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Measured Radio Frequency Emissions
From

Delphi UWB 24 GHz Automotive Radar
Model(s): 12237659

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Summary

Tests for compliance with FCC Regulations, according to Part 15.515, were performed on Delphi Automotive Systems UWB Radar. In testing completed on October 24, 2005, the device tested met the UWB emission limits at the fundamental by 1.9 dB at f_M, and by more than 0.3 dB for all other UWB emissions. With regard to RF exposure, the maximum RF field at a 20 cm distance was calculated to be 13.0 nW/cm^2. The DUT is designed for vehicular applications, and as such, digital emissions from support circuitry are not subject to FCC Part 15, Subpart B; however, these emissions were recorded in the process of characterizing the device. Radiated digital emissions from circuitry used to enable the operation of the UWB transmitter meet the FCC/IC Class B (15.209) limit by 15.4 dB.

1. Introduction

Delphi Automotive Systems UWB Radar was tested for compliance with FCC Regulations, Part 15, adopted under Docket 87-389, April 18, 1989. The tests were performed at the University of Michigan Radiation Laboratory Willow Run Test Range following the procedures described in ANSI C63.4-2003 "Methods of Measurement of Radio-Noise Emissions from Low-Voltage Electrical and Electronic Equipment in the Range of 9 kHz to 40 GHz" and the FCC Part 15, Subpart F, "Ultra-Wideband Operation." The Site description and attenuation characteristics of the Open Site facility are on file with FCC Laboratory, Columbia, Maryland (FCC Reg. No: 91050) and with Industry Canada, Ottawa, ON (File Ref. No: IC 2057).

2. Test 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 8592L, SN: 3710A00856
Spectrum Analyzer (9kHz-26GHz)	X	Hewlett-Packard 8593E, SN: 3412A01131
Spectrum Analyzer (9kHz-26GHz)		Hewlett-Packard 8563E, SN: 3310A01174
Spectrum Analyzer (9kHz-40GHz)	X	Hewlett-Packard 8564E, SN: 3745A01031
Spectrum Analyzer (9kHz-50GHz)		Agilent Model 8565EC, S/N:4220A00809
Harmonic Mixer (40-60 GHz)	X	Hewlett-Packard 11970U, SN: 2332A00500
Harmonic Mixer (60-90 GHz)	X	Pacific Millimeter Prod., VN, SN: 47
Harmonic Mixer (75-110 GHz)	X	Hewlett-Packard 11970W, SN: 2521A00179
Harmonic Mixer (140-220 GHz)		Pacific Millimeter Prod., GMA, SN: 26
L-band horn (0.9-2.0 GHz)	X	FXR, L6008, SN:622
S-band horn (2.0-4.5 GHz)	X	Scientific Atlanta, SGH2.6, SN: 43
C-band horn (4.5-6.0 GHz)	X	Bondardi, DBK-520, SN: 940410
Xn-band horn (6.0-8.0 GHz)	X	Univ. of Michigan, RLXN, SN: 1
X-band horn (8.2- 12.4 GHz)	X	Scientific Atlanta , 12-8.2, SN: 730
K-band horn (18-26.5 GHz)	X	FXR, Inc., K638KF
Ka-band horn (26.5-40 GHz)	X	FXR, Inc., U638A
U-band horn (40-60 GHz)	X	Custom Microwave, HO19
V-band horn (60-90 GHz)	X	Custom Microwave, HO12
W-band horn (75-110 GHz)	X	Custom Microwave, HO10
G-band horn (140-220 GHz)		Custom Microwave, HO5R
Bicone Antenna (30-250 MHz)	X	University of Michigan, RLBC-1
Bicone Antenna (200-1000 MHz)	X	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)		Avantek, A11-1, A25-1S
Amplifier (5-4500 MHz)	X	Avantek
Amplifier (4.5-13 GHz)	X	Avantek, AFT-12665
Amplifier (6-18 GHz)	X	Trek
Amplifier (18-26.5 GHz)	X	Avantek, AMT-26158-13
Amplifier (18-40.0 GHz)	X	CTT Inc., ALO/400-8035
LISN (50 μH)		University of Michigan
Signal Generator (0.1-2060 MHz)		Hewlett-Packard, 8657B
Signal Generator (0.01-20 GHz)		Hewlett-Packard, 8550B / 83592A

3. Configuration and Identification of Device Under Test

The Device Under Test (DUT) is a 24 GHz UWB Radar. It is a BPSK (Binary Phase Shift Keyed) system with a constant amplitude 24.7 GHz signal modulated at keying frequencies of 625 MHz and 1250 MHz. The size of the DUT is 25(W) x 10(H) x 3(D) cm with a single connector on the backside. The DUT is a complete radar unit; however, additional signal processing and controlling may be performed by other processors on the vehicle. When installed on a vehicle, the device will operate (transmit) only when the vehicle ignition is on. During testing, a laptop with serial communication was used to control and verify correct device operation. Nominal operating voltage is 13.4 VDC; for testing this was supplied by a laboratory style power supply.

The DUT was manufactured by Delphi Delco Electronics de Mexico SA de CV, Parque Industrial Reynosa, Tamaulipas, Mexico. It is identified as:

Delphi 24 GHz UWB Radar
Model(s): 12237659
S/N: 5610000052830002
FCC ID(s): L2C0030TR

3.1 Changes made to the DUT

No changes where made to the DUT by this test laboratory.

4. Emission Limits

4.1 UWB Radiated Emission Limits (FCC 15.515, 15.521)

The DUT tested falls under the category of an UWB vehicular radar, subject to FCC 15.515, and all other sections referred to therein. The applicable critical testing frequencies with corresponding emission limits are given in Tables 4.1 - 4.2.

Table 4.1. UWB Radiated Emission Limits (Ref: FCC: 15.515(d))

Frequency (MHz)	RMS EIRP Limit* (dBm)
960-1610	-75.3
1610-22,000	-61.3
22,000-29,000	-41.3
29,000-31,000	-51.3
Above 31,000	-61.3

*1 MHz RBW, VBW >= RBW, SWP < 1ms / bin

Table 4.2. UWB Radiated Emission Limits (Ref: FCC: 15.515(e), 15.521)

Frequency (MHz)	RMS EIRP Limit* (dBm)
1164-1240	-85.3
1559-1610	-85.3

*RBW >= 1kHz, VBW >= RBW, SWP < 1ms / bin

Additionally, for a Vehicular UWB radar, a Peak radiated emission limit (Ref: FCC: 15.515(f)) of 0 dBm EIRP in a 50 MHz bandwidth is applicable to the maximum UWB emission (f_M). For measurements performed with a Spectrum Analyzer resolution bandwidth less than 50 MHz, the limit may be computed as 20 log (RBW/50) dBm (per FCC regulations).

4.2 Digital Radiated Emission Limits (FCC 15.109, 15.209, 15.521)

As a vehicular device, all digital emissions from circuitry that are not used to enable the operation of the UWB transmitter are exempt (FCC 15.103). However, emissions from circuitry that are used to enable the operation of the UWB transmitter are subject to the emissions limits of FCC 15.209 (FCC 15.521). In this report, digital radiated emission limits are compared with all measured digital emissions from the DUT in an effort to fully characterize the UWB device.

Table 4.3. Digital Radiated Emission Limits (FCC: 15.33, 15.35, 15.109/15.209; IC: RSS-210, 7.3)

Freq. (MHz)	Class A, E_{lim} dB(μV/m)	Class B, E_{lim} dB(μV/m)
30-88	49.5	40.0
88-216	54.0	43.5
216-960	56.9	46.0
Above 960	60.0	54.0

Note: Average readings apply above 1000 MHz (1 MHz BW)
Quasi-Peak readings apply up to 1000 MHz (120 kHz BW)

4.3 Emission Attenuation Above Horizon (FCC 15.515(c))

Vehicular radar systems authorized, manufactured or imported on or after a particular date are subject to verification that; any emissions within the 23.6-24.0 GHz band that appear a certain number of degrees above the horizon must maintain a certain emission level below the limits of Section 4.1. The following table illustrates the limits set forth by the commission.

Table 4.4. Attenuation below Table 4.1 limits (Ref: FCC: 15.515(c))

Effective Date	Minimum Off-Boresight Angle	Required Attenuation	Resulting Limit
Currently	38^o	25 dB	-66.3 dBm
1/1/2005	30^o	25 dB	-66.3 dBm
1/1/2010	30^o	30 dB	-71.3 dBm
1/1/2014	30^o	35 dB	-76.3 dBm

4.4 Conductive Emission Limit (FCC 15.107)

Conductive emissions limits do not apply, as this is a vehicular device operating on 12 VDC.

5. Test Procedure and Computations

5.1 Test Procedure

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 some of the high frequency tests performed, the unit was hand-held at a 3 meter (or less) distance, depending on the available signal strength, and rotated through 360 degrees to determine the most intense radiation lobe. Care was taken to eliminate any interference from the hand or body. Due to the rigid connection of the receive antenna to the spectrum analyzer, the DUT is also rotated around its antenna axes to match polarization for maximum emission measurement.

5.2 Field Computations

EIRP calculations are performed using a 20 dB/decade far-field attenuation rate for all measurement ranges, per FCC

To convert the dBm measured and extrapolated to EIRP, the E(dBμV/m) at the test receiver antenna is computed from

$$E(dB\mu V/m) = 107\ dB + Pr(R_{meas}) + K_a - Kg$$

Where P_r = power recorded on spectrum analyzer, dBm
K_a = antenna factor, dB/m
K_g = pre-amp gain and/or cable loss, dB

For conversion to EIRP as required to meet the regulations in FCC 15.515, 15.521, we use

$$EIRP\ (dBm) = E(dB\mu V/m) - 104.77 + 20\ \log_{10}(R_{meas})$$

Thus:

$$EIRP\ (dBm) = 2.23 + Pr(dBm) + Ka - Kg + 20\ \log_{10}(R_{meas})$$

For microwave measurements above 40 GHz, the receive antenna is connected directly to an external mixer followed by an insignificant length of cable for the LO and IF signals. The mixer conversion loss and cable loss are programmed into the spectrum analyzer and are included in the measured values. The results are given in Table 6.1. For the UWB emissions measured, we see that the DUT peak detected emissions meet the RMS limits at the maximum emission frequency (f_M) by 1.9 dB and for emissions above 40 GHz, the limit is met by more than 0.3 dB.

The EIRP limits set forth in FCC 15.515 are RMS limits. However, as peak detected emissions will always be greater than RMS detected emissions (for identical receiver bandwidth, sweep, and span settings), peak detected emissions can be applied to the RMS limits for demonstration of DUT compliance with said limits. This method is used herein. (See FCC/U. of Mich. correspondence in the Attestations exhibit in this regard.)

5.3 Sample Field Computations – UWB Emission Calculations

Refer to: (a) Table 6.1; line 19; p 8
(b) Section 6.2; Figure 6.5, power measurement; p. 6
(c) Table 4.1; limit; p. 3 (-41.3 dBm RMS EIRP)

The approach is to follow standard equations for computing EIRP assuming a 20 dB/decade field attenuation rate. See equations in Section 5.2, p. 5 of the report (above).

To compute the field strength we use:

$Pr(R_{meas}) = -28.2$ dBm
Rmeas = 0.3 m

$$\begin{aligned} EIRP\ (dBm) &= 2.23 + Pr(dBm) + Ka - Kg + 20\ \log_{10}(R_{meas}) \\ &= 2.23 + -\ 28.2 + 33.2 - 40 + 20\ \log_{10}(0.3) \\ &= -41.9\ dBm\ (pk\ detected) \end{aligned}$$

The limit is -41.3 dBm (rms detected), and thus the device passes the limit by at least 0.6 dB. Measurements made over a smaller span indicate the DUT meets the limit by at least 1.9 dB.

5.4 Measurement Procedure for Emission Attenuation Above Horizon (FCC 15.515(c))

Initially, the peak level of the radiated emissions is measured over all azimuth and elevation angles. (The dominant source of radiated energy is the transmit antenna.) This peak occurs at the same angle that the antenna gain is maximized, which is perpendicular to the radome (azimuth = 0 degrees). This is measured with the radar in spread spectrum mode, operating as it would in the field, with the receive antenna co-polarized with the radar antenna.

Next, the radar module is placed in a CW test mode, with the spread spectrum modulation disabled. In this mode, the unit transmits higher power spectral density, providing a means of making the pattern measurement with sufficient dynamic range. With the device in this mode, the worst case azimuth and elevation patterns are measured. Once antenna patterns are obtained, the peak UWB transmitted power level, measured in the 23.6 to 24.0 GHz band (Section 6.2) is assumed to correlate to the peak of the measured antenna pattern. The off angle power is then computed by subtracting the sidelobe level (dBc) from the main lobe transmitted power measured in the 23.6 to 24.0 GHz band.

6. Measurement Results

6.1 Fundamental Spectrum Measurements (FCC 15.515, 15.521)

Figures 6.1-6.2. Fundamental spectrum. RBW=1 MHz, VBW=3 MHz; 10 cm measurement distance, peak detect, peak hold. DUT rotated for maximum emissions. From this data, the following parameters were measured:

	Measured	Applicable Limit	Complies
Maximum Frequency:	f_M = 24.690 GHz	f_M > 24.075 GHz	Yes
Lower Frequency:	f_L = 24.185 GHz	f_L > 22.000 GHz	Yes
High Frequency:	f_H = 25.050 GHZ	f_H < 29.000 GHz	Yes
Center Frequency:	f_C = 24.617 GHz	f_M > 24.075 GHz	Yes

10 dB Bandwidth: BW = 865 MHz > 500 MHz or 20% CF Yes

6.2 UWB Radiated Emission Measurements (FCC 15.515, 15.521)

Figures 6.3-6.5. UWB Emissions: 9 kHz – 110 GHz (three example plots only). RBW=1 MHz, VBW>RBW; measurement distance varied as necessary to maintain receive signal to noise ratio, peak detect, peak hold. (Peak vs. RMS detection; see section 5.2 of this report.) All significant emissions reported in Table 6.1.

Figures 6.6-6.7. UWB Emissions: 1164-1240, 1559-1610 MHz. RBW>= 1 kHz, VBW>RBW; measurement distance 0.3 m, peak detect, peak hold, see Table 6.2. (Peak vs. RMS detection; see section 5.2 of this report.)

Peak Power Limit FCC 15.515(f): Figure 6.5. Peak Power Limit = 20 Log_{10}(RBW/50) = -34 dBm

<u>Peak Power EIRP</u>: -41.9 dBm <u>Limit</u>: -34 dBm <u>Complies</u>: Yes

The antennas used are standard gain horn antennas and thus may not see the entire device at close range. Therefore, the DUT was rotated through all axes and angles in front of the antenna, keeping the separation distance listed.

6.3 Digital Radiated Emission Measurements (FCC 15.209, 15.521)

Data Provided in Table 6.3. Digital Emissions: RBW=120 kHz, VBW>RBW; 3 m measurement distance, measured on OATS, peak detection, peak hold. NOTE: Table 6.3, all other digital emissions > 20 dB below FCC Class B.

6.4 Receive Chain Emissions (FCC 15.101(b))
Figures 6.8-6.10. Receive Chain Emissions: RBW=1 MHz, VBW>=RBW; measurement distance 0.3 m, peak detection, peak hold. Data compared with FCC Class B limit for reference, Table 6.2.

The 8.236 GHz radiated emission is not an emission from the TX chain, but is a spurious emission emanating from the device receive chain LO (the doubler in the RX chain requires the largest portion of the LO power, the reference signal to the transmitter is 14 dB lower). The 8 GHz emission does not radiate at a level above the UWB emission from the transmitter's antenna, as computed from the theoretical performance of the BPSK digital encoder and both the calculated and measured response of the TX chain Bandpass Filter (-30 dB at 8 GHz). The waveform associated with the particular PN code has the center spectral line reduced by 36 dB relative to the first upper and lower spectral lines of the waveform. Thus, this emission is solely an emission from the receiver portion of the radar.

The 16.472 GHz emission is an LO generated for use only in the receive chain of the radar (see block diagram).

The 32.944 GHz emission is the 2nd harmonic of the LO generated for use only in the receive chain of the radar.

6.5 Emission Attenuation Above Horizon (FCC 15.515(c))
Figure 6.11, 6.5. Emissions in the 23.6 to 24.0 GHz band above the horizon. Figure 6.11 demonstrates the TX antenna pattern for the DUT. Figure 6.5 shows the peak detected emissions levels in the 23.6 to 24.0 GHz band, EIRP computed in Table 6.1. Description of measurement procedure in Section 5.4.

Angle	Sidelobe Level.	Emission Level.	Total Emission Level	Compliance
30^o min	-24.0 dB	-58.3 dBm @ 24.00 GHz	-82.3 dBm < -76.3 dBm	beyond 1/1/2014

6.6 Health Hazard EM Radiation Level
Health hazard radiation levels are computed from the measured EIRP value following FCC OET Bulletin 65 as follows, where S is power density,

Power density is formulated as: $S(mW/cm^2) = EIRP(mW)/(4\pi\ R(cm)^2)$

The highest peak power density in the 10 dB UWB Bandwidth of the DUT recorded with a 1 MHz RBW, as reported in Table 6.1 is -50.8 dBm. Using the UWB bandwidth of the device (1.003 GHz), the maximum EIRP over the emission bandwidth can be computed as:

$$EIRP_{max} = EIRP\ (dBm) + 10\ Log_{10}(BW/1MHz) = -41.9\ dBm + 30.0\ dB = -11.9\ dBm = 64.6\ uW$$

Thus, the maximum power density at a distance of 20 cm is computed as:

$$S(mW/cm^2) = 0.0646\ mW\ /\ (4\pi\ 20(cm)^2) = \mathbf{13\ nW/cm^2}$$

6.7 Conducted Emission Measurements
Not applicable.

6.8 Effect of Supply Voltage Variation
The DUT is designed to operate on 13.4 VDC, originating from a vehicular 12-volt system. The relative radiated emissions and frequency were recorded at the "fundamental" (24.69 GHz) as the supply voltage was varied from 8 to 16 VDC. Figure 6.12 shows the emission power variation. Current at 12.0 VDC was 445 mA.

Table 6.1 Highest UWB Emissions Measured

UWB Radiated Emissions (FCC 15.515(d))												Delphi UWB 24
#	Freq. GHz	Ant. Used	Ant. D,cm	Meas. dist, m	NF* m	Pr dBm	Ka dB/m	Kg dB	EIRP dBm	EIRPlim dBm	Pass dB	Comments (Notes)
1	1.87	L-Band	56.0	0.200	3.90	-72.6	18.2	28.0	-94.1	-61.3	32.8	Pk., (3,4)
2	1.38	L-Band	56.0	0.200	2.89	-72.8	18.5	28.0	-94.0	-75.3	18.7	Pk., (3,4)
3	1.93	L-Band	56.0	0.200	4.04	-73.2	19.6	28.0	-93.3	-61.3	32.0	Pk., (3,4)
4	2.50	S-Band	33.0	0.300	1.82	-53.6	21.5	26.3	-66.6	-61.3	5.3	Pk., (3,4)
5	2.81	S-Band	33.0	0.300	2.04	-54.4	22.0	25.7	-66.3	-61.3	5.0	Pk., (3,4)
6	3.29	S-Band	33.0	0.300	2.39	-56.6	22.7	24.6	-66.8	-61.3	5.5	Pk., (3,4)
7	5.01	C-Horn	21.6	0.300	1.56	-47.3	24.6	38.0	-68.9	-61.3	7.6	Pk., (3,4)
9	5.54	C-Horn	21.6	0.300	1.72	-56.3	24.8	38.0	-77.8	-61.3	16.5	Pk., (1,3,4)
10	5.30	C-Horn	21.6	0.300	1.65	-56.7	24.7	38.0	-78.2	-61.3	16.9	Pk., (1,3,4)
11	7.81	Xn-Horn	28.9	0.300	4.35	-53.3	25.6	36.8	-72.7	-61.3	11.4	Pk., (1,3,4)
12	6.99	Xn-Horn	28.9	0.300	3.89	-53.3	24.9	36.8	-73.4	-61.3	12.1	Pk., (1,3,4)
13	7.98	Xn-Horn	28.9	0.300	4.44	-53.4	25.8	36.8	-72.7	-61.3	11.4	Pk., (1,3,4)
14	11.87	X-Horn	19.4	0.300	2.98	-52.1	29.1	36.8	-68.1	-61.3	6.8	Pk., (1,3,4)
15	11.26	X-Horn	19.4	0.300	2.83	-52.3	28.7	36.8	-68.6	-61.3	7.3	Pk., (1,3,4)
16	11.75	X-Horn	15.2	0.300	1.81	-52.5	29.3	34.0	-65.4	-61.3	4.1	Pk., (1,3,4)
17	17.36	Ku-Horn	15.2	0.300	2.67	-60.0	29.3	34.6	-73.4	-61.3	12.1	Pk., (1,3,4)
18	24.69	K-Horn	10.2	0.300	1.71	-28.2	33.2	40.0	-43.2	-41.3	**1.9**	Pk., (3,4), fmax
19	24.64	K-Horn	10.2	0.300	1.71	-26.9	33.2	40.0	-41.9	-41.3	**0.6**	Pk., (3,4)
20	24.00	K-Horn	10.2	0.300	1.66	-42.0	33.0	41.0	-58.3	-41.3	17.0	Pk., (3,4)
21	24.50	K-Horn	10.2	0.300	1.70	-28.0	33.1	40.0	-43.1	-41.3	1.8	Pk., (3,4)
22	24.76	K-Horn	10.2	0.300	1.72	-28.0	33.2	40.0	-43.0	-41.3	1.7	Pk., (3,4)
23	24.98	K-Horn	10.2	0.300	1.73	-33.9	33.3	40.0	-48.8	-41.3	7.5	Pk., (3,4)
24	23.48	K-Horn	10.2	0.300	1.63	-38.4	32.8	40.0	-53.9	-41.3	12.6	Pk., (3,4)
25	25.26	K-Horn	10.2	0.300	1.75	-39.3	33.4	40.0	-54.1	-41.3	12.8	Pk., (3,4);
26	23.22	K-Horn	10.2	0.300	1.61	-40.2	32.7	40.0	-55.8	-41.3	14.5	Pk., (3,4)
27	22.86	K-Horn	10.2	0.300	1.59	-40.8	32.5	40.0	-56.5	-41.3	15.2	Pk., (3,4);
28	23.00	K-Horn	10.2	0.300	1.60	-41.5	32.6	40.0	-57.1	-41.3	15.8	Pk., (3,4)
29	25.62	K-Horn	10.2	0.300	1.78	-42.0	33.5	40.0	-56.7	-41.3	15.4	Pk., (3,4)
30	27.21	Ka-Horn	6.9	0.300	0.86	-40.5	36.0	40.0	-52.7	-41.3	11.4	Pk., (3,4)
31	37.00	Ka-Horn	6.9	0.200	1.17	-49.5	36.0	40.0	-65.2	-61.3	3.9	Pk., (1,3,4)
32	40-65	U-Horn	4.6	0.001	0.92	-57.7	41.0	0.0	-74.5	-61.3	13.2	Pk., (1,2,3,4)**
33	65-100	W-Horn	2.5	0.001	0.42	-49.1	45.3	0.0	-61.6	-61.3	**0.3**	Pk., (1,2,3,4)**
34	* NF, near-field criterion for the test receiver antenna (Rx)											
35	** These emssion measurements were made with the receive antenna in contact with the surface of the DUT.											
36	While we are demonstrating compliance at a distance of 1mm, the measurement distance is actually smaller. It is also											
37	important to recognize that the receive chain sensitivity could never be increased more than 27 dB from that used, and in											
38	doing so a measurement range of ~ 2.2 cm is required. That range is still well within the near field of the DUT and the Rx,											
39	and we would not consider that measureement any more accurate than the one currently provided.											
40	NOTES:											
41	(1) When measured, no signal was detected (noise floor)											
42	(2) Mixer conversion loss is programmed in the spectrum analyzer and automatically adjusts the readings											
43	(3) When extrapolating a 20 dB/dec Field Attenuation Rate is used											
44	(4) RBW was always 1 MHz, VBW > RBW, Sweep < 1ms/bin, Pk. Detect > RMS Detect											

Meas. 10/17-24/2005; U of Mich.

Table 6.2 Highest UWB Emissions Measured

	UWB Radiated Emissions (FCC 15.515(e))											Delphi UWB 24
#	Freq. GHz	Ant. Used	Ant. D,cm	Meas. dist, m	Pr dBm	NF*** m	Ka dB/m	Kg dB	EIRP dBm	EIRPlim dBm	Pass dB	Comments (Notes)
1	1.2005	L-Band	56.0	0.30	-63.1	2.51	17.1	28.0	-82.2	-85.3	- 3.1	background
2	1.1998	L-Band	56.0	0.30	-76.7	2.51	17.1	28.0	-95.8	-85.3	10.5	Pk., (1,2,3)
3	1.1928	L-Band	56.0	0.30	-79.5	2.49	17.2	28.0	-98.6	-85.3	13.3	Pk., (1,2,3)
4	1.1935	L-Band	56.0	0.30	-76.8	2.50	17.2	28.0	-95.8	-85.3	10.5	Pk., (1,2,3)
5	1.1958	L-Band	56.0	0.30	-76.8	2.50	17.2	28.0	-95.8	-85.3	10.5	Pk., (1,2,3)
6	1.2038	L-Band	56.0	0.30	-77.1	2.52	17.5	28.0	-95.8	-85.3	10.5	Pk., (1,2,3)
7	1.2208	L-Band	56.0	0.30	-77.2	2.55	17.6	28.0	-95.8	-85.3	10.5	Pk., (1,2,3)
9	1.6030	L-Band	56.0	0.30	-73.7	3.35	18.3	28.0	-91.6	-85.3	**6.3**	Pk., (2,3)
10												
11												
12												
13												
14												
15												
16	NOTES:											
17		(1) When measured, no signal was detected above the system noise floor										
18		(2) When extrapolating a 20 dB/dec Field Attenuation Rate is used										
19		(3) RBW > 1 kHz, Sweep < 1ms/bin, Pk. Detect > RMS Detect										
20												
21												

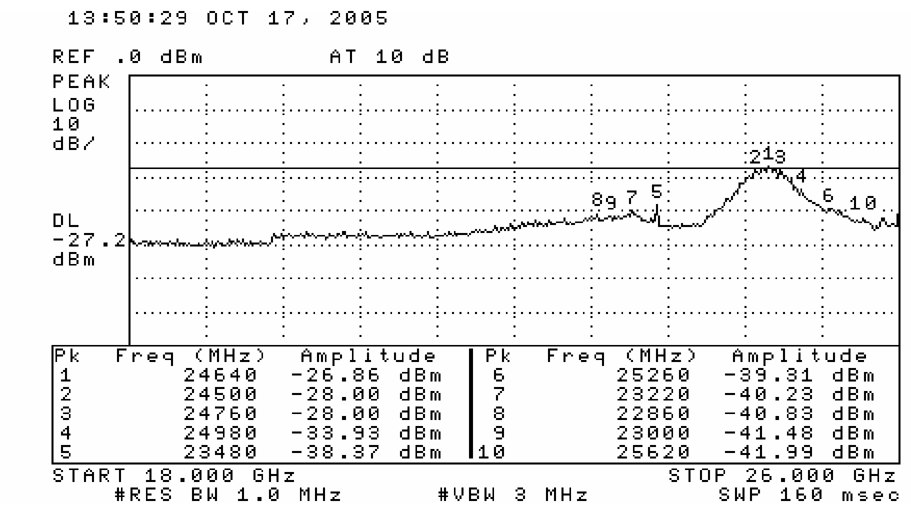
	Receiver Emissions (FCC 15.101(b))											
#	Freq. GHz	Ant. Used	Ant. D,cm	Meas. dist, m	Pr dBm	NF*** m	Ka dB/m	Kg dB	EIRP dBm	EIRPlim* dBm	Pass** dB	Comments (Notes)
23	8.236	Xn-Horn	28.9	0.30	-35.7	4.59	27.0	36.8	-53.7	-41.3	12.4	Pk., (3,4)
24	16.472	Ku-Horn	15.2	0.30	-40.5	2.54	29.3	32.0	-51.4	-41.3	**10.1**	Pk., (3,4)
25	32.944	Ka-Horn	6.9	0.30	-45.0	1.05	36.0	40.0	-57.2	-41.3	16.0	Pk., (3,4)
26												
27												
28												
29	NOTES:											
30		(3) When extrapolating a 20 dB/dec Field Attenuation Rate is used										
31		(4) RBW was always 1 MHz, VBW > RBW, Sweep < 1ms/bin, Pk. Detect > RMS Detect										
32												
33												
34												
35	* For reference: FCC Class B, 54 dBuV/m @ 3m = -41.3 dBm EIRP (Far-Field)											
36	** Note that per FCC Part 15.101(b), receiver emissions are exempt.											
37	*** NF, near-field criterion for the test receiver antenna (Rx)											
38												
39												

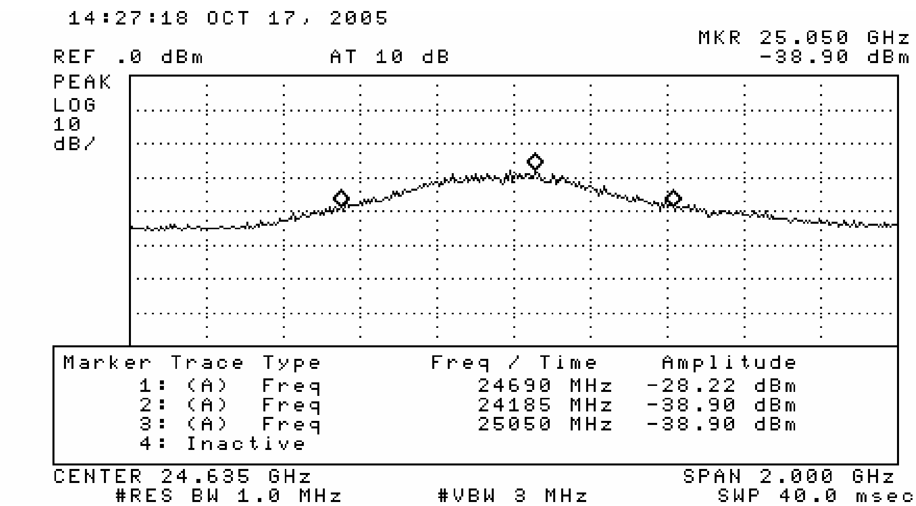
Meas. 10/17-24/2005; U of Mich.

Table 6.3 Highest Digital Emissions Measured

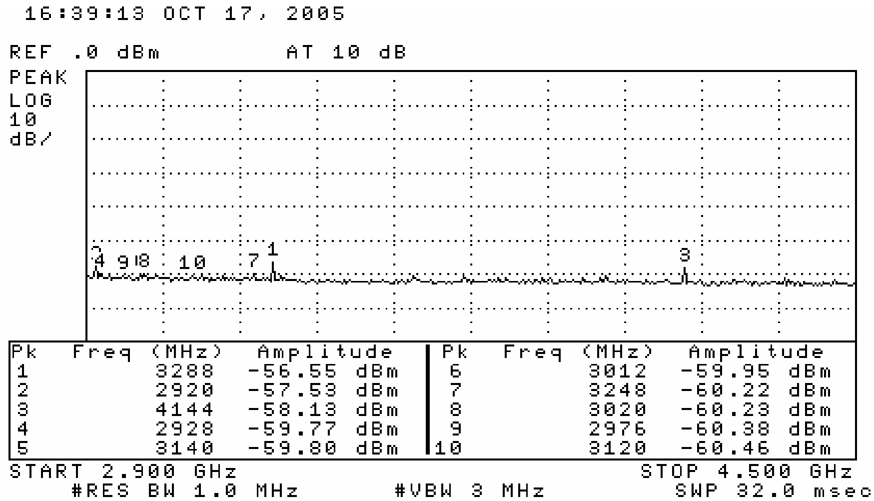
	Digital Radiated Emissions (FCC 15.209)											Delphi UWB 24
#	Freq. MHz	Ant. Used	Ant. Pol.	Meas. dist, m	NF*** m	Pr dBm	Ka dB/m	Kg dB	EIRP dBm	EIRPlim* dBm	Pass** dB	Comments (Notes)
1	73.1	Bic	H	3.00	0.00	-80.2	11.0	25.5	-82.9	-41.3	41.7	120 kHz
2	73.1	Bic	V	3.00	0.00	-80.2	11.0	25.5	-82.9	-41.3	41.7	120 kHz
3	129.8	Bic	H	3.00	0.00	-80.1	13.7	24.6	-79.2	-41.3	37.9	120 kHz
4	129.8	Bic	V	3.00	0.00	-79.4	13.7	24.6	-78.5	-41.3	37.2	120 kHz
5	229.7	Bic	H	3.00	0.00	-77.6	16.5	23.2	-72.5	-41.3	31.3	120 kHz
6	272.7	SBic	H	3.00	0.00	-71.9	17.6	22.8	-65.3	-41.3	24.1	noise, 120 kHz
7	272.7	SBic	V	3.00	0.00	-73.1	17.6	22.8	-66.5	-41.3	25.3	noise, 120 kHz
8	485.9	SBic	H	3.00	0.00	-79.3	22.8	20.5	-65.2	-41.3	24.0	noise, 120 kHz
9	485.9	SBic	V	3.00	0.00	-77.9	22.8	20.5	-63.8	-41.3	22.6	noise, 120 kHz
10	706.7	SBic	V	3.00	0.00	-78.9	26.2	18.7	-59.6	-41.3	18.4	noise, 120 kHz
11	823.30	SBic	H	3.00	0.00	-78.10	27.6	18.0	-56.7	-41.3	15.4	noise, 120 kHz
12												
13												
14												
15												
16	NOTE: All other digital emissions > 20 dB below FCC Class B Limit											
17												
18												
19												
20												
21												
22												
23												
24												
25	* Digital Emissions: FCC Class B, 54 dBuV/m @ 3m = -41.3 dBm EIRP (Far-Field)											
26	** Note that per FCC Part 15.103(a), emissions from a digital device in a transporation vehicle are exempt.											
27	*** NF, near-field criterion for the test receiver antenna (Rx)											
28												
29												
30												
31												
32												
33												
34												
35												
36												
37												
38												
39												
40												

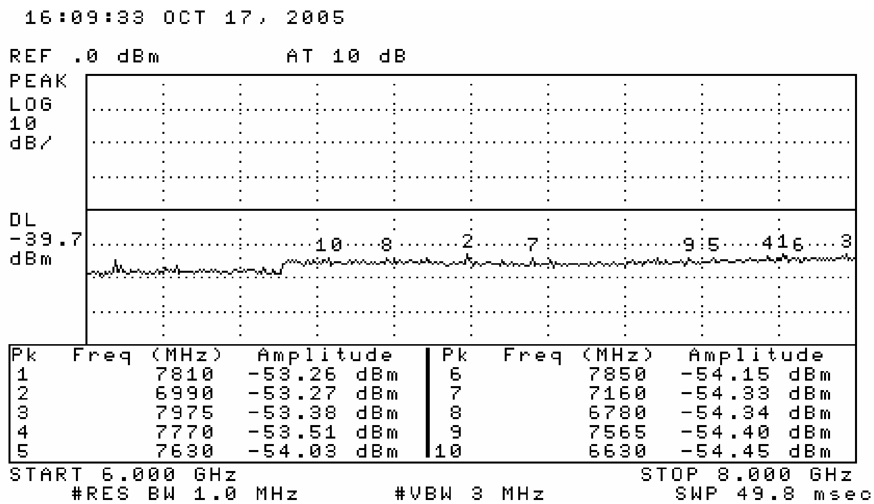
Meas. 10/17-24/2005; U of Mich.

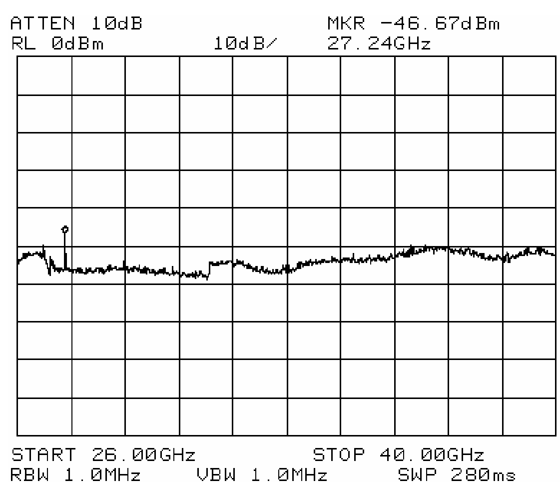




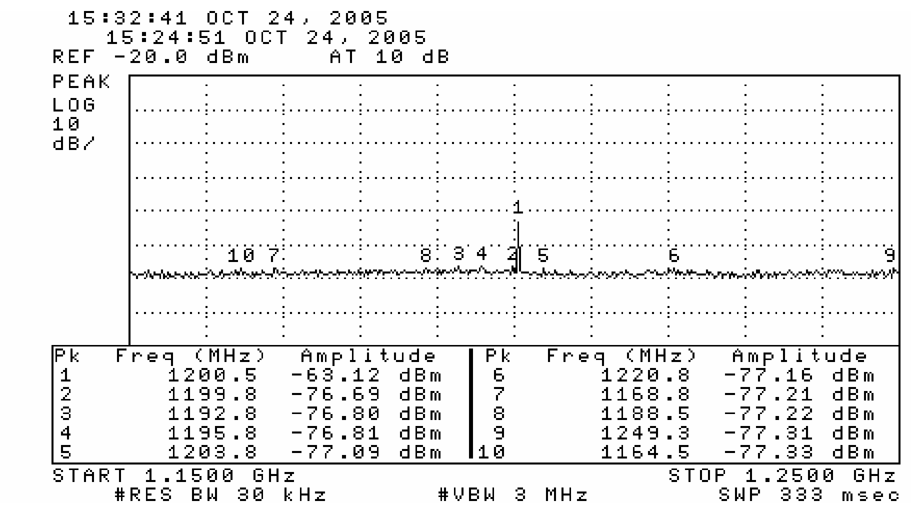
Figures 6.1-6.2. Fundamental spectrum. RBW=1 MHz, VBW>=3 MHz; 30 cm measurement distance, peak detect, peak hold. DUT rotated for maximum emissions.

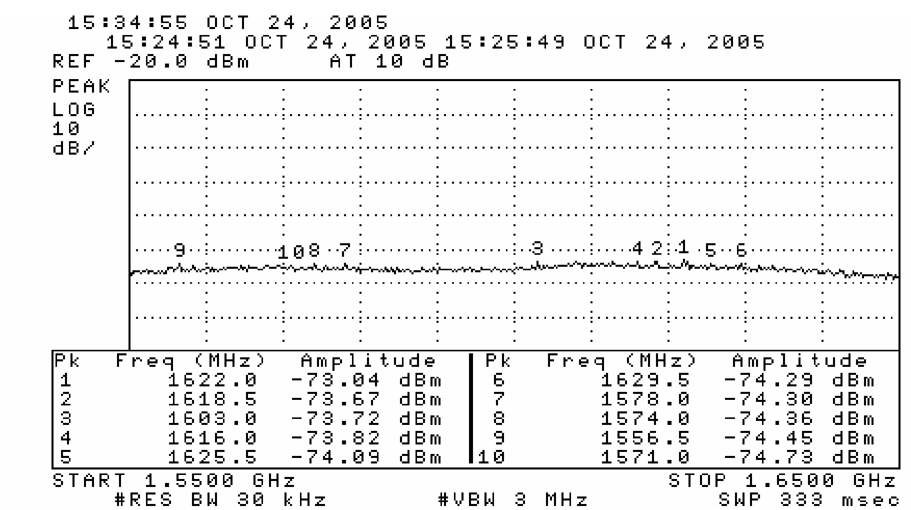




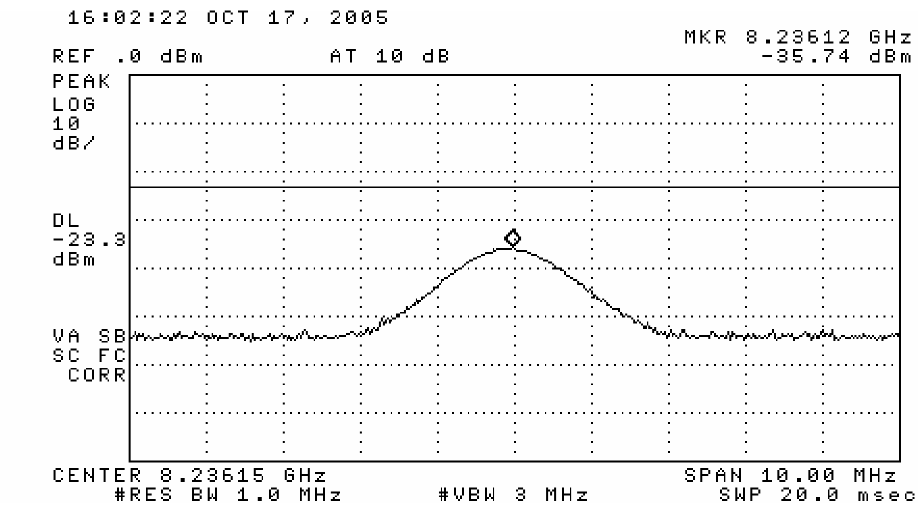


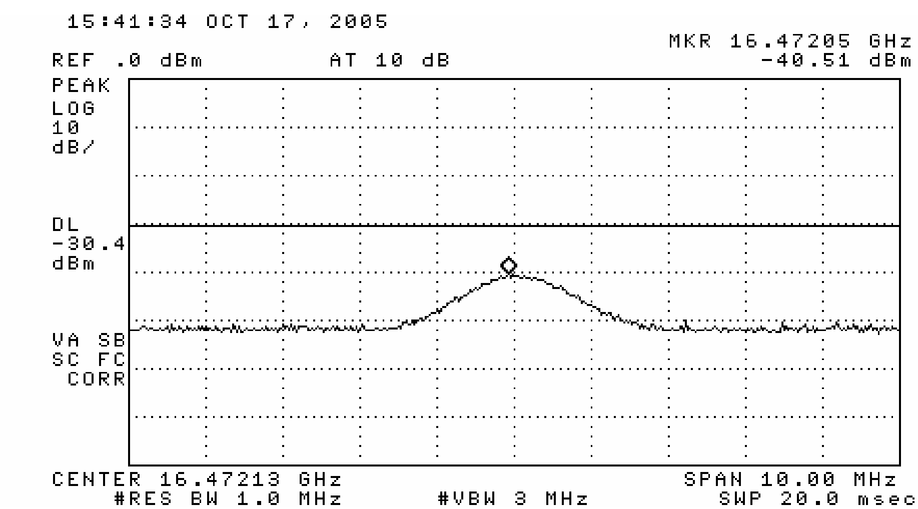
Figures 6.3-6.5. UWB Emissions: 9 kHz – 110 GHz (three example plots only). RBW=1 MHz, VBW>=RBW; measurement distance varied as necessary to maintain receive signal to noise ratio, peak detect, peak hold. (Peak vs. RMS detection; see section 5.2 of this report.) All significant emissions reported in Table 6.1.

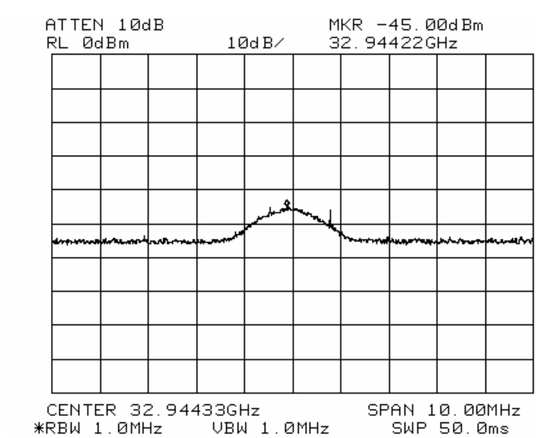




Figures 6.6-6.7. UWB Emissions: 1164-1240, 1559-1610 MHz. RBW= 30 kHz >= 1 kHz, VBW>RBW; measurement distance 30 cm, peak detect, peak hold, see Table 6.2. (Peak vs. RMS detection; see section 5.2 of this report.)







Figures 6.8-6.10. Receive Chain Emissions: RBW=1 MHz, VBW>RBW; measurement distance varied as necessary to maintain receive signal to noise ratio, peak detection, peak hold.
Results reported in Table 6.2.

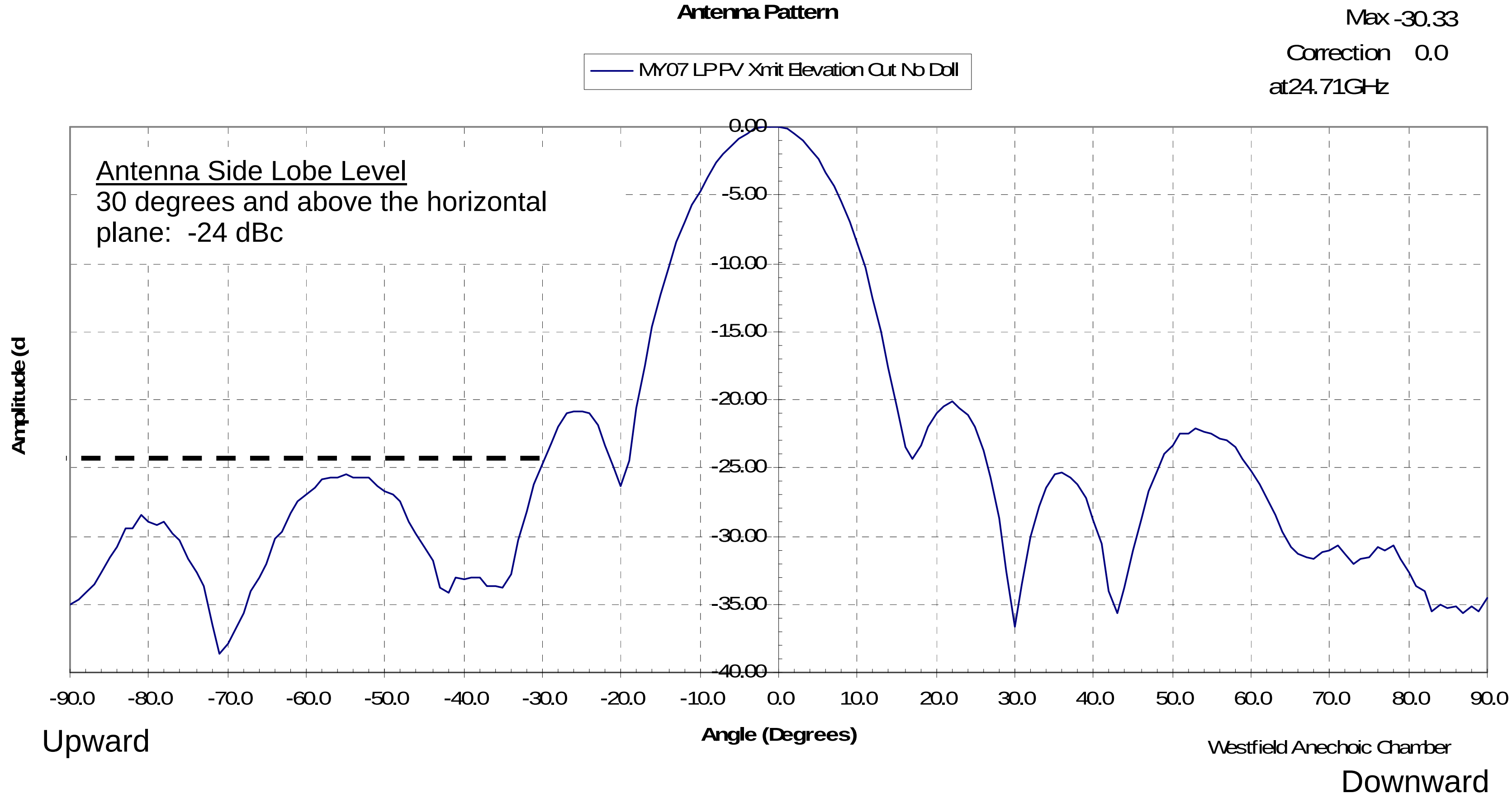


Figure 6.11(a). Radar/Antenna Elevation Pattern. Provided by Manufacturer.

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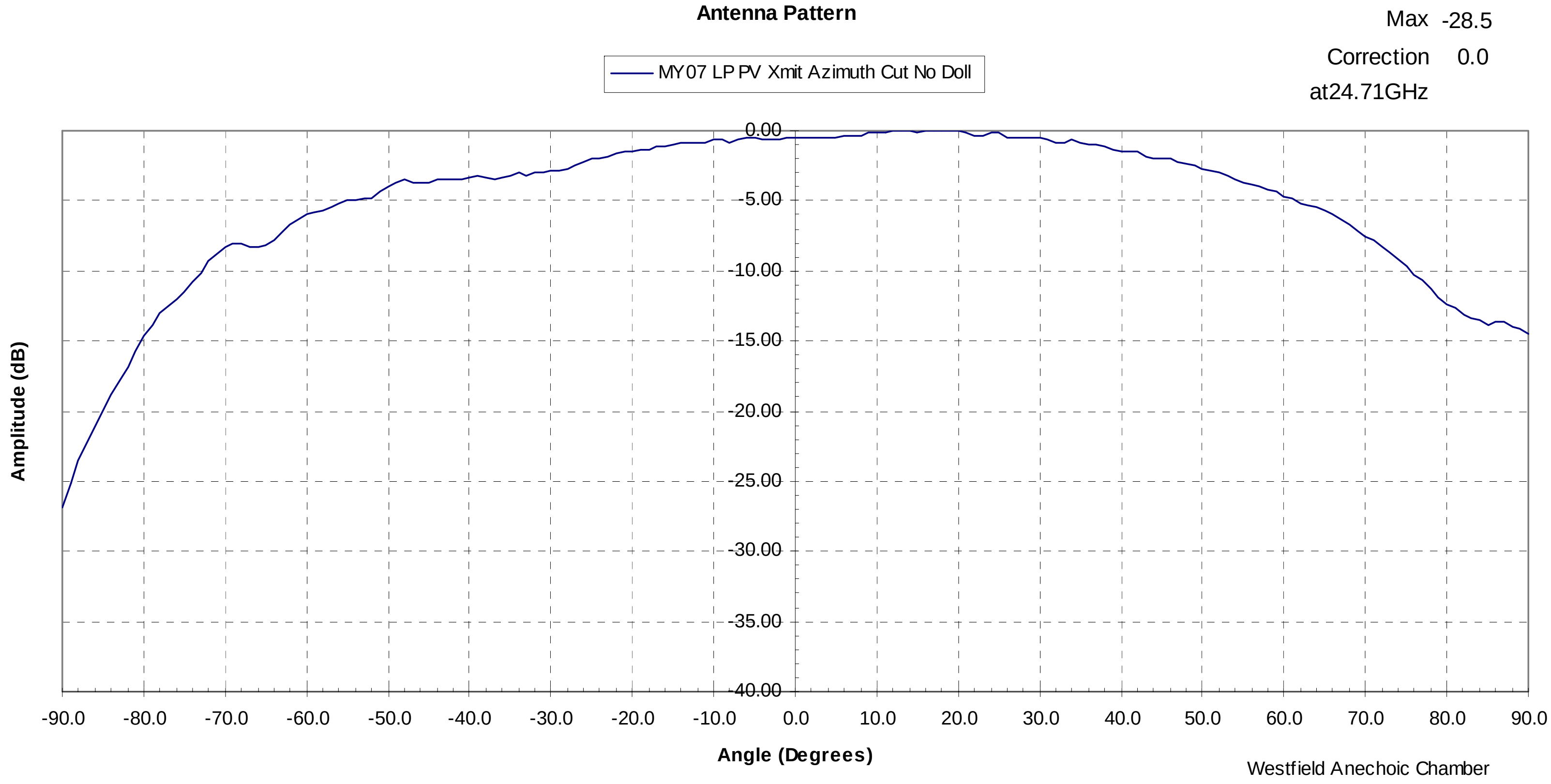

Figure 6.11(b). Radar/Antenna Azimuth Pattern. Provided by Manufacturer.

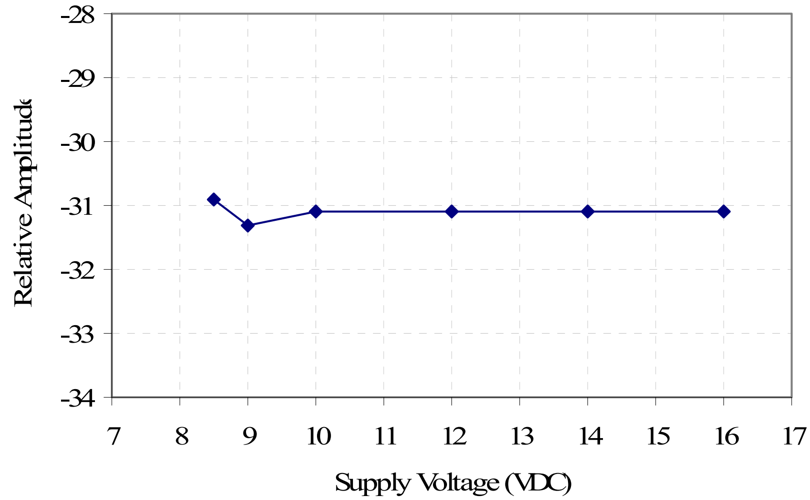

Figure 6.12. Relative emission at fundamental (f_M) vs. supply voltage.