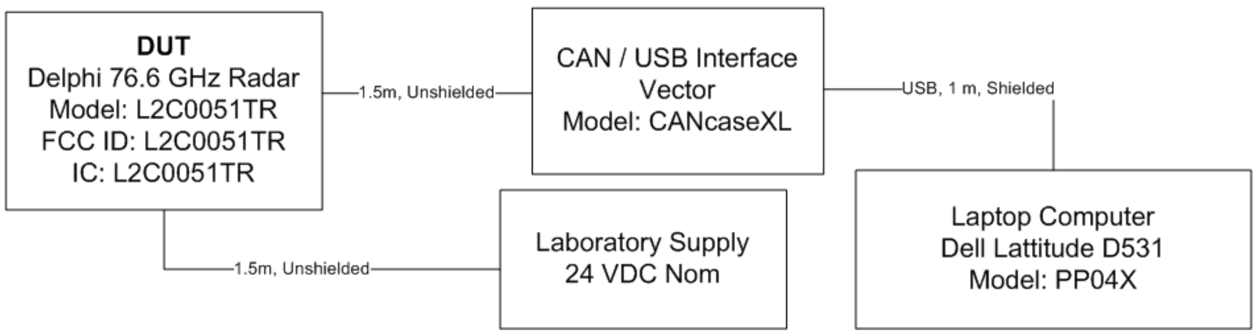


Figure 3.1 Test Configuration Block Diagram

3.2 Variants

There is only a single variant of the radar in question.

3.4 Samples

A laptop was provided to setup radar functionality over the CAN bus, directing the radar to operate in both the normal dual chirp modulated mode and a CW at the lowest and highest frequencies of each chirp band. The nominal operating voltage is 24 VDC; for testing this was supplied by a laboratory power supply.

3.3 Modes of Operation

The DUT is capable of only one normal mode of operation, as tested. Furthermore, the device operates only when the motor vehicle onto which it is installed is running.

In normal operation, the DUT transmits alternating Long Range and Short Range chirps using two transmit chains. The Short Range (SR) chirp emanates from the transmit chain TX1 array which exhibits a manufacturer declared nominal gain of 16 dBi. The Long Range (LR) chirp emanates from the transmit chain TX2 array which exhibits a manufacturer declared nominal antenna gain of 22 dBi. Both chains emit uniform broadside patterns (e.g. normal to the radome)

The DUT chirps (sweeps) 76.55 to 76.78 GHz and back in 55 us starting with the TX1(SR) mode. The up-sweep is blanked (attenuated) and the down-sweep transmits at full power. The TX1(SR) chirp lasts 18.2 ms. The DUT then switches to TX2(LR) and chirps 76.55 to 76.66 GHz at the same 55 us rate, but transmits only on the second down-sweep (e.g. other sweeps are attenuated/blanked). The TX2(LR) chirp lasts 17.8 ms. The DUT returns to TX1(SR) modulation approximately 14 ms after TX2(LR) completes, and continues to repeat with a measured 50.3 ms overall periodicity.

3.5 EMI/EMC Relevant Modifications

There were no modifications made to the DUT by this laboratory.

4. Emission Limits

4.1 Radiated Emission Limits

The DUT tested falls under the category of an Intentional Radiator, subject to FCC Part 15.253 and Industry Canada RSS-210 / RSS-GEN. The applicable critical testing frequencies with corresponding emission limits are given in Table 4.1. As a digital device this product is exempt because as it is deployed for use only in a motor vehicle.

Table 4.1. Radiated Emission Limits (Ref: FCC: 15.253 / RSS-210)

Frequency (GHz)	Forward Looking	Side Looking	Not Moving
0.030 - 40000	per 15.209	per 15.209	per 15.209
76.0 - 77.0	60 μW/cm^2	30 μW/cm^2	200 nW/cm^2
76.0 – 77.0*	88 μW/cm^2 (Avg)	88 μW/cm^2 (Avg)	88 μW/cm^2 (Avg)
76.0 – 77.0*	279 μW/cm^2 (Pk)	279 μW/cm^2 (Pk)	279 μW/cm^2 (Pk)
40.0 - 200.0	600 pW/cm^2	300 pW/cm^2	dependent
200.0 - 231.0	1000 pW/cm^2	1000 pW/cm^2	1000 pW/cm^2
* Note: Per FCC Decision 12-72, July 2012, FCC Regulations now permit greater field strength at the fundamental and do not distinguish power density limits based on the radar's use in moving vs. non-moving applications in the 77 GHz band. As these regulations have not yet been adoped into the CFR, the original emission limit of 60 μW/cm^2 is still applied throughout this test report.			

5. Test Procedures

5.1 Indoor Measurements

Prior to any measurements, all active components of the test setup were allowed a warm-up for a period of approximately one hour, or as recommended by their manufacturers.

For the tests, the unit was mounted at a 3 or 1 (or even 0.25 m) meter distance, depending on the available signal strength, and rotated through 360 degrees to determine the most intense radiation lobe. Care is taken such that there is no interference from the hand or body. Due to the rigid connection of the receive antenna to the spectrum analyzer in many instances, the DUT is also rotated around its antenna axes to match the polarization of the emission.

5.2 Field Calculation for Radiated Emission Measurements

When the measurement is made at a distance other than 3 m, but is called out at 3 m, the reading is extrapolated to the 3 m distance. This is done using the 20 dB/decade field behavior relation when translating in the far field, and 40 dB/decade relation when translating in the near field. The near-field/far-field criterion, N/F, is based on

$$N/F = 2\ D^2 / \text{wavelength}$$

where D is the maximum dimension of the transmitter or receiver antenna , and the wavelength is that of the measurement frequency. Suppose N/F = 2 m and the measurement is made at 1 m. Here the 40 dB/ decade relation is applied from 1 to 2 m, and a 20 dB/decade relation is applied from 2 to 3 m. In dB, this gives a 15.6 dB adjustment.

To convert the dBm measured and extrapolated to 3 m, the E_3(dBμV/m) is computed from

$$E_3(\text{dB}\mu\text{V/m}) = 107 + Pr + CF + K_a - Kg + K_E$$

Where P_r = power recorded on spectrum analyzer, dBm (extrapolated to 3 m distance)

CF = correction factor to compute peak power value from insufficient Rx bandwidth
K_a = antenna factor, dB/m
K_g = pre-amp gain, dB
K_E = pulse operation correction factor, dB (see 6.1)

For conversion to power densities specified in 15.253, we used

$$\text{EIRP (dBm)} = \text{S (dBm/cm}^2) + 10 \text{ Log}_{10}(4\ \pi\ \text{R(cm)}\text{\^{}}2)$$
$$\text{EIRP (dBm)} = \text{E3m (dBuV/m)} - 95.2 \text{ dB}$$

Thus, at a 3m distance:

$$\text{E3m (dBuV/m)} = \text{S (dBm/cm}^2) + 10 \text{ Log}_{10}(4\ \pi\ (300)\text{\^{}}2) + 95.2 \text{ dB} = \text{S (dBm/cm}^2) + 155.74 \text{ dB}$$

and we note that
$60 \text{ uW/cm}^2 = -12.2 \text{ dBm/cm}^2$
$600 \text{ pW/cm}^2 = -62.2 \text{ dBm/cm}^2$
$1000 \text{ pW/cm}^2 = -60.0 \text{ dBm/cm}^2$

For microwave measurements, either the receive antenna is connected directly to the spectrum analyzer, or it is connected to an external mixer followed by an insignificant length of cable. Hence, no cable loss term is used. The mixer conversion losses are programmed in the spectrum analyzer and are included in the dB values. However, for 125 GHz and up, an external mixer with an external LO and pre-amplifier was used. The mixer conversion loss, IF amp gain and cable losses are included in mixer conversion factor.

6. Test Results

6.1 Correction for Pulse Operation

In the following measurements, the maximum spectrum analyzer RBW of 1 MHz was employed. Peak power measurements were made with the DUT employing CW mode at both the high or low end of the chirp band in either TX1(SR) or TX2(LR) chains. Duty cycle correction is applied to the CW measurements to determine the average power values by examining the worst-case time-domain transmission from the DUT at a single frequency for each transmit chain.

Duty Cycle to Obtain Average Power

When the DUT operates, the signal received at a single frequency is a pulse resulting from the test receiver's (spectrum analyzer's) IF bandwidth, dictated by regulations as RBW/VBW = 1 MHz/3MHz. In this case, the resulting pulse is measured to be 2 us wide. As explained in section 3.3 of this report, when the DUT is operating in normal modulating mode it remains in TX1(SR) mode for 18.2 ms and then transmits TX2(LR) for 17.8 ms with a repeating period of 50.5 ms. Thus a worst-case duty cycle for this device is computed as:

$$K_E = (2 \text{ us} / 55 \text{ us} \times 18.2 \text{ ms} + 2 \text{ us} / 110 \text{ us} \times 17.8 \text{ ms}) / 50.5 \text{ ms} = 0.0195 = \mathbf{-17.1\ dB}$$

Note that the EIRP power level of the TX2(LR) mode is approximately 8 dB higher than that of the TX1(SR) modulation, but such is neglected in this formulation.

6.2 Potential Health Hazard EM Radiation Level

We use two methods to determine health hazard levels and these are obtained (1) by probing the near field and (2) by computing EIRP from measured emission data.

(1) Direct measured radiation level from the unit is determined using a W-band Standard Gain horn fed directly into the spectrum analyzer via the harmonic mixer. The analyzer is set to RBW=1 MHz, VBW=3 MHz. The physical aperture of the horn antenna is 1.869 x 2.461cm (A = 4.60 cm^2). Its effective aperture (Aeff) at 76.5 GHz is 2.23 cm^2, based on a Gain of 22.6 dB. For the subject DUT, the near-field region

was probed, rotating the DUT on all axis and polarizations and moving the DUT closer and closer to the radome. The maximum average reading at the radome was

$$P_{cw} = Pr + K_E = -2.2 \text{ dBm} - 17.1 \text{ dB} = -19.3 \text{ dBm} = 0.012 \text{ mW}$$

Hence the worst case power density of the device at its radome is

$$S_{meas} \text{ (mW/cm}^2) = P_{cw} \text{ /Aeff} = 0.012 \text{ mW/ } 2.23 \text{ cm}^2 = 0.0054 \text{ mW/cm}^2$$

and meets the FCC Part 1.1307, 1.1310, 2.1091, and 2.0193 requirements.

(2) The worst case power density at a given separation distance can be calculated following FCC OET Bulletin 65 as follows, where S is power density,

$Scalc_{cw}$ (3m) = -47.8 dBm/cm^2 (avg. from Table 6.2)
$EIRP_{cw}$ = Scalc (3m) x 4π (300 cm)^2 = -47.8 + 60.5 = 12.7 dBm = 18.6 mW
ERP_{cw} = EIRP – 2.15 = 12.7 – 2.15 = 10.6 dBm = 11.5 mW

S_{calc} (mW/cm^2) = EIRP(mW)/(4π R(cm)^2).

The DUT will be mounted in the bumper of an automobile and will only be in operation when the vehicle is running. In general, the DUT will be mounted no less than 1.5 cm from the exterior surface of the vehicle. Following the formulation for power density at a distance given the radar's EIRP is

S_{calc} (mW/cm^2) = 18.6 mW /(4π 1.5cm ^{2}) = 0.99 mW/ cm^2.

Which is an overestimated value that also demonstrates compliance with FCC Part 1.1307, 1.1310, 2.1091, and 2.0193 requirements when the DUT is mounted into the motor vehicle.

6.3 Emission Bandwidth

The Short Range (high resolution) chirp demonstrates a 234 MHz emission bandwidth, while the higher EIRP Long Range (low resolution) chirp demonstrates a 118 MHz emission bandwidth. Since both emissions alternate and overlap in the same frequency band, the cumulative emission bandwidth is reported at 234 MHz.

6.3 Effect of Supply Voltage Variation

The DUT is designed to operate on a nominal 24 VDC originating from a vehicular 24-volt system. The relative radiated emissions and frequency were recorded at the CW mode "fundamental" (76.7 GHz) center frequency as the supply voltage was varied from 18 to 30 VDC. Figure 6.2 shows the emission power variation vs. supply voltage.

6.4 Effect of Temperature Variation on Fundamental Frequency

The DUT was cooled to –20 C and its temperature was slowly increased to +55 C, during which time the fundamental emission was monitored. Measurements of band-edge frequencies were taken every 10 C. Figure 6.3 shows the emission center frequency as a function of temperature.

6.5 Sample Field Computations

FUNDAMENTAL
Refer to: (a) Table 6.2 (f > 40 GHz); line 5
(c) Table 4.1; limit; (60 uW/cm^2)

To compute the power density we use:

$P3_{avg}$ dB(mW/ cm^2) = 107 + Pr(3m) + Ka - Kg + K_E – 155.74
= 107 – 27.3 + 45.3 – 0 – 17.1 – 155.74
= -47.8 dBm/cm^2

The limit is 60 uW/cm^2 = -12.2 dBm/cm^2

SPURIOUS
Here we present computation for the reference signal emission at 4.8 GHz.
Refer to: (a) Table 6.1 (f < 40 GHz); line 3
(c) Table 4.1; 15.209 limit; 54 dB(μV/m)

To compute received power at 3 m from that measured at 1 m, with a N/F transition at 1.49 m we use:

Pr(3m) = Pr(1m) - 40 x Log10(1.49 m / 1.0 m) – 20 x Log10 (3 m / 1.49 m)

and field strength at 3 meters is:

E3 dB(μV/m) = 107 + Pr(3m) + Ka - Kg + Ke
= 107 – 65.8 + 24.7 – 37.5 + 0
= 28.4 dB(μV/m)

The limit is 54.0 dB(μV/m).

Table 6.1 Highest Emissions Measured (f<40 GHz)

RF/Microwave Radiated Emissions — Delphi 51TR

#	Freq. GHz	Ant. Used	Ant. D,cm	Meas. dist, m	Pr dBm	N/F m	Pr(3m) dBm	Ka dB/m	Kg dB	E3 dBµV/m	E3lim dBµV/m	Pass dB	Comments (Notes)
1													
2	4 to 4.8	C-horn	21.6	1.00	-60.0	1.24	-71.4	24.7	37.5	22.8	54.0	31.2	Noise, Pk (1,3,4,5)
3	4.80	C-horn	21.6	1.00	-52.8	1.49	-65.8	24.7	37.5	28.4	54.0	25.6	Freg / 16, Pk (8)
4	4.8 to 6	C-horn	21.6	1.00	-58.0	1.49	-71.0	24.7	37.5	23.2	54.0	30.8	Noise, Pk (1,3,4,5)
5	6 to 8	XN-horn	28.9	0.25	-57.3	3.34	-100.5	25.3	37.0	- 5.2	54.0	59.2	Noise, Pk (1,3,4,5)
6	8 to 9.6	X-horn	19.4	0.25	-55.9	2.01	-88.6	28.5	37.0	9.9	54.0	44.1	Noise, Pk (1,3,4,5)
7	9.60	X-horn	19.4	0.25	-55.0	2.41	-92.4	29.5	37.0	7.1	54.0	46.9	Freq / 8, Pk. (8)
9	9.6-12.6	X-horn	15.2	0.25	-58.5	1.48	-83.2	29.3	17.0	36.1	54.0	17.9	Noise, Pk (1,3,4,5)
10	12.6to18	Ku-horn	15.2	0.25	-58.5	1.94	-90.3	29.3	17.0	29.0	54.0	25.0	Noise, Pk (1,3,4,5)
13	18 to 26	K-horn	10.0	0.10	-62.8	1.20	-98.0	33.2	0.0	42.1	54.0	**11.9**	Noise, Ave (1,3,4,5)*
14	26 to 40	Ka-horn	7.0	0.10	-68.5	1.11	-101.7	36.0	0.0	41.3	54.0	12.7	Noise, Pk (1,3,4,5)
15													*Pk 8.6 dB higher
16	NOTES:												
17	(1) When measured at stated distance from the DUT, no signal was detected.												
18	(2) Mixer conversion loss is programmed and compensated in SA.												
19	(3) When extrapolating to 3 m, use Near (40 dB/dec) and Far Fld (20 dB/dec) behavior.												
20	(4) For Ave. measurement a VBW >= 1% RBW was used; RBW was always 1 MHz.												
21	(5) DUT max. antenna size, D = 8.0 cm.												
22	(6) Extermal mixer was used and CL was compensated in SA.												
23	(7) For ridge-horn (R-Horn) use aperture dimension of one half wavelength.												
24	(8)Peak to Average ratiowas not applied in demonstrating compliance.												
25													
26													

Digital Radiated Emissions

#	Freq. MHz	Ant. Used	Ant. Pol.	Pr dBm	Det. Used			Ka dB/m	Kg dB	E3 dBµV/m	E3lim dBµV/m	Pass dB	Comments
27													
28	Not applicable, device used exclusively in transportation vehicles (15.103(a)).												
29													

Conducted Emissions

#	Freq. MHz	Line Side	Det. Used	Vtest dBµV	Vlim dBµV	Pass dB							Comments
33													
34	Not applicable, DC powered.												
35													

Meas.7/23/12-9/06/12; U of Mich.

Table 6.2 Highest Emissions Measured (f>40 GHz)

RF/Microwave Radiated Emissions — Delphi 51TR; FCC/IC

#	Freq. GHz	Ant. Used	Ant. D,cm	Meas. dist, m	Pr dBm	N/F m	Pr(3m) dBm	Ka dB/m	Kg dB	E3 dBm/cm2	E3lim dBm/cm2	Pass dB	Comments (Notes)
1	40-76	U-horn	4.63	0.25	-64.0	1.71	-102.3	41.0	0.0	-110.0	-62.2	47.8	Noise, pk. meas. (1-5)
2	76.55	W-horn	2.46	3.00	-27.5	3.27	-27.5	45.3	0.0	-30.9	7.8	38.7	Signal CW pk. meas (2-5)
3	76.55	W-horn	2.46	3.00	-27.5	3.27	-27.5	45.3	0.0	-48.0	-12.2	35.8	Signal Avg. (2-5,7)
4	76.66	W-horn	2.46	3.00	-27.3	3.27	-27.3	45.3	0.0	-30.7	7.8	38.5	Signal CW pk. meas (2-5)
5	76.66	W-horn	2.46	3.00	-27.3	3.27	-27.3	45.3	0.0	-47.8	-12.2	**35.6**	Signal Avg. (2-5,7)
6	76.78	W-horn	2.46	3.00	-38.3	3.28	-38.3	45.3	0.0	-41.7	7.8	49.5	Signal CW pk. meas (2-5)
7	76.78	W-horn	2.46	3.00	-38.3	3.28	-38.3	45.3	0.0	-58.8	-12.2	46.6	Signal Avg. (2-5,7)
8	77-125	W-horn	2.46	0.25	-53.2	3.29	-96.4	46.4	0.0	-98.7	-62.2	36.5	Noise, pk. meas.(1-6)
9	125-200	G-horn	1.25	0.25	-66.3	5.33	-109.5	54.0	0.0	-104.2	-62.2	42.0	Noise, pk. meas.(1-6)
10	200-231	G-horn	1.25	0.25	-66.3	8.53	-109.5	54.0	0.0	-104.2	-60.0	44.2	Noise, pk. meas.(1-6)
11													
12													
13													
14													
15	NOTES:												
16	(1) When measured at 0.25 cm from the DUT, no signal was detected anywhere, even at the radome.												
17	(2) Mixer conversion loss is programmed in the spectrum analyzer and automatically adjusts the readings.												
18	(3) When extrapolating to 3 m, use Near (40 dB/dec) and Far Fld (20 dB/dec) behavior.												
19	(4) For Ave. measurement a VBW >= 1% RBW was used; RBW was always 1 MHz.												
20	(5) DUT max. antenna size, D = 8.0 cm												
21	(6) Extermal mixer, LO, and 36.5 dB IF amp were used												
22	(7) Average Power Limits Apply. A duty of -17.1 dB has been applied to the fundamental emission (see section 6.1 of test report)												
23													
24													

RF Health Hazard

#	Freq. GHz	Ant. Used	Ant. D,cm	Meas. dist, m	Pr dBm	N/F m	Pr(3m) dBm	Ka dB/m	Kg dB	E3 dBm/cm2	EIRP dBm	Pass dB	Comments (Notes)
25	76.66	W-horn	8.0	3.00	-27.3	3.27	-27.3	45.3	0.0	-30.7	29.8		Peak
26	76.66	W-horn	8.0	3.00	-27.3	3.27	-27.3	45.3	0.0	-47.8	12.7		Avg = Pk - 17.1 dB
27													
28													
29													
30													
31													
32													

Meas.7/23/12-9/06/12; U of Mich.

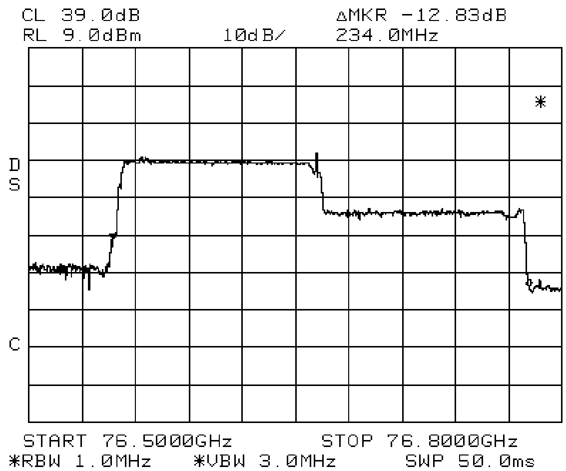


Fig. 6.1(a) Emission Bandwidth including both Long and Short range chirps (234.0 MHz).

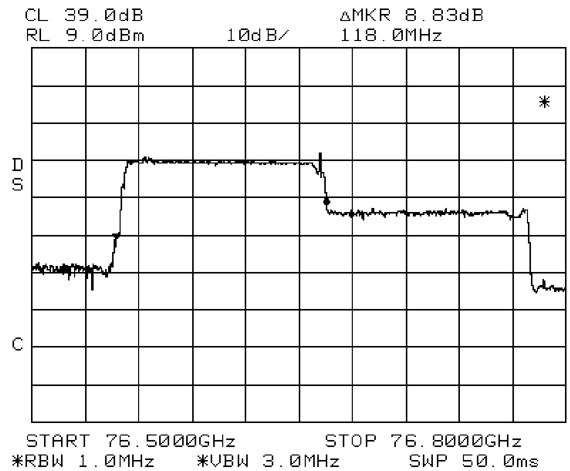


Fig. 6.1(b) Emission Bandwidth of Long range chirp only (118.0 MHz).

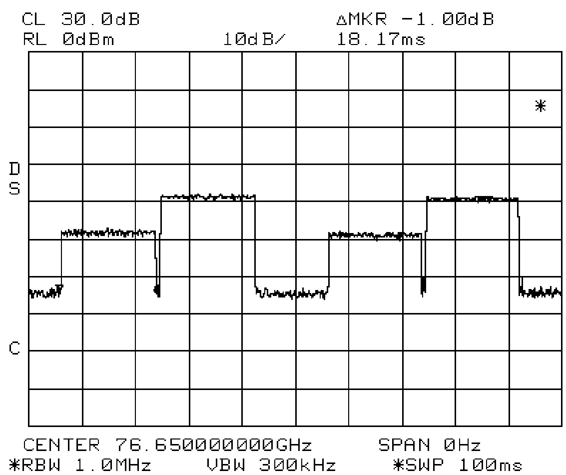


Fig. 6.1(c) Center Frequency Time Domain, Short Range chirp frame width (18.17 ms / 1MHz RBW)

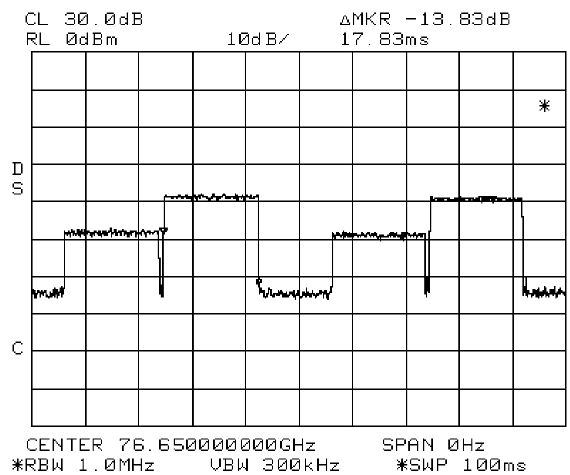


Fig. 6.1(d) Center Frequency Time Domain, Long Range chirp frame width (17.83 ms / 1MHz RBW)

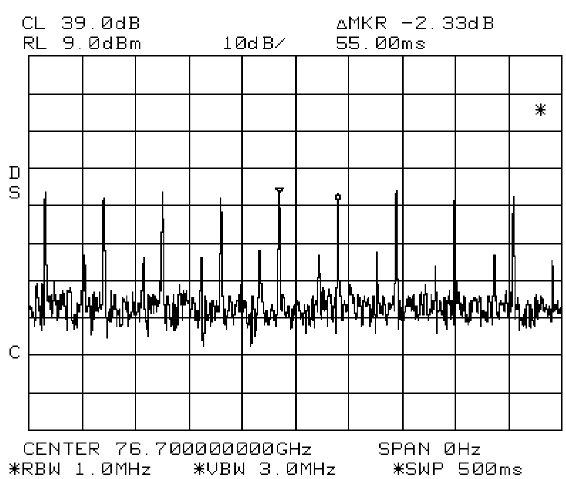


Fig. 6.1(e) Short Range Chirp Rate.

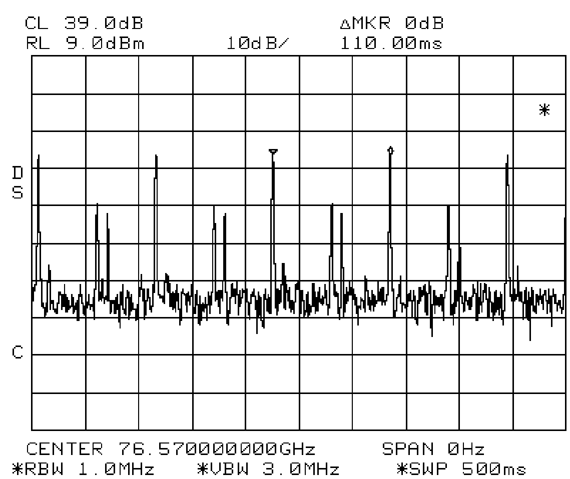


Fig. 6.1(f) Long Range Chirp Rate

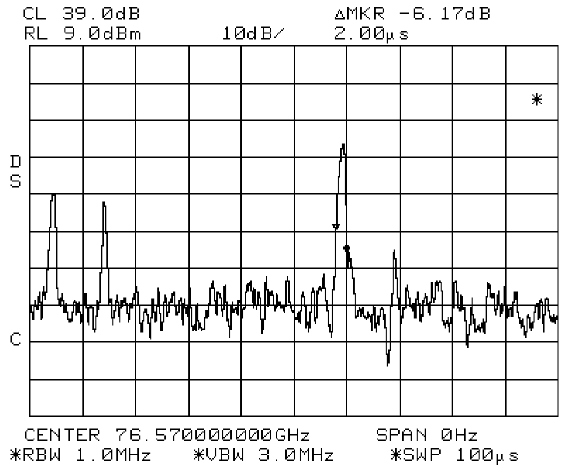


Fig. 6.1(g) Chirp Pulse Width in RBW / VBW = 1 / 3 MHz

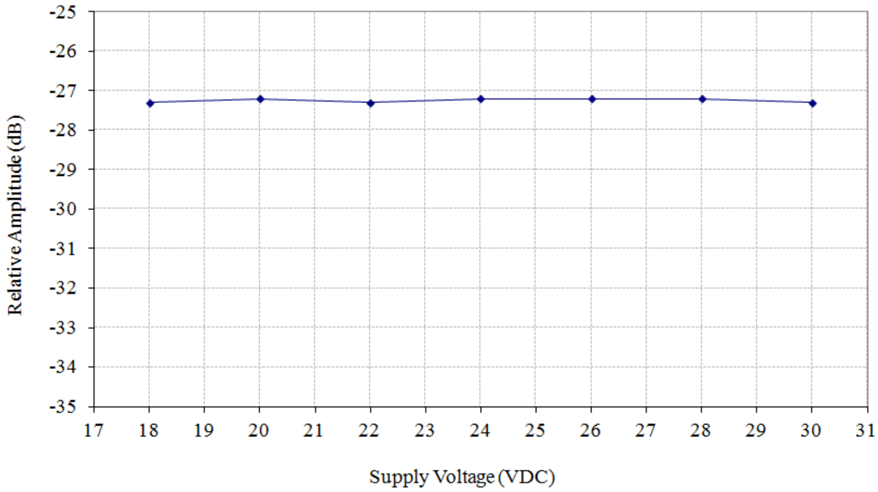


Fig. 6.2 Relative amplitude vs. supply voltage.

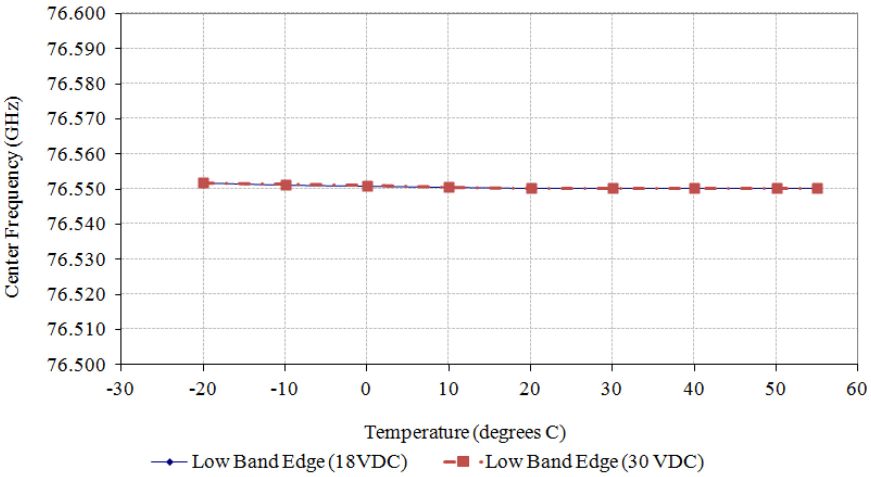
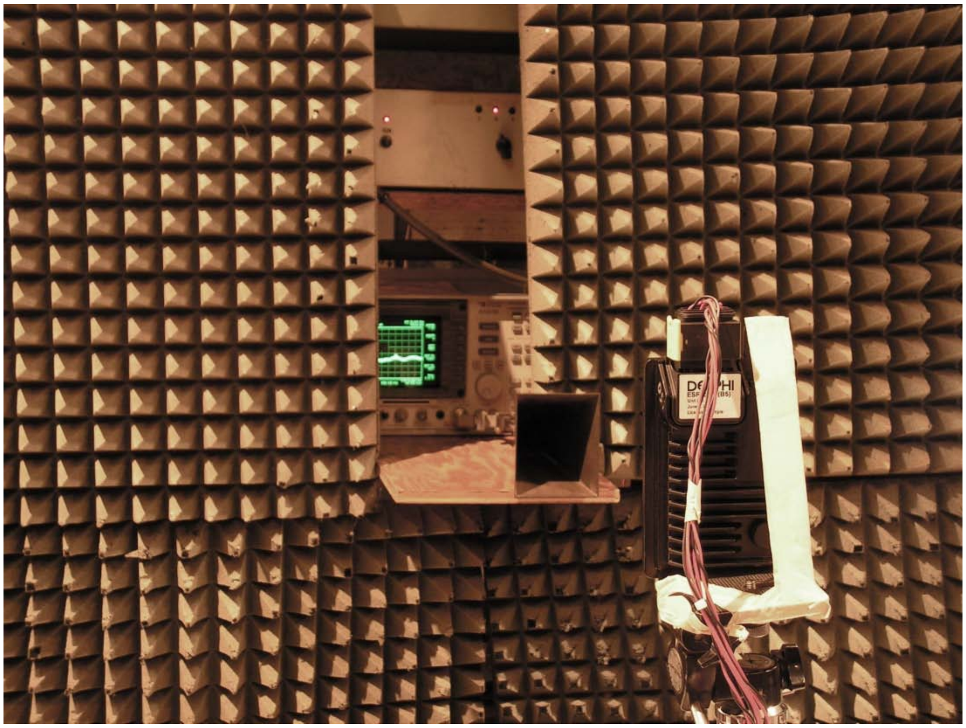


Fig. 6.3 Relative CW frequency vs. supply voltage at lower band edge.



High Frequency DUT test setup (one of three axes tested)