



Measurement of RF Interference from a Smart Cap Bluetooth Low Energy Transceiver

For Caterpillar, Inc.
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Mossville, IL 61552

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FCC "Code of Federal Regulations" Title 47, Part 15, Subpart 15B, Section 15.107 and 15.109 for Receivers
Innovation, Science, and Economic Development
Canada RSS-247
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REVISION HISTORY

Revision	Date	Description
—	19 June 2017	Initial release

Measurement of RF Emissions from a Bluetooth Low Energy Transceiver, Part No. Smart Cap

1. INTRODUCTION

1.1 Scope of Tests

This document represents the results of the series of radio interference measurements performed on a Caterpillar, Inc. Bluetooth Low Energy Transceiver, Part No. Smart Cap (hereinafter referred to as the EUT). MAC Address FOC77FDA0CAB was assigned to the EUT used for all case spurious radiated emissions tests. MAC Address FOC77FDA68F4 was assigned to the EUT used for all antenna port conducted tests. The EUT is a digital modulation transceiver. The transceiver was designed to transmit and receive in the 2400-2483.5 MHz band using a Taoglas Antenna Solutions SWLP.2450.12.4.B.02 Patch Antenna with 2.0dBi gain. The EUT was manufactured and submitted for testing by Caterpillar, Inc. located in Mossville, IL.

1.2 Purpose

The test series was performed to determine if the EUT meets the conducted RF emission requirements, radiated RF emissions requirements, and additional provisions of the FCC "Code of Federal Regulations" Title 47, Part 15, Subpart B, Sections 15.107 and 15.109, for receivers and Subpart C, Sections 15.207 and 15.249 for Intentional Radiators Operating within the 2400-2483.5 MHz band.

The test series was also performed to determine if the EUT meets the conducted RF emission requirements, radiated RF emissions requirements, and additional provisions of the Innovation, Science, and Economic Development Canada Radio Standards Specification RSS-Gen Section 8.8 and Section 7.1.2 for receivers and Innovation, Science, and Economic Development Canada Radio Standards Specification RSS-Gen Section 8.8 and Innovation, Science, and Economic Development Canada Radio Standards Specification RSS-247 for Transmitters.

Testing was performed in accordance with ANSI C63.4-2014 and ANSI C63.10-2013.

1.3 Deviations, Additions and Exclusions

There were no deviations, additions to, or exclusions from the test specification during this test series

1.4 EMC Laboratory Identification

This series of tests was performed by Elite Electronic Engineering Incorporated of Downers Grove, Illinois. The laboratory is accredited by the American Association for Laboratory Accreditation (A2LA), A2LA Lab Code: 1786-01.

1.5 Laboratory Conditions

The temperature at the time of the test was 22C° and the relative humidity was 37%.

2. APPLICABLE DOCUMENTS

The following documents of the exact issue designated form part of this document to the extent specified herein:

- Federal Communications Commission "Code of Federal Regulations", Title 47, Part 15, Subparts B and C, dated 1 October 2016
- ANSI C63.4-2014, "American National Standard for Methods of Measurement of Radio-Noise Emissions from Low-Voltage Electrical and Electronic Equipment in the Range of 9 kHz to 40 GHz"
- ANSI C63.10-2013, "American National Standard of Procedures for Compliance Testing of Unlicensed Wireless Devices"
- Federal Communications Commission Office of Engineering and Technology Laboratory Division, Guidance For Performing Compliance Measurements On Digital Transmissions Systems (DTS)

Operating Under §15.247
April 5, 2017

- Innovation, Science, and Economic Development Canada RSS-247, Issue 2, February 2017, "Spectrum Management and Telecommunications Radio Standards Specification, Digital Transmission Systems (DTSS), Frequency Hopping Systems (FHSs), and License-Exempt Local Area Network (LE-LAN) Devices"
- Innovation, Science, and Economic Development Canada RSS-Gen, Issue 4, November 2014, "Spectrum Management and Telecommunications Radio Standards Specification, General Requirements for Compliance of Radio Apparatus"

3. EUT SET-UP AND OPERATION

3.1 General Description

The EUT is a Bluetooth Low Energy Transceiver, Part No. Smart Cap. A block diagram of the EUT setup is shown as Figure 1 and Figure 2. A photograph of the EUT is shown as Figure 3.

3.1.1 Power Input

The EUT normally obtains 3.6VDC from an internal TL-2450 Tadiran battery. For testing purposes, the battery was removed and short wires were soldered onto the battery leads and a power supply was used to provide 3.6VDC to the EUT.

3.1.2 Peripheral Equipment

The following peripheral equipment was submitted with the EUT:

Item	Description
Laptop computer	HP ProBook Laptop Computer: Running HP SmartRF Studio 7.
Debugger	TI CC Debugger

3.1.3 Interconnect Cables

The following interconnect cables were submitted with the EUT:

Item	Description
USB Cable	Used to connect the HP laptop computer to the TI CC Debugger
Ribbon Cable	Used to connect the TI CC Debugger to the EUT

3.1.4 Grounding

The EUT was not grounded during testing.

3.2 Software

For all tests the EUT had software loaded from the HP SmartRF Studio 7 program prior to each test.

3.3 Operational Mode

The EUT and all peripheral equipment were energized. The EUT was connected to the TI CC Debugger and laptop computer. The TI SmartRF Studio 7 software was used to program the EUT to continuously transmit separately at each of the following channels:

- Transmit at 2402MHz (Ch. 37), Power Setting = 4dBm
- Transmit at 2442MHz (Ch. 18), Power Setting = 4dBm
- Transmit at 2480MHz (Ch. 39), Power Setting = 4dBm

The TI CC Debugger was disconnected from the EUT during testing.

3.4 EUT Modifications

No modifications were required for compliance.

4. TEST FACILITY AND TEST INSTRUMENTATION

4.1 Shielded Enclosure

All tests were performed in a 32ft. x 20ft. x 18ft. hybrid ferrite-tile/anechoic absorber lined test chamber. With the exception of the floor, the reflective surfaces of the shielded chamber are lined with ferrite tiles on the walls and ceiling. Anechoic absorber material is installed over the ferrite tile. The floor of the chamber is used as the ground plane. The chamber complies with ANSI C63.4-2014 for site attenuation.

4.2 Test Instrumentation

The test instrumentation and auxiliary equipment used during the tests are listed in Table 9-1.

Conducted and radiated emission tests were performed with an EMI receiver utilizes the bandwidths and detectors specified by the FCC.

4.3 Calibration Traceability

Test equipment is maintained and calibrated on a regular basis with a calibration interval not greater than two years. All calibrations are traceable to the National Institute of Standards and Technology (NIST).

4.4 Measurement Uncertainty

All measurements are an estimate of their true value. The measurement uncertainty characterizes, with a specified confidence level, the spread of values which may be possible for a given measurement system.

The measurement uncertainty for these tests is presented below:

Conducted Emissions Measurements		
Combined Standard Uncertainty	1.06	-1.06
Expanded Uncertainty (95% confidence)	2.12	-2.12

Radiated Emissions Measurements		
Combined Standard Uncertainty	2.09	-2.09
Expanded Uncertainty (95% confidence)	4.19	-4.19

5. TEST PROCEDURES

5.1 Receiver

Per the FCC "Code of Federal Regulations" Title 47, Part 15, Subpart B, Section 15.101(b), receivers operating above 960MHz are exempt from complying with the technical provisions of part 15.

Per the Innovation, Science, and Economic Development Canada RSS-Gen, Section 5.3, only radiocommunication receivers operating in stand-alone mode within the band 30-960 MHz are subject to Industry Canada requirements, as described above. All other receivers are exempted from any Industry Canada certification, testing, labeling and reporting requirements.

5.2 Transmitter

5.2.1 Powerline Conducted Emissions

5.2.1.1 Requirements

Since the EUT is powered by internal batteries and has no connections for AC power, no conducted emissions tests are required.

5.2.2 6dB Bandwidth

5.2.2.1 Requirements

Per 15.247(a)(2), the minimum 6dB bandwidth shall be at least 500kHz for all systems using digital modulation techniques.

5.2.2.2 Procedures

The antenna port of the EUT was connected to the spectrum analyzer through 10dB of attenuation.

The EUT was allowed to transmit continuously. The transmit channel was set separately to low, middle, and high channels. The resolution bandwidth (RBW) was set to 100kHz, the video bandwidth (VBW) was set to the same as or 3 times greater than the RBW, and the span was set to 3 times the RBW.

The 'Max-Hold' function was engaged. The analyzer was allowed to scan until the envelope of the transmitter bandwidth was defined. The analyzer's display was plotted using a 'screen dump' utility.

5.2.2.3 Results

The plots on pages 21 through 23 show that the minimum 6 dB bandwidth was 823.53kHz which is greater than minimum allowable 6dB bandwidth requirement of 500kHz for systems using digital modulation techniques. The 99% bandwidth was measured to be 1.393MHz.

5.2.3 Peak Conducted Output Power

5.2.3.1 Requirements

Per section 15.247(b)(3), for systems using digital modulation the maximum peak output conducted power shall not be greater than 1.0W (30dBm).

5.2.3.2 Procedures

The antenna port of the EUT was connected to the spectrum analyzer through 10dB of attenuation. The EUT was set to transmit separately at the low, middle, and high channels. The resolution bandwidth (RBW) was set to greater than the 6dB bandwidth. The 'Max-Hold' function was engaged. The maximum meter reading was recorded. The peak power output was calculated for the low, middle and high channels.

5.2.3.3 Results

The results are presented on pages 24 through 26. The maximum peak conducted output power from the transmitter was 0.0012W (0.9dBm) which is below the 1 Watt limit.

5.2.4 Peak EIRP

5.2.4.1 Requirements

Per section 15.247(b)(3), for systems using digital modulation the maximum peak output conducted power shall not be greater than 1.0W (30dBm). Per section 15.247(b)(4), this limit is based on the use of antennas with directional gains that do not exceed 6dBi. Since the limit allows for a 6dBi antenna gain, the maximum EIRP can be increased by 6dB to 4 Watt (36dBm).

5.2.4.2 Procedures

The EUT was placed on a 1.5 meter high, non-conductive stand and set to transmit. A double ridged waveguide antenna was placed at a test distance of 3 meters from the EUT. The resolution bandwidth (RBW) of the spectrum analyzer was set to greater than the 6dB bandwidth. The EUT was maximized for worst case emissions (or maximum output power) at the measuring antenna. The maximum meter reading was recorded. The peak power output was measured for the low, middle and high channels.

The equivalent power was determined from the field intensity levels measured at 3 meters using the substitution method. To determine the emission power, a double ridged waveguide antenna was then set in place of the EUT and connected to a calibrated signal generator. The output of the signal generator was adjusted to match the received level at the spectrum analyzer. The signal level was recorded. The reading was then corrected to compensate for cable loss (and antenna gain for all measurements above 1GHz), as required. The peak power output was calculated for low, middle, and high hopping frequencies.

5.2.4.3 Results

The results are presented on pages 27 and 29. The maximum EIRP measured from the transmitter was 4.4dBm or 0.00275 W which is below the 4 Watt limit.

5.2.5 Radiated Spurious Emissions Measurements

5.2.5.1 Requirements

Per section 15.247(d), in any 100kHz bandwidth outside the frequency band in which the spread spectrum or digitally modulated intentional radiator is operating, the radio frequency power that is produced by the intentional radiator shall be at least 20 dB below that in the 100kHz bandwidth within the band that contains the highest level of the desired power, based on either an RF conducted or a radiated emissions measurement. Attenuation below the general limits specified in §15.209(a) is not required. In addition, radiated emissions which fall in the restricted bands, as defined in §15.205(a), must comply with the radiated emission limits specified in §15.209(a).

Radiated emissions which fall in the restricted bands, as defined in §15.205(a), must comply with the radiated emission limits specified in §15.209(a).

Paragraph 15.209(a) has the following radiated emission limits:

Frequency MHz	Field Strength (microvolts/meter)	Measurement distance (meters)
0.009-0.490	2400/F(kHz)	300
0.490-1.705	24000/F(kHz)	30
1.705-30.0	30	3
30.0-88.0	100	3
88.0-216.0	150	3
216.0-960.0	200	3
Above 960	500	3

5.2.5.2 Procedures

Radiated measurements were performed in a 32ft. x 20ft. x 14ft. high shielded enclosure. The shielded enclosure prevents emissions from other sources, such as radio and TV stations from interfering with the measurements. All powerlines and signal lines entering the enclosure pass through filters on the enclosure wall. The powerline filters prevent extraneous signals from entering the enclosure on these leads.

Preliminary radiated emissions tests were performed to determine the emission characteristics of the EUT. For the preliminary test, a broadband measuring antenna was positioned at a 3 meter distance from the EUT. The entire frequency range from 30MHz to 25GHz was investigated using a peak detector function.

The final emission tests were then manually performed over the frequency range of 30MHz to 25GHz.

- 1) For all harmonics not in the restricted bands, the following procedure was used:
 - a) The field strength of the fundamental was measured using a double ridged waveguide antenna. The waveguide antenna was positioned at a 3 meter distance from the EUT. The EUT was placed on a 1.5 meter high non-conductive stand. A peak detector with a resolution bandwidth of 100 kHz was used on the spectrum analyzer.
 - b) The field strengths of all of the harmonics not in the restricted band were then measured using a double-ridged waveguide antenna. The waveguide antenna was positioned at a 3 meter distance from the EUT. The EUT was placed on a 1.5 meter high non-conductive stand. A peak detector with a resolution bandwidth of 100 kHz was used on the spectrum analyzer.
 - c) To ensure that maximum or worst case emission levels at the fundamental and harmonics were measured, the following steps were taken when measuring the fundamental emissions and the spurious emissions:
 - i) The EUT was rotated so that all of its sides were exposed to the receiving antenna.
 - ii) Since the measuring antenna is linearly polarized, both horizontal and vertical field components were measured.
 - iii) The measuring antenna was raised and lowered for each antenna polarization to maximize the readings.
 - iv) In instances where it was necessary to use a shortened cable between the measuring antenna and the spectrum analyzer. The measuring antenna was not raised or lowered to ensure maximized readings, instead the EUT was rotated through all axis to ensure the maximum readings were recorded for the EUT.
 - d) All harmonics not in the restricted bands must be at least 20 dB below levels measured at the fundamental. However, attenuation below the general limits specified in §15.209(a) is not required.
- 2) For all emissions in the restricted bands, the following procedure was used:
 - a) The field strengths of all emissions below 1 GHz were measured using a bi-log antenna. The bi-log antenna was positioned at a 3 meter distance from the EUT. The EUT was placed on an 80cm high non-conductive stand. A peak detector with a resolution bandwidth of 100 kHz was used on the spectrum analyzer.
 - b) The field strengths of all emissions above 1 GHz were measured using a double-ridged waveguide antenna. The waveguide antenna was positioned at a 3 meter distance from the EUT. The EUT was placed on a 1.5 meter high non-conductive stand. A peak detector with a resolution bandwidth of 1 MHz was used on the spectrum analyzer.
 - c) To ensure that maximum or worst case emission levels were measured, the following steps were taken when taking all measurements:
 - i) The EUT was rotated so that all of its sides were exposed to the receiving antenna.
 - ii) Since the measuring antenna is linearly polarized, both horizontal and vertical field components were measured.
 - iii) The measuring antenna was raised and lowered for each antenna polarization to maximize the readings.
 - iv) In instances where it was necessary to use a shortened cable between the measuring antenna and the spectrum analyzer. The measuring antenna was not raised or lowered to ensure maximized readings, instead the EUT was rotated through all axis to ensure the maximum readings were recorded for the EUT.
 - d) For all radiated emissions measurements below 1 GHz, if the peak reading is below the limits listed in

15.209(a), no further measurements are required. If however, the peak readings exceed the limits listed in 15.209(a), then the emissions are remeasured using a quasi-peak detector.

- e) For all radiated emissions measurements above 1 GHz, the peak readings must comply with the 15.35(b) limits. 15.35(b) states that when average radiated emissions measurements are specified, there also is a limit on the peak level of the radiated emissions. The limit on the peak radio frequency emissions is 20 dB above the maximum permitted average emission limit applicable to the equipment under test. Therefore, all peak readings above 1 GHz must be no greater than 20 dB above the limits specified in 15.209(a).
- f) Next, for all radiated emissions measurements above 1GHz, the resolution bandwidth was set to 1MHz. The analyzer was set to linear mode with a 10Hz video bandwidth in order to simulate an average detector. An average reading was taken.

5.2.5.3 Results

Preliminary radiated emissions plots with the EUT transmitting at 2402MHz, 2442MHz, and 2480MHz are shown on pages 30 through 53. Final radiated emissions data are presented on data pages 54 through 62. As can be seen from the data, all emissions measured from the EUT were within the specification limits. The emissions level closest to the limit (worst case) occurred at 7326MHz. The emissions level at this frequency was 4.9dB within the limit. See data pages 54 through 62 for details. Photographs of the test configuration which yielded the highest, or worst case, radiated emission levels are shown on Figures 4 through 6.

5.2.6 Band Edge Compliance

5.2.6.1 Requirements

Per section 15.247(d), the emissions at the band-edges must be at least 20dB below the highest level measured within the band but attenuation below the general limits listed in 15.209(a) is not required. In addition, the radiated emissions which fall in the restricted band beginning at 2483.5 MHz must meet the general limits of 15.209(a).

5.2.6.2 Procedures

5.2.6.2.1 Low Band Edge

- 1) The antenna port of the EUT was connected to the spectrum analyzer through 10dB of attenuation.
- 2) The EUT was set to transmit continuously at the channel closest to the low band-edge.
- 3) To determine the band edge compliance, the following spectrum analyzer settings were used:
 - a. Center frequency = low band-edge frequency.
 - b. Span = Wide enough to capture the peak level of the emission operating on the channel closest to the band-edge, as well as any modulation products which fall outside of the authorized band of operation.
 - c. Resolution bandwidth (RBW) = 100kHz, Video bandwidth (VBW) = 300kHz.
 - d. The 'Max-Hold' function was engaged. The analyzer was allowed to scan until the envelope of the transmitter bandwidth was defined.
 - e. The marker was set on the peak of the in-band emissions. A display line was placed 20dB down from the peak of the in-band emissions. All emissions which fall outside of the authorized band of operation must be below the 20dB down display line. (All emissions to the left of the center frequency (band-edge) must be below the display line.)
 - f. The analyzer's display was plotted using a 'screen dump' utility.

5.2.6.2.2 High Band Edge

- 1) The EUT was set to transmit continuously at the channel closest to the high band-edge.
- 2) A double ridged waveguide was placed 3 meters away from the EUT. The antenna was connected to the input of a spectrum analyzer.
- 3) The center frequency of the analyzer was set to the high band edge (2483.5MHz)
- 4) The resolution bandwidth was set to 1MHz.

- 5) To ensure that the maximum or worst case emission level was measured, the following steps were taken:
 - a. The EUT was rotated so that all of its sides were exposed to the receiving antenna.
 - b. Since the measuring antenna is linearly polarized, both horizontal and vertical field components were measured.
 - c. The measuring antenna was raised and lowered from 1 to 4 meters for each antenna polarization to maximize the readings.
- 6) The highest measured peak reading was recorded.
- 7) The highest measured average reading was recorded.

5.2.6.3 Results

Page 63 shows the low band edge antenna port conducted emissions compliance results. Pages 64 through 65 show the radiated band-edge compliance results. As can be seen from these plots, the emissions at the low end band edge are within the 20 dB down limits. The radiated emissions at the high end band edge are within the general limits.

5.2.7 Power Spectral Density

5.2.7.1 Requirement

Per section 15.247(e), the peak power spectral density from the intentional radiator shall not be greater than 8 dBm in any 3 kHz band during any time interval of continuous transmission.

5.2.7.2 Procedures

- 1) The antenna port of the EUT was connected to the spectrum analyzer through a 10dB pad.
- 2) The EUT was set to transmit continuously at the lowest channel.
- 3) To determine the power spectral density, the following spectrum analyzer settings were used:
 - a. Center frequency = transmit frequency
 - b. Span = 1.5 times the DTS (6 dB) bandwidth
 - c. Resolution bandwidth (RBW): $3\text{kHz} \leq \text{RBW} \leq 100\text{kHz}$
 - d. Sweep time = auto
 - e. The peak detector and 'Max-Hold' function was engaged.
 - f. The display line represents the 8 dBm limit
 - g. The analyzer's display was plotted using a 'screen dump' utility.
- 4) If measured value exceeds limit, reduce RBW (no less than 3kHz) and repeat.
- 5) Steps 1) through 4) were repeated separately for the mid channel and the high channel.

5.2.7.3 Results

Pages 66 through 68 show the power spectral density results. As can be seen from these plots, the peak power spectral density is less than 8dBm in a 3kHz band during any time interval of continuous transmission.

6. CONCLUSIONS

It was determined that the Caterpillar, Inc. Bluetooth Low Energy Transceiver, Part No. Smart Cap, did fully meet the conducted and radiated emission requirements of the FCC "Code of Federal Regulations" Title 47, Part 15, Subpart B, Sections 15.107 and 15.109 for receivers and Subpart C, Sections 15.207 and 15.247 for Intentional Radiators Operating within the 2400-2483.5 MHz band, when tested per ANSI C63.4-2014 and ANSI C63.10-2013.

It was also determined that the Caterpillar, Inc. Bluetooth Low Energy Transceiver, Part No. Smart Cap, did fully meet the conducted and radiated RF emission requirements of the Innovation, Science, and Economic Development Canada Radio Standards Specification, RSS-Gen, Section 8.8 and Section 7.1.2 for receivers and

the Innovation, Science, and Economic Development Canada Radio Standards Specification RSS-Gen Section 8.8 and Radio Standards Specification RSS-247 for transmitters, when tested per ANSI C63.4-2014 and ANSI C63.10-2013.

7. CERTIFICATION

Elite Electronic Engineering Incorporated certifies that the information contained in this report was obtained under conditions which meet or exceed those specified in the test specifications.

The data presented in this test report pertains to the EUT at the test date. Any electrical or mechanical modification made to the EUT subsequent to the specified test date will serve to invalidate the data and void this certification.

8. ENDORSEMENT DISCLAIMER

This report must not be used to claim product certification, approval, or endorsement by A2LA, NIST or any agency of the Federal Government.

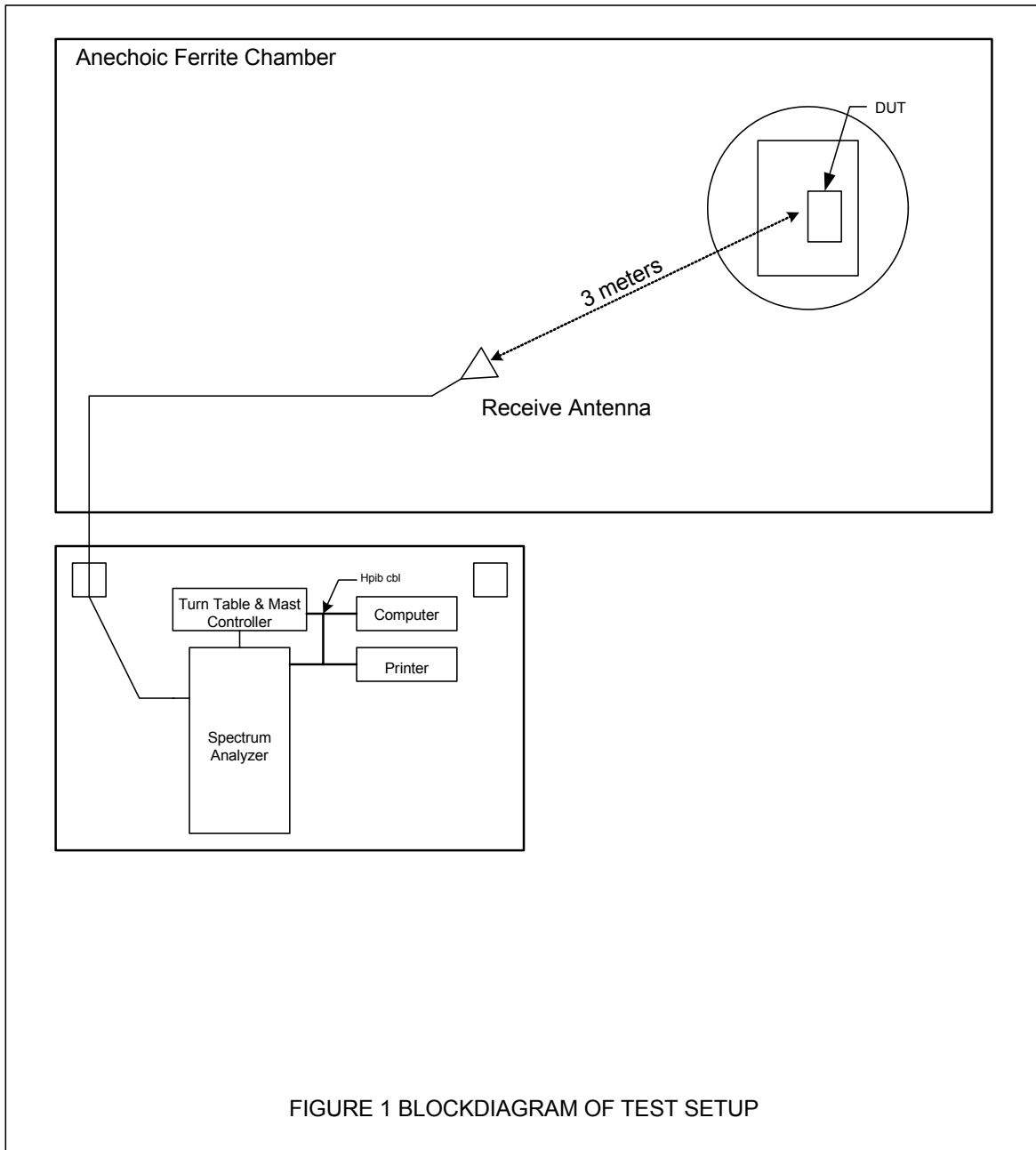
9. EQUIPMENT LIST

Table 9-1 Equipment List

Eq ID	Equipment Description	Manufacturer	Model No.	Serial No.	Frequency Range	Cal Date	Due Date
APW0	PREAMPLIFIER	PLANAR ELECTRONICS	PE2-30-20G20R6G	PL2926/0646	20GHZ-26.5GHZ	3/22/2017	3/22/2018
APW11	PREAMPLIFIER	PMI	PE2-35-120-5R0-10-12-SFF	PL11685/1241	1GHZ-20GHZ	3/22/2017	3/22/2018
CDX5	COMPUTER	ELITE	WORKSTATION			N/A	
GSE0	SIGNAL GENERATOR (40GHZ)	ROHDE & SCHWARZ	SMB100A	175137	100KHZ-40GHZ	3/3/2017	3/3/2018
GSFA	OSP-B157 OSP MODULE	ROHDE & SCHWARZ	OSP-B157	100867		9/9/2016	9/9/2017
GSFB	OSP120 BASE UNIT	ROHDE & SCHWARZ	OSP120	101246	---	9/9/2016	9/9/2017
NHG0	STANDARD GAIN HORN ANTENNA	NARDA	638	---	18-26.5GHZ	NOTE 1	
NTA3	BILOG ANTENNA	TESEQ	6112D	32853	25-1000MHz	3/23/2016	7/23/2017
NWQ0	DOUBLE RIDGED WAVEGUIDE ANTENNA	ETS LINDGREN	3117	66657	1GHZ-18GHZ	5/18/2016	6/18/2018
NWQ1	DOUBLE RIDGED WAVEGUIDE ANTENNA	ETS-LINDGREN	3117	66655	1GHZ-18GHZ	4/4/2016	4/4/2018
RBG2	EMI ANALYZER	ROHDE & SCHWARZ	ESW44	101591	2HZ-44GHZ	11/22/2016	11/22/2017
RBJ2	EMI RECEIVER	ROHDE & SCHWARZ	ESW8	100987	2HZ-8GHZ	12/6/2016	12/6/2017
SES1	24VDC POWER SUPPLY	P TRANS	FS-32024-1M	002	18-27VDC	NOTE 1	
XOB2	ADAPTER	HEWLETT PACKARD	K281C,012	09407	18-26.5GHZ	NOTE 1	

I/O: Initial Only N/A: Not Applicable

Note 1: For the purpose of this test, the equipment was calibrated over the specified frequency range, pulse rate, or modulation prior to the test or monitored by a calibrated instrument.



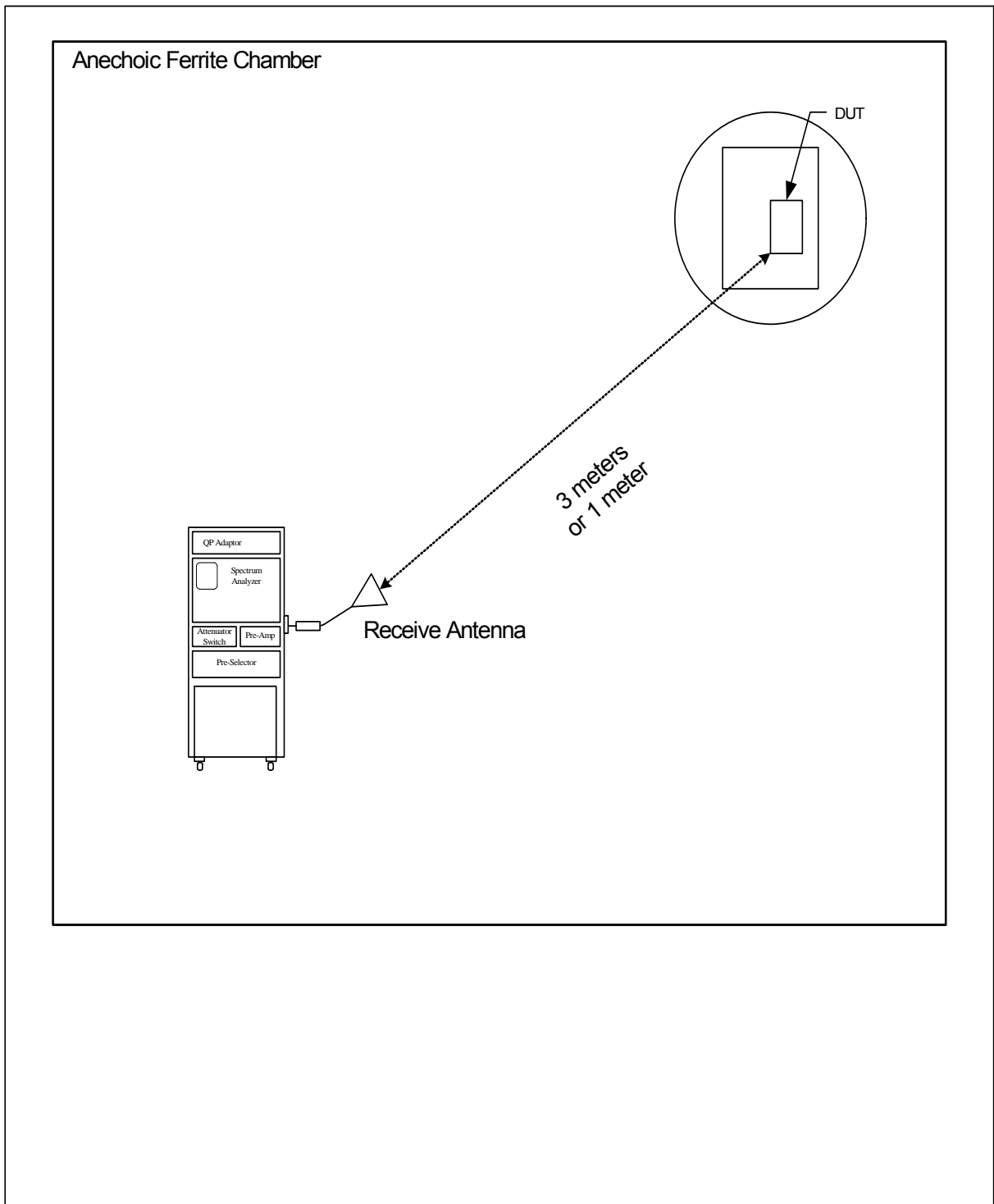
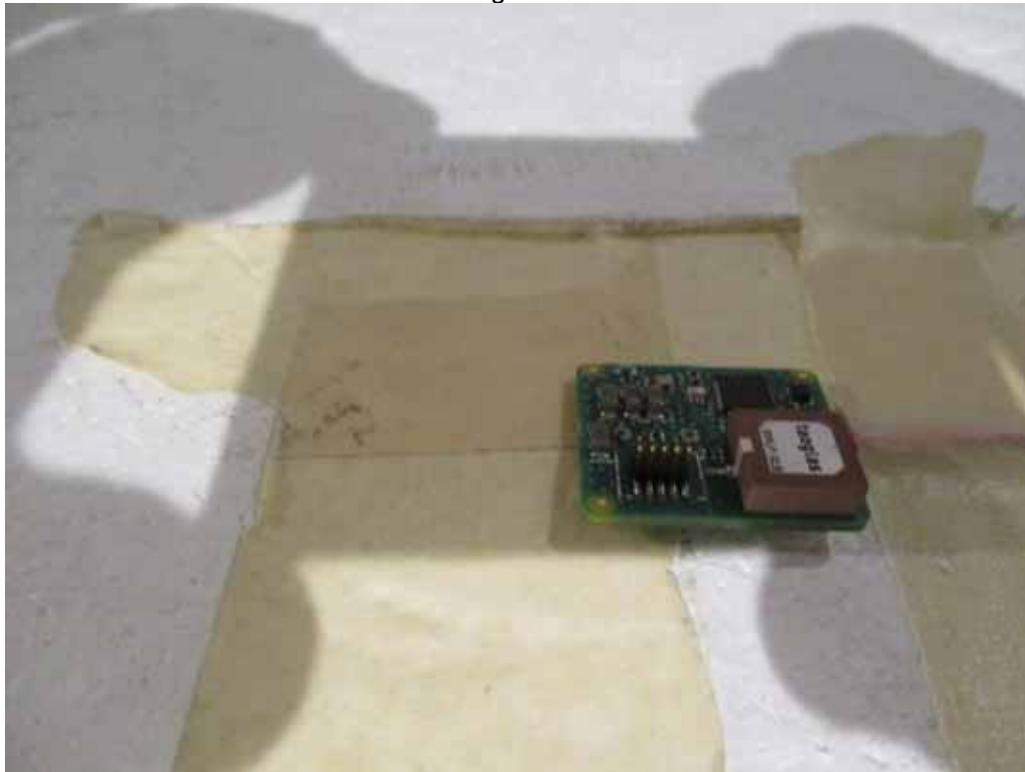


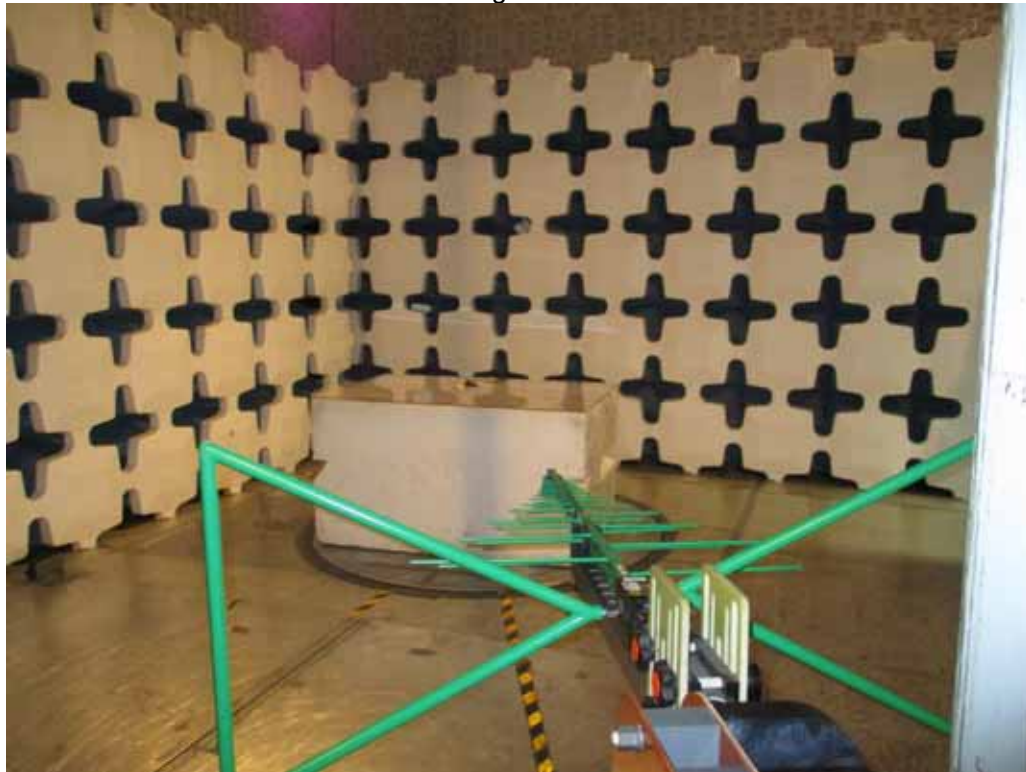
Figure 2: BLOCK DIAGRAM OF TEST SETUP FOR RADIATED EMISSIONS ABOVE 18GHZ

Figure 3

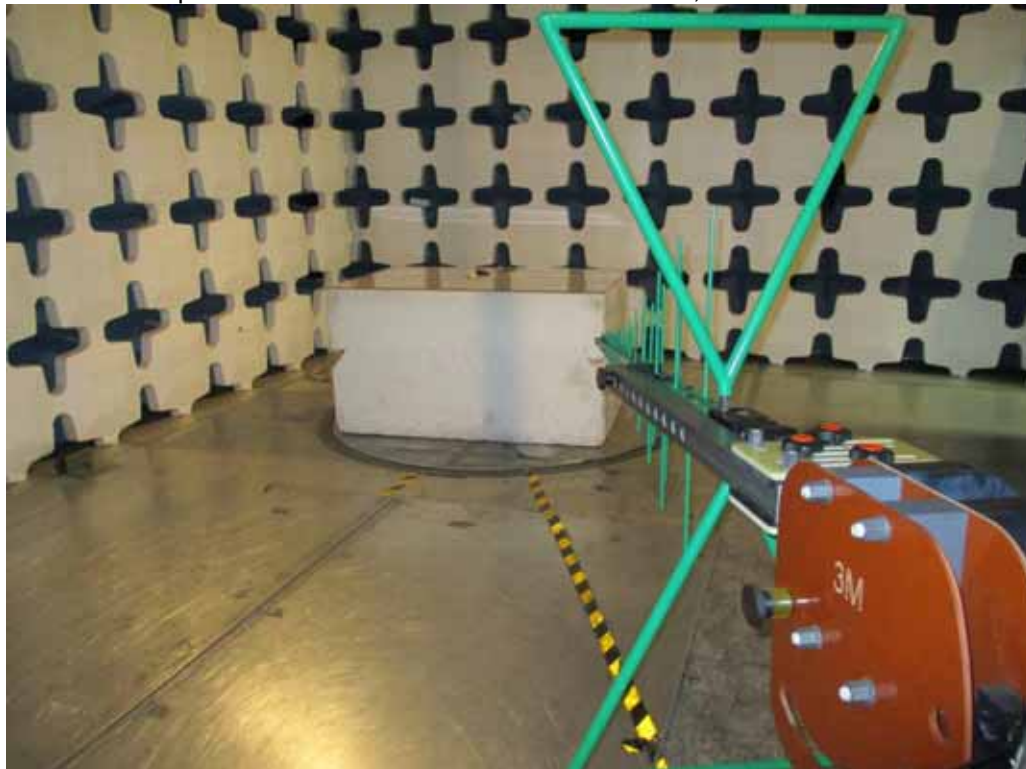


Photograph of EUT

Figure 4



Test Setup for Radiated Emissions – 30MHz to 1GHz, Horizontal Polarization



Test Setup for Radiated Emissions – 30MHz to 1GHz, Vertical Polarization

Figure 5

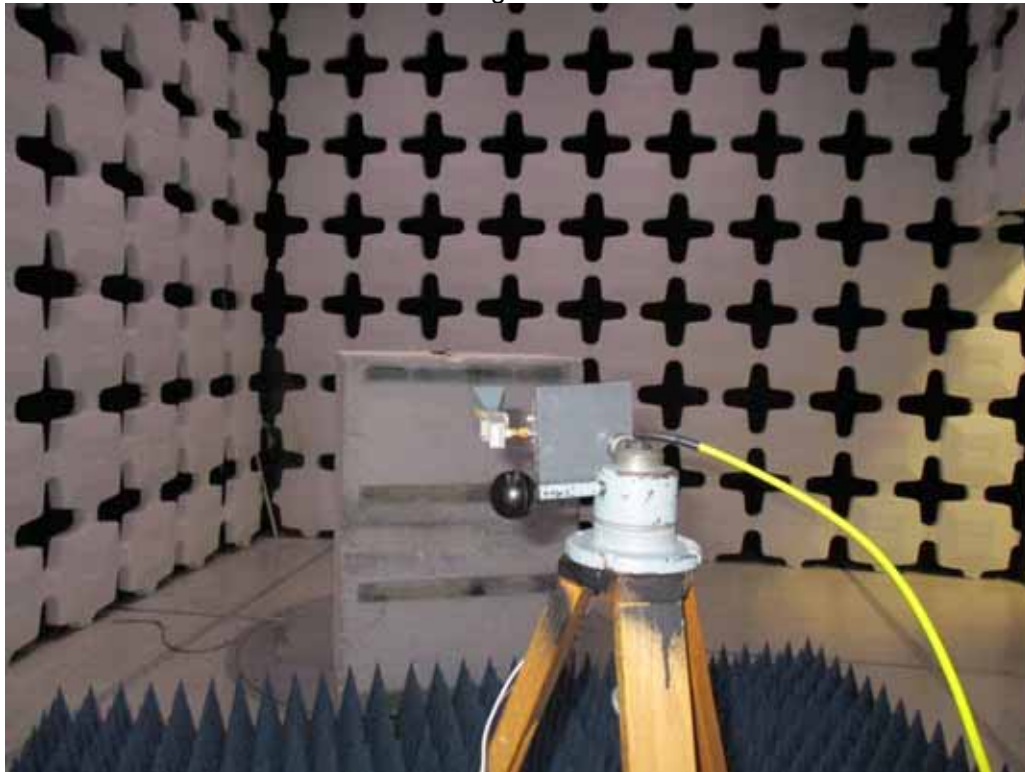


Test Setup for Radiated Emissions – 1GHz to 18GHz, Horizontal Polarization

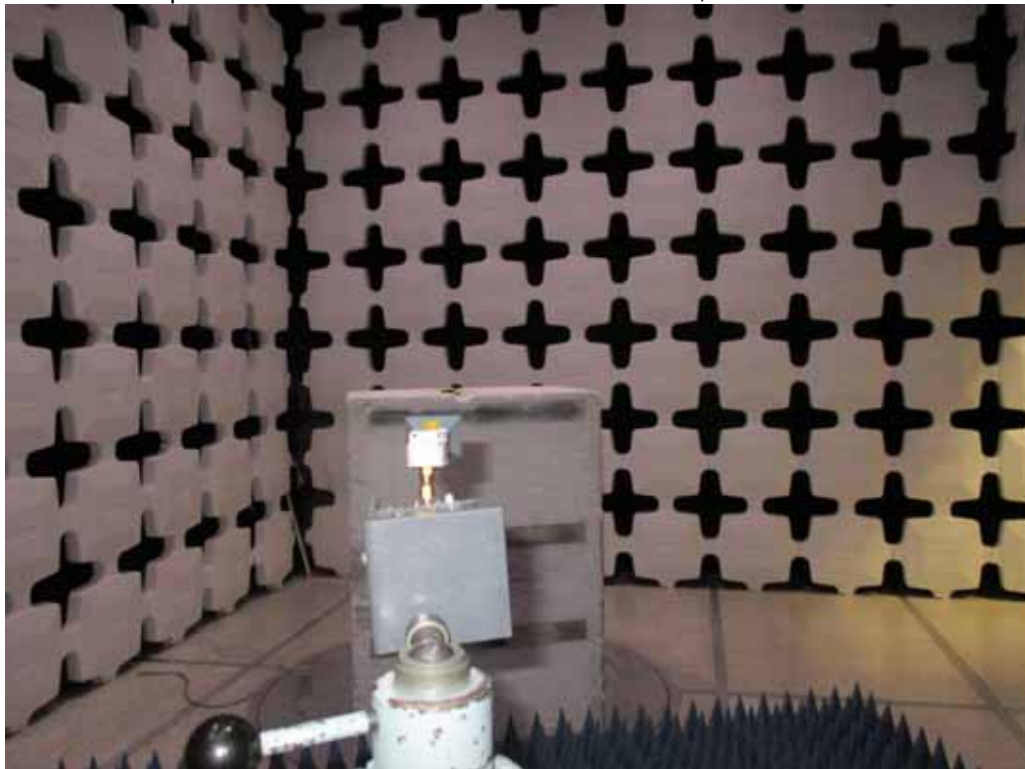


Test Setup for Radiated Emissions – 1GHz to 18GHz, Vertical Polarization

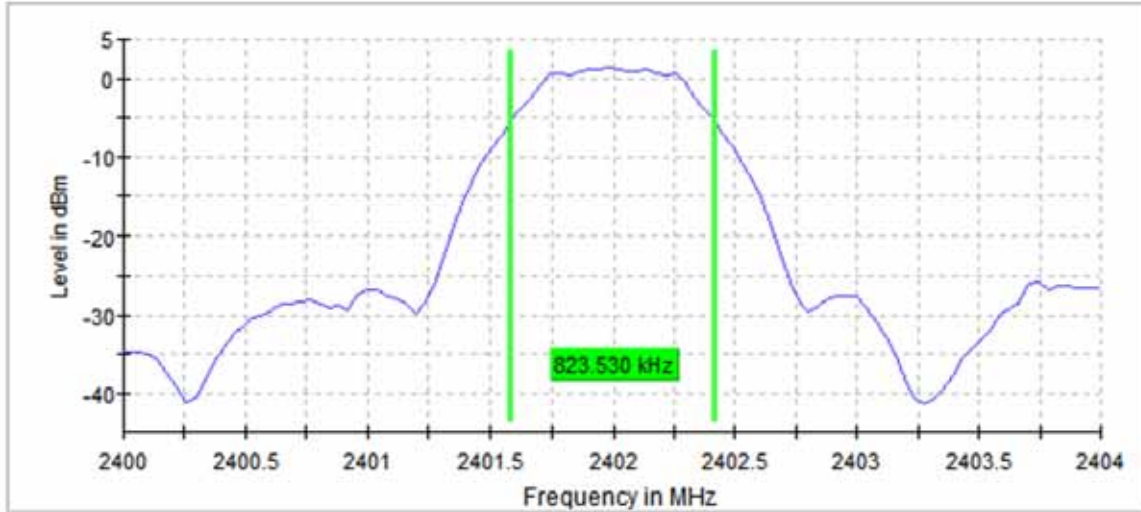
Figure 6



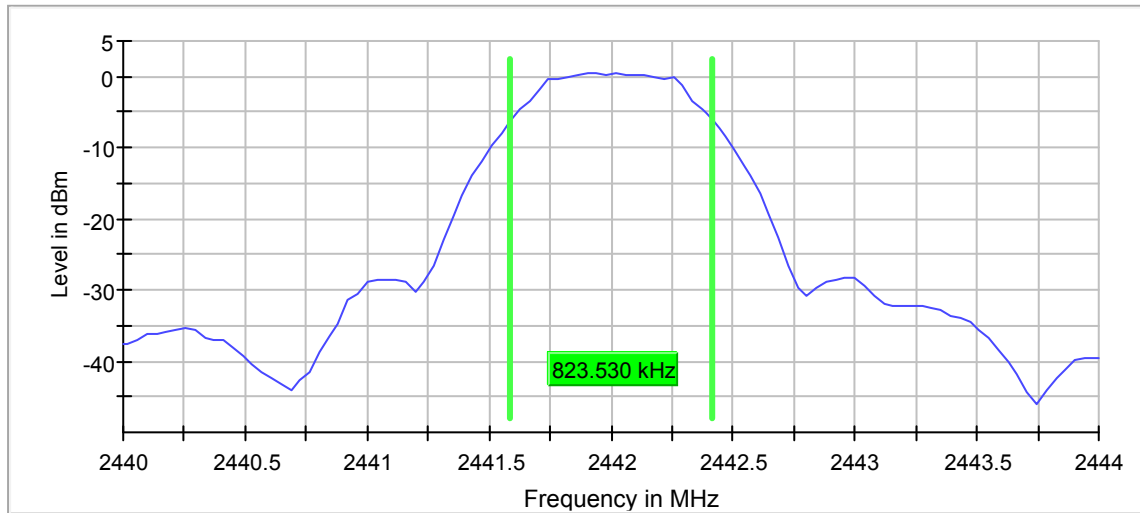
Test Setup for Radiated Emissions – 18GHz to 25GHz, Horizontal Polarization



Test Setup for Radiated Emissions – 18GHz to 25GHz, Vertical Polarization

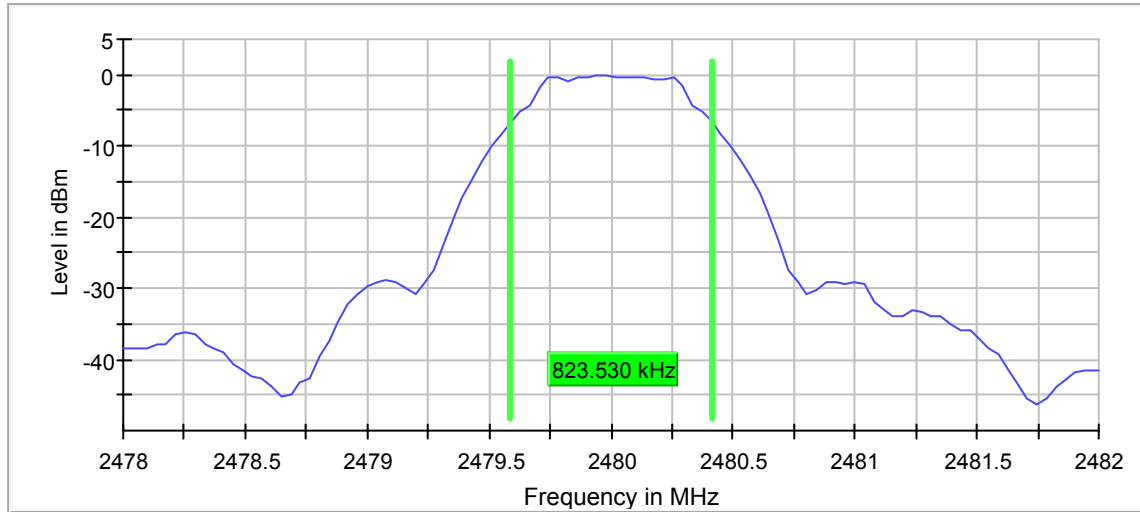
**FCC 15.247 6dB Bandwidth**

MANUFACTURER : Caterpillar
MODEL NUMBER : Smart Cap
SERIAL NUMBER : FOC77FDA68F4
TEST MODE : Transmit at 2402MHz (Ch. 37), Power Setting = 4dBm
TEST DATE : May 8, 2017
NOTES : 6dB bandwidth = 823.53kHz
EQUIPMENT USED : GSFA, GSFB, RBJ2



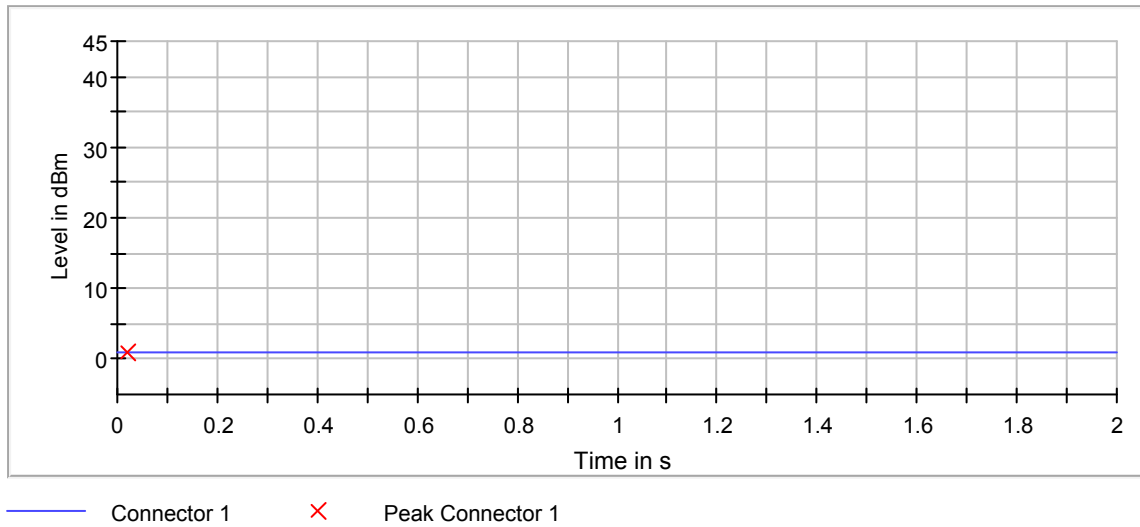
FCC 15.247 6dB Bandwidth

MANUFACTURER : Caterpillar
MODEL NUMBER : Smart Cap
SERIAL NUMBER : FOC77FDA68F4
TEST MODE : Transmit at 2442MHz (Ch. 18), Power Setting = 4dBm
TEST DATE : May 8, 2017
NOTES : 6dB bandwidth = 823.53kHz
EQUIPMENT USED : GSFA, GSFB, RBJ2



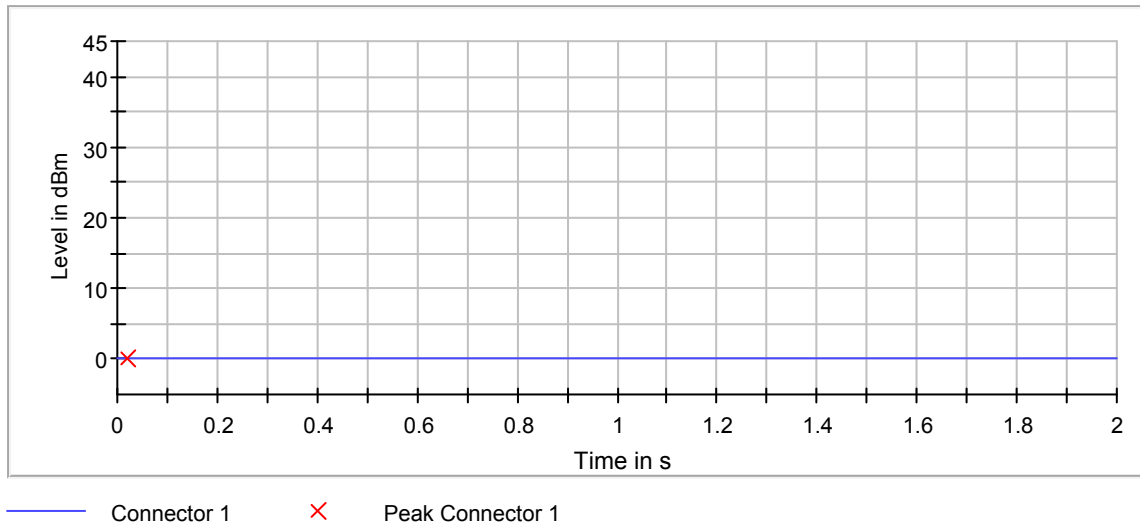
FCC 15.247 6dB Bandwidth

MANUFACTURER : Caterpillar
MODEL NUMBER : Smart Cap
SERIAL NUMBER : FOC77FDA68F4
TEST MODE : Transmit at 2480MHz (Ch. 39), Power Setting = 4dBm
TEST DATE : May 8, 2017
NOTES : 6dB bandwidth = 823.53kHz
EQUIPMENT USED : GSFA, GSFB, RBJ2



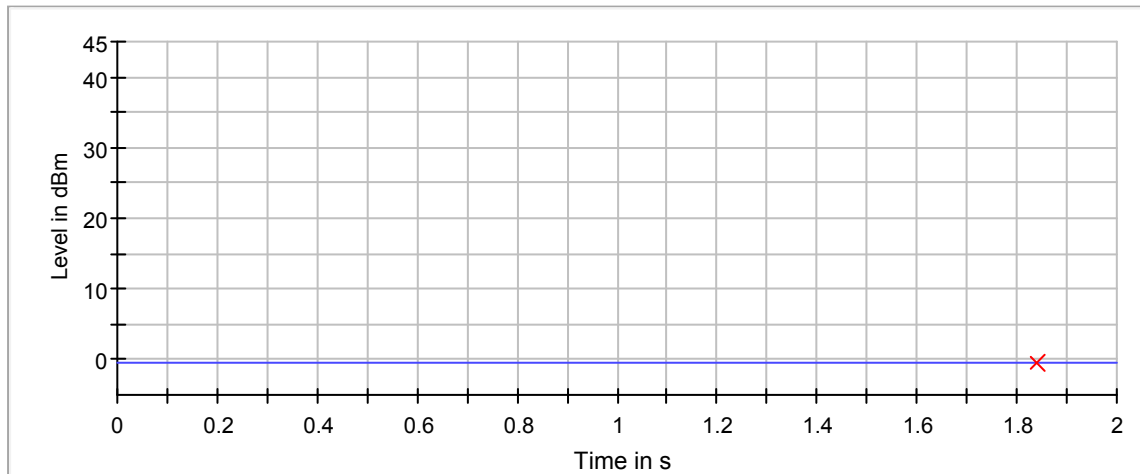
FCC 15.247 Antenna Conducted Peak Output Power

MANUFACTURER : Caterpillar
MODEL NUMBER : Smart Cap
SERIAL NUMBER : FOC77FDA68F4
TEST MODE : Transmit at 2402MHz (Ch. 37), Power Setting = 4dBm
TEST DATE : May 8, 2017
NOTES : Antenna Conducted Output Power = 0.9dBm
EQUIPMENT USED : GSFA, GSFB, RBJ2



FCC 15.247 Antenna Conducted Peak Output Power

MANUFACTURER : Caterpillar
MODEL NUMBER : Smart Cap
SERIAL NUMBER : FOC77FDA68F4
TEST MODE : Transmit at 2442MHz (Ch. 18), Power Setting = 4dBm
TEST DATE : May 8, 2017
NOTES : Antenna Conducted Output Power = 0.2dBm
EQUIPMENT USED : GSFA, GSFB, RBJ2



— Connector 1 × Peak Connector 1

FCC 15.247 Antenna Conducted Peak Output Power

MANUFACTURER : Caterpillar
MODEL NUMBER : Smart Cap
SERIAL NUMBER : FOC77FDA68F4
TEST MODE : Transmit at 2480MHz (Ch. 39), Power Setting = 4dBm
TEST DATE : May 8, 2017
NOTES : Antenna Conducted Output Power = -0.3dBm
EQUIPMENT USED : GSFA, GSFB, RBJ2



Manufacturer : Caterpillar, Inc.
Test Item : Bluetooth Low Energy Transceiver
Model No. : Smart Cap
Serial No. : FOC77FDA0CAB
Mode : Transmit at 2402MHz (Ch. 37), Power Setting = 4dBm
Test Specification : FCC-15.247, RSS-247 Peak Output Power
Date : May 26, 2017
Test Distance : 3 meters
Notes :

Freq. (MHz)	Ant Pol	Wide BW Meter Reading (dBUV)	Matched Sig. Gen. Reading (dBm)	Equivalent Antenna Gain (dB)	Cable Loss (dB)	EIRP (dBm)	Limit (dBm)	Margin (dB)
2402.00	H	62.5	1.4	4.8	2.7	3.4	27.0	-23.6
2402.00	V	63.1	1.9	4.8	2.7	3.9	27.0	-23.1

$EIRP = \text{Sig. Gen. Reading (dBm)} + \text{Antenna Gain (dB)} - \text{Cable Loss (dB)}$

Checked By:

MARK E. LONGINOTTI

Mark E. Longinotti



Manufacturer : Caterpillar, Inc.
Test Item : Bluetooth Low Energy Transceiver
Model No. : Smart Cap
Serial No. : FOC77FDA0CAB
Mode : Transmit at 2442MHz (Ch. 18), Power Setting = 4dBm
Test Specification : FCC-15.247, RSS-247 Peak Output Power
Date : May 26, 2017
Test Distance : 3 meters
Notes :

Freq. (MHz)	Ant Pol	Wide BW Meter Reading (dBuV)	Matched Sig. Gen. Reading (dBm)	Equivalent Antenna Gain (dB)	Cable Loss (dB)	EIRP (dBm)	Limit (dBm)	Margin (dB)
2442.00	H	62.9	1.3	5.9	2.8	4.4	27.0	-22.6
2442.00	V	62.8	1.3	5.9	2.8	4.4	27.0	-22.6

$EIRP = \text{Sig. Gen. Reading (dBm)} + \text{Antenna Gain (dB)} - \text{Cable Loss (dB)}$

MARK E. LONGINOTTI

Mark E. Longinotti



Manufacturer : Caterpillar, Inc.
Test Item : Bluetooth Low Energy Transceiver
Model No. : Smart Cap
Serial No. : FOC77FDA0CAB
Mode : Transmit at 2480MHz (Ch. 39), Power Setting = 4dBm
Test Specification : FCC-15.247, RSS-247 Peak Output Power
Date : May 26, 2017
Test Distance : 3 meters
Notes :

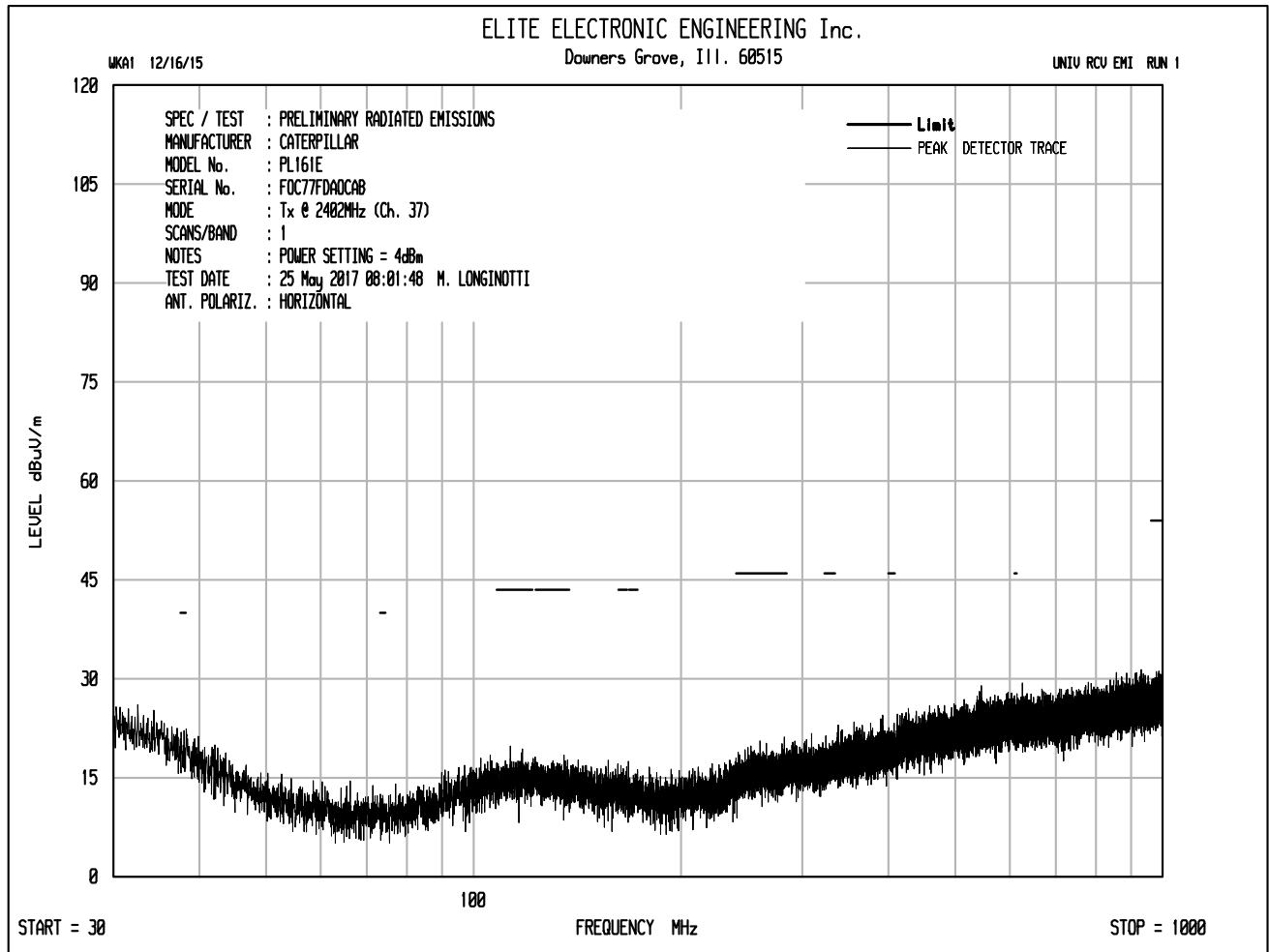
Freq. (MHz)	Ant Pol	Wide BW Meter Reading (dBUV)	Matched Sig. Gen. Reading (dBm)	Equivalent Antenna Gain (dB)	Cable Loss (dB)	EIRP (dBm)	Limit (dBm)	Margin (dB)
2480.00	H	57.8	-2.6	4.9	2.8	-0.5	27.0	-27.5
2480.00	V	57.1	-4.1	4.9	2.8	-2.0	27.0	-29.0

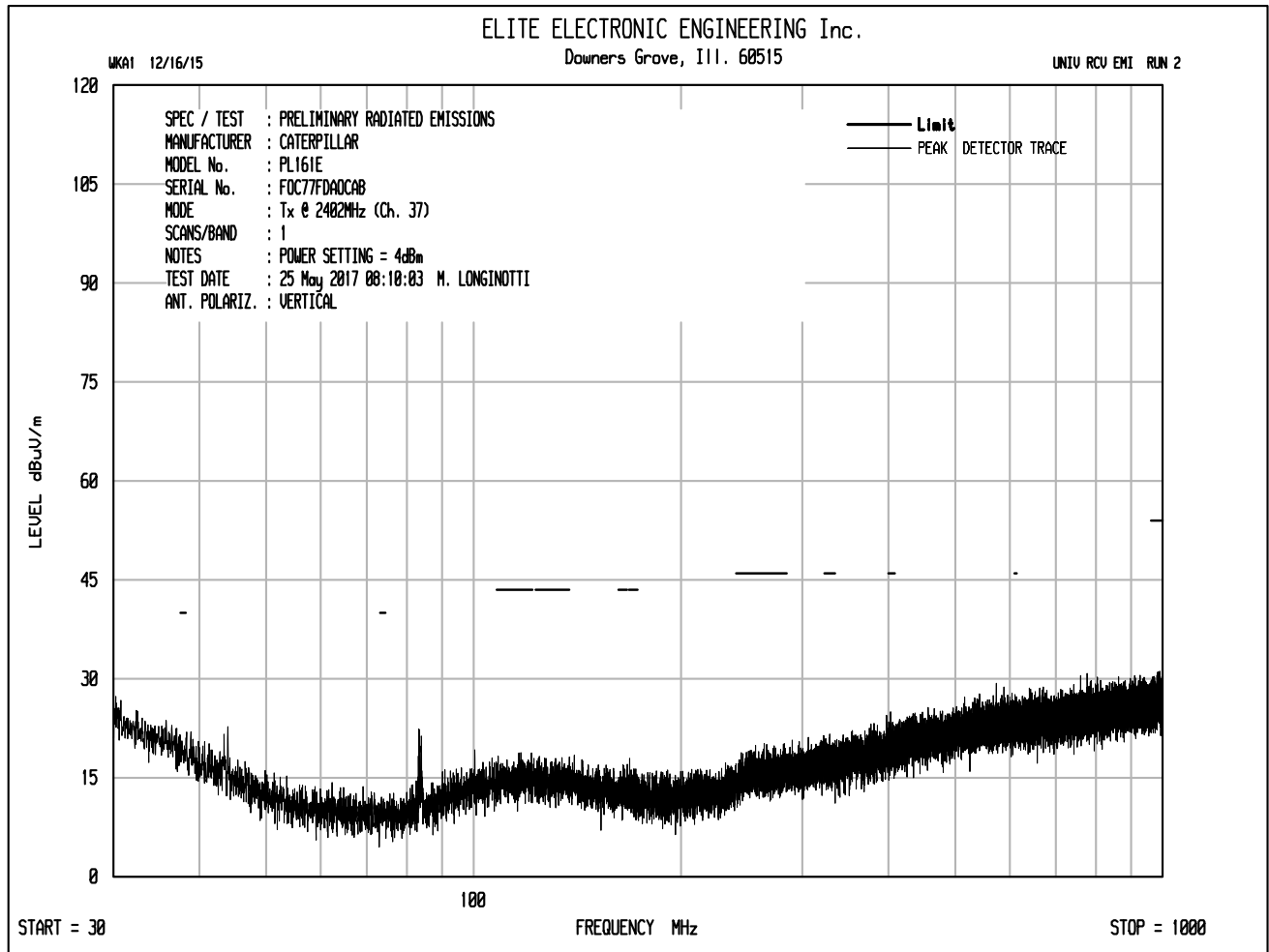
$EIRP = \text{Sig. Gen. Reading (dBm)} + \text{Antenna Gain (dB)} - \text{Cable Loss (dB)}$

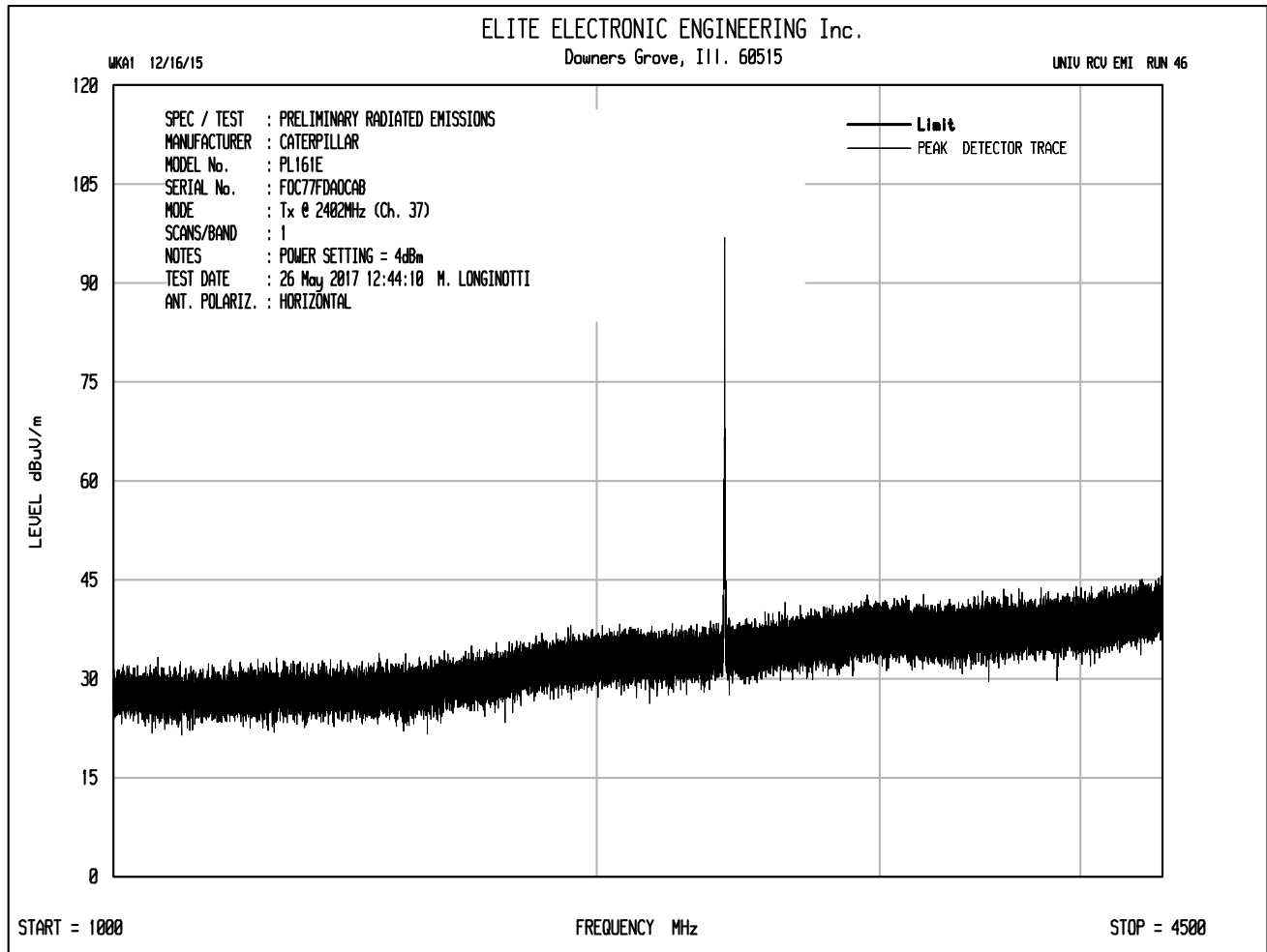
Checked By:

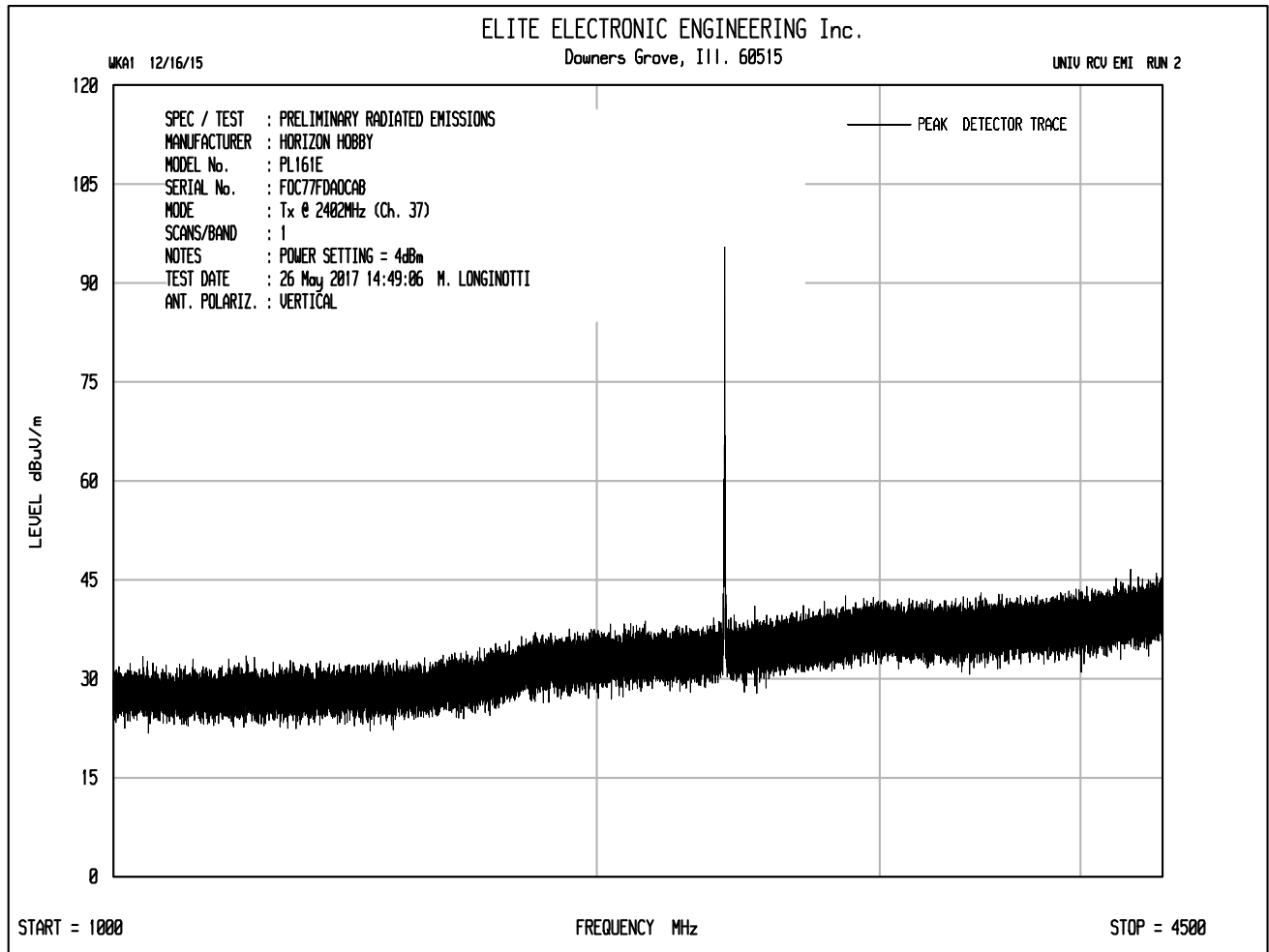
MARK E. LONGINOTTI

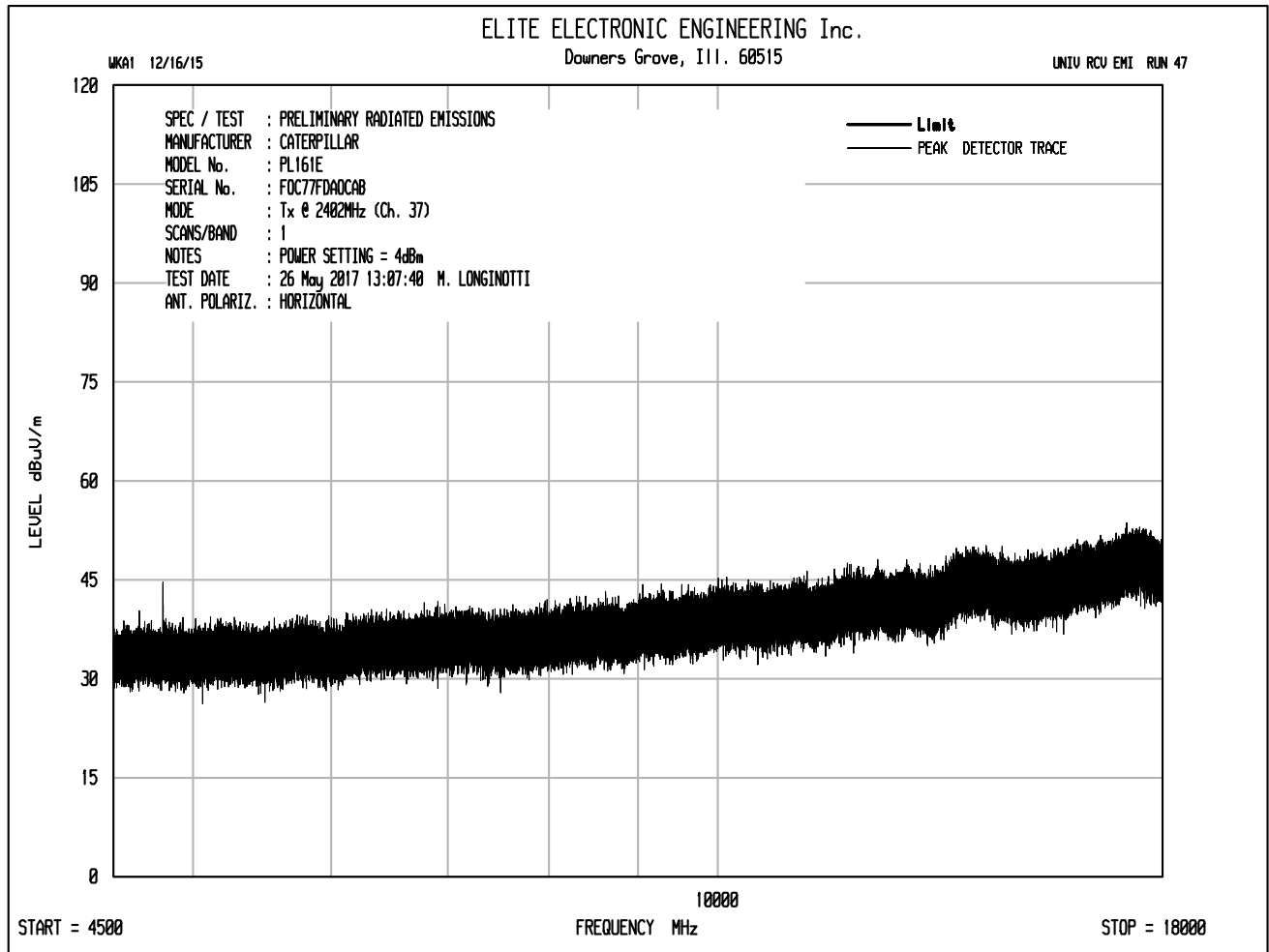
Mark E. Longinotti

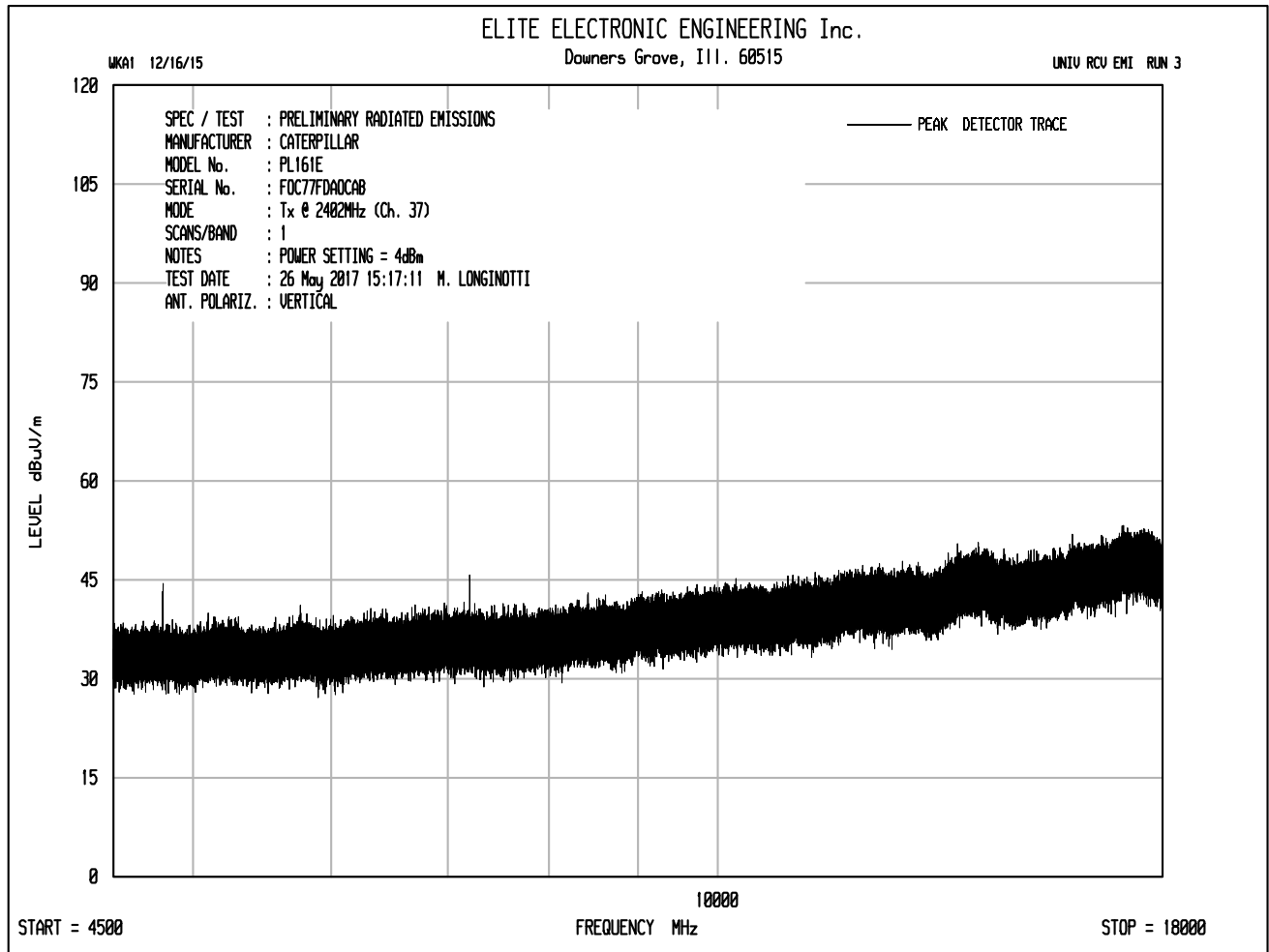


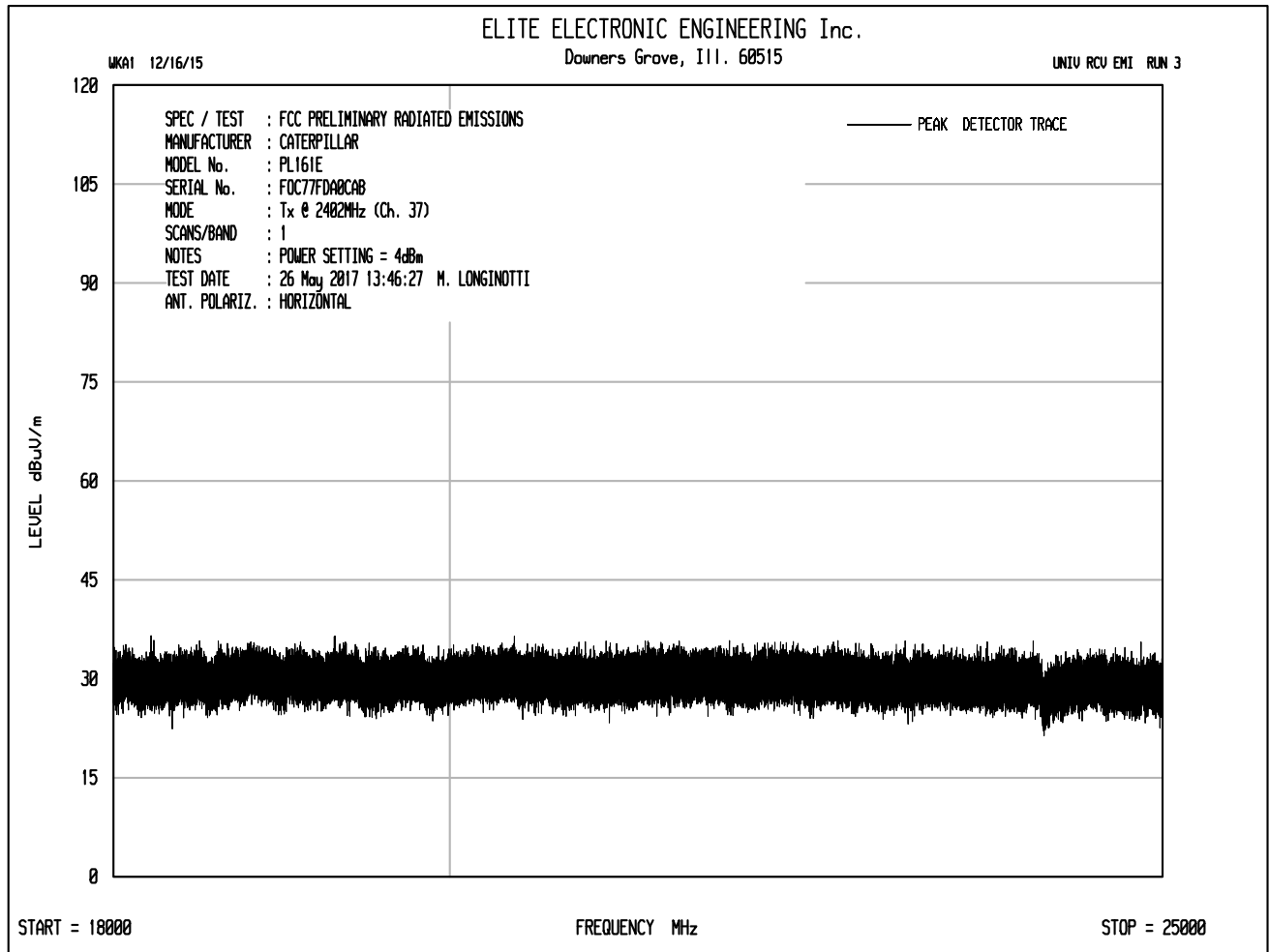


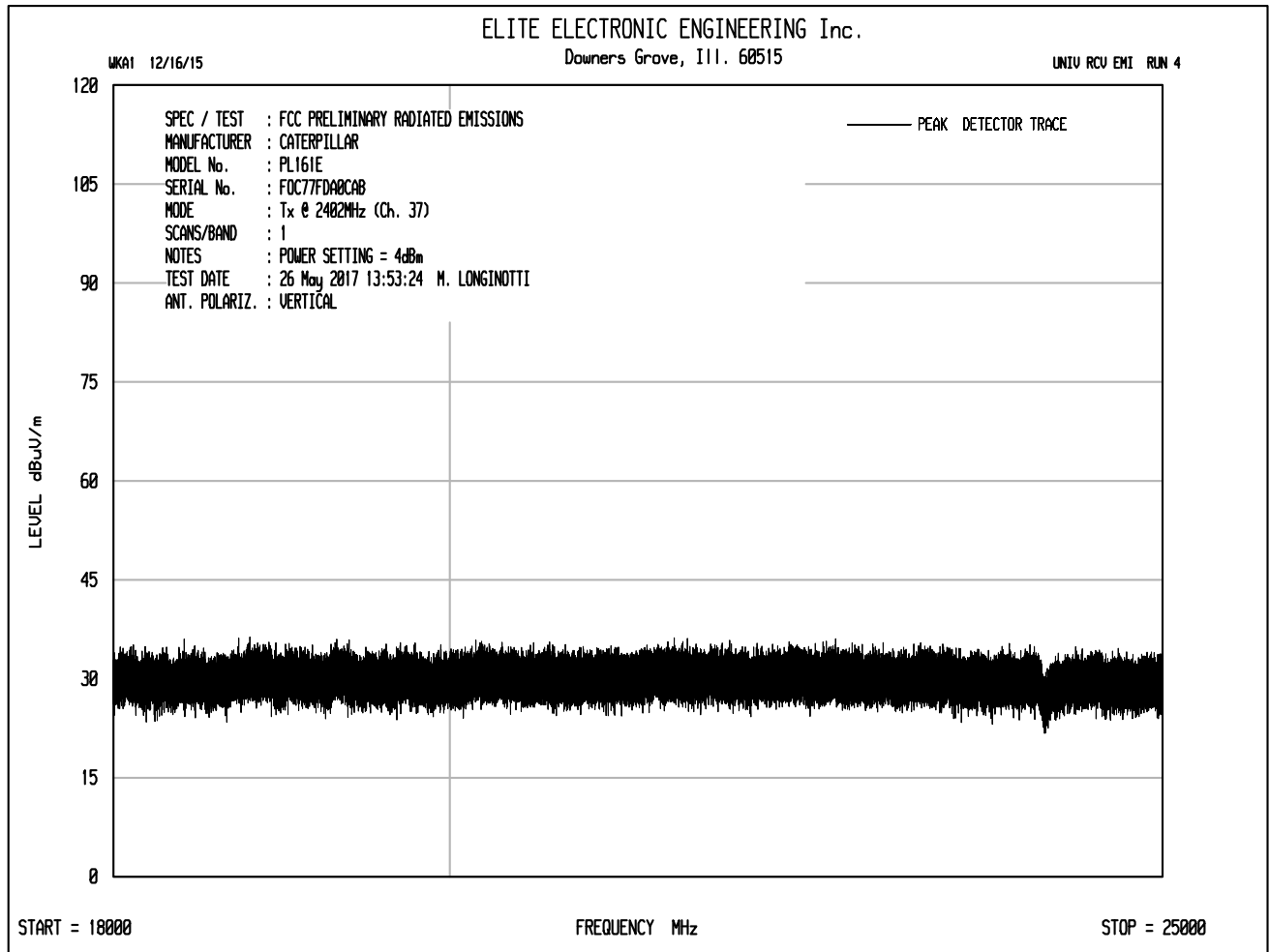


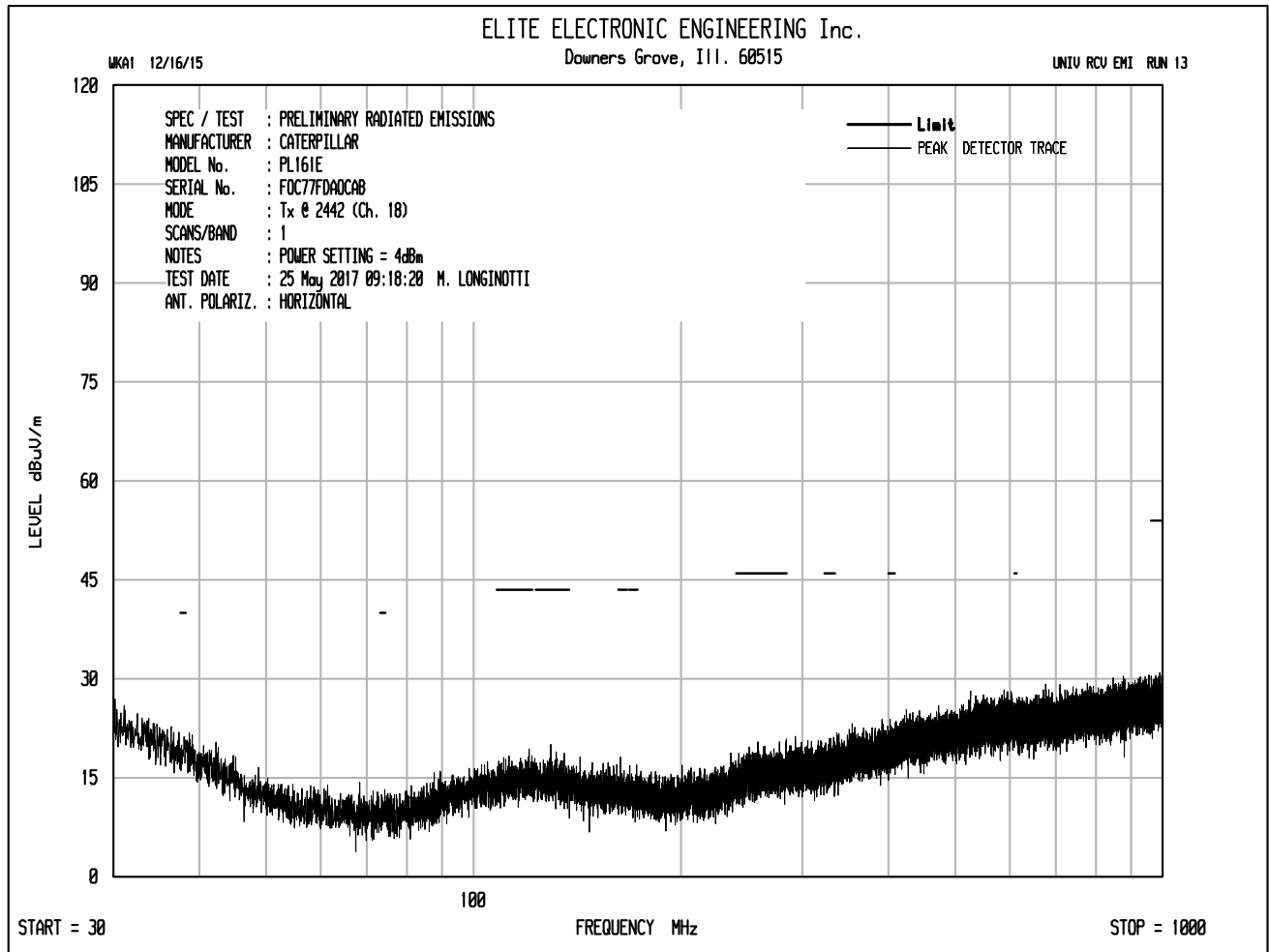


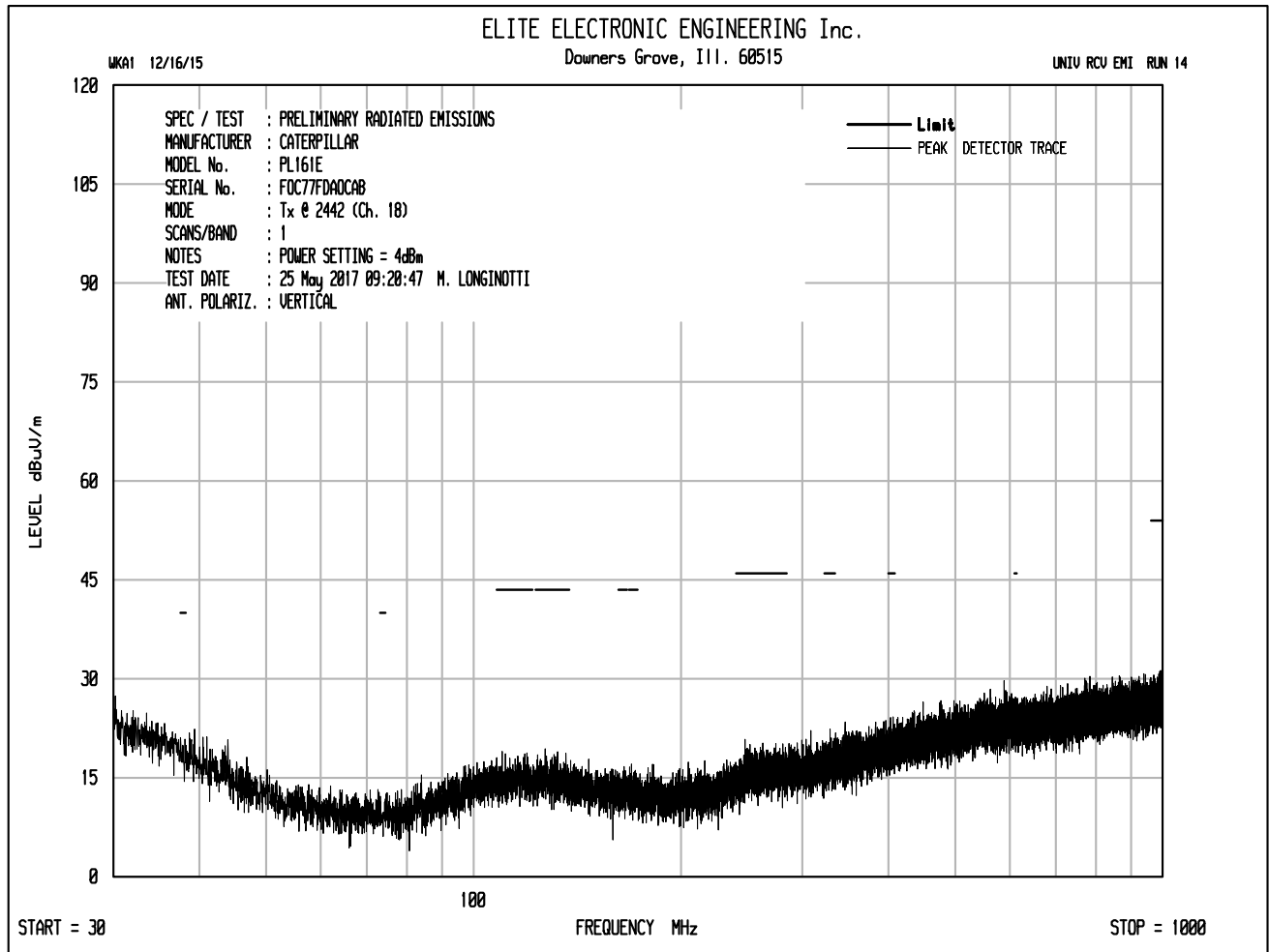


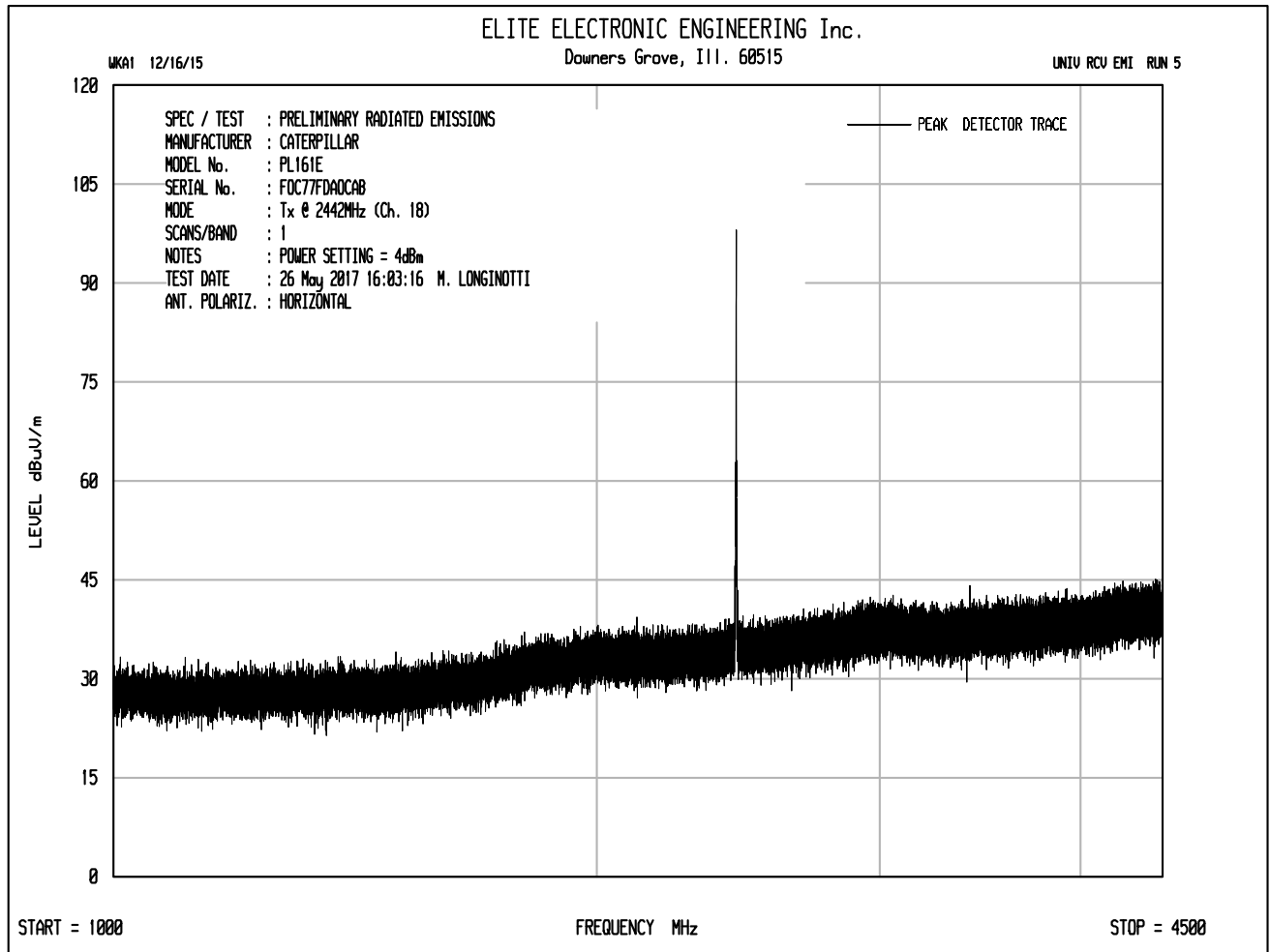


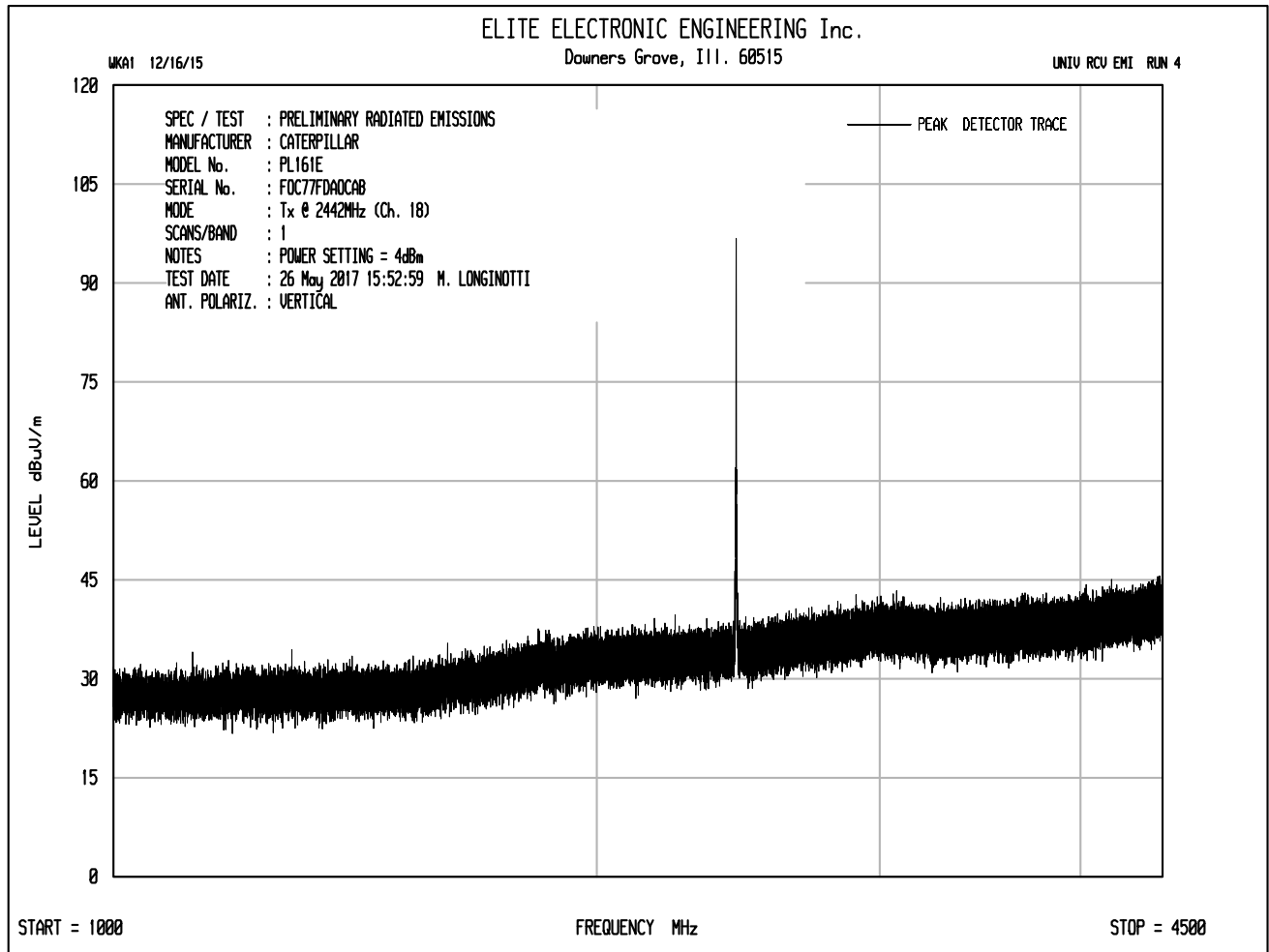


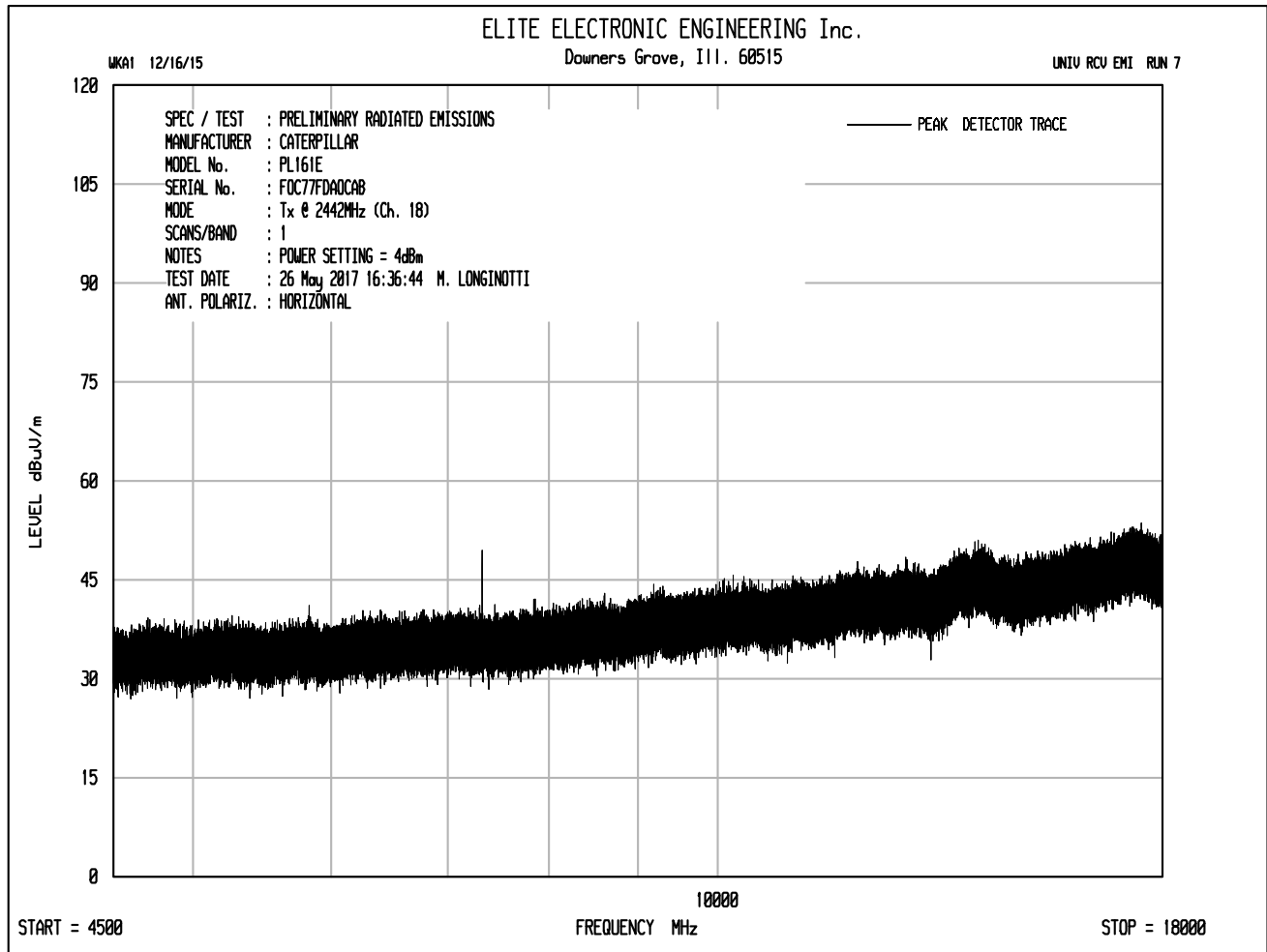


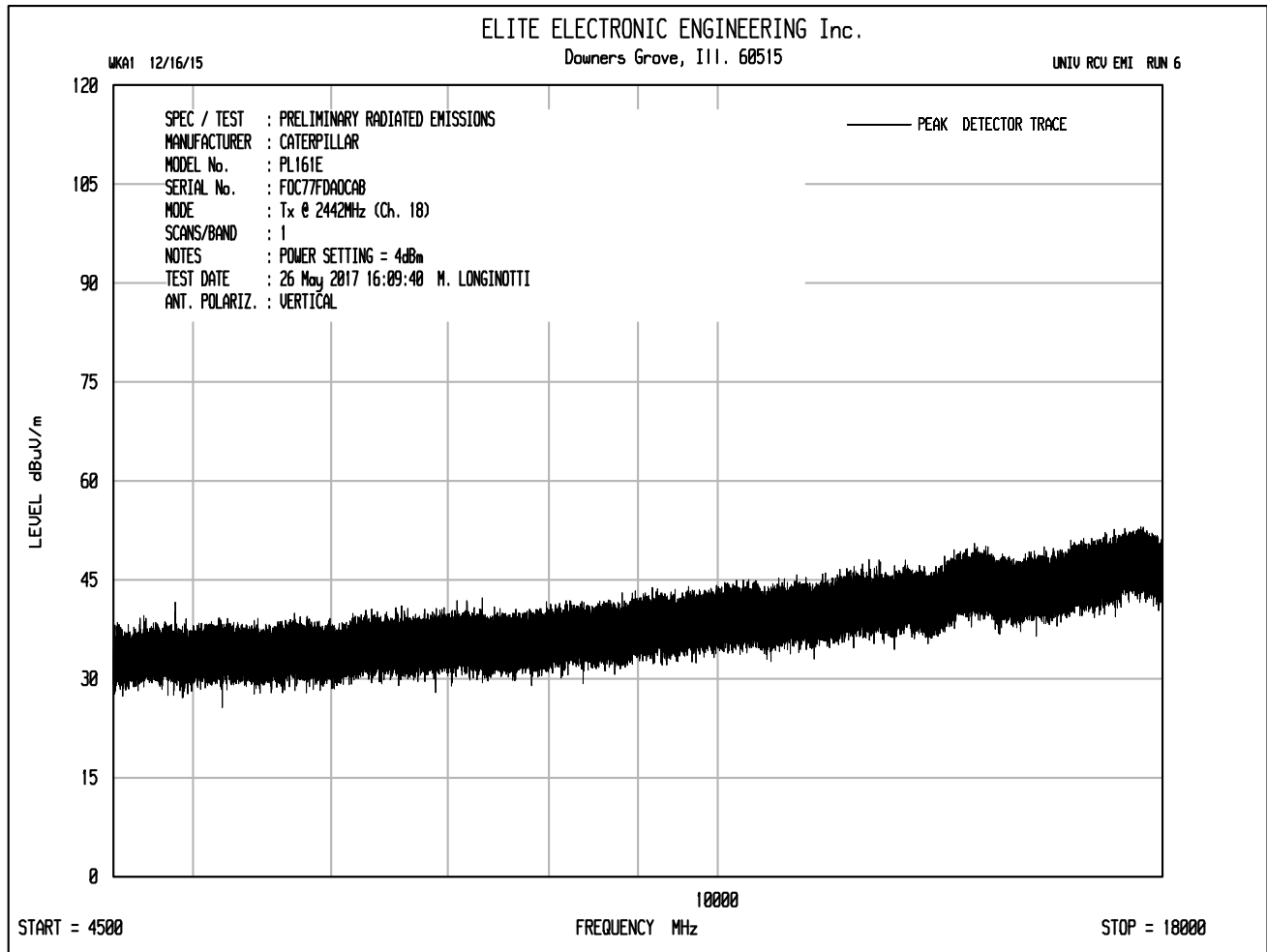


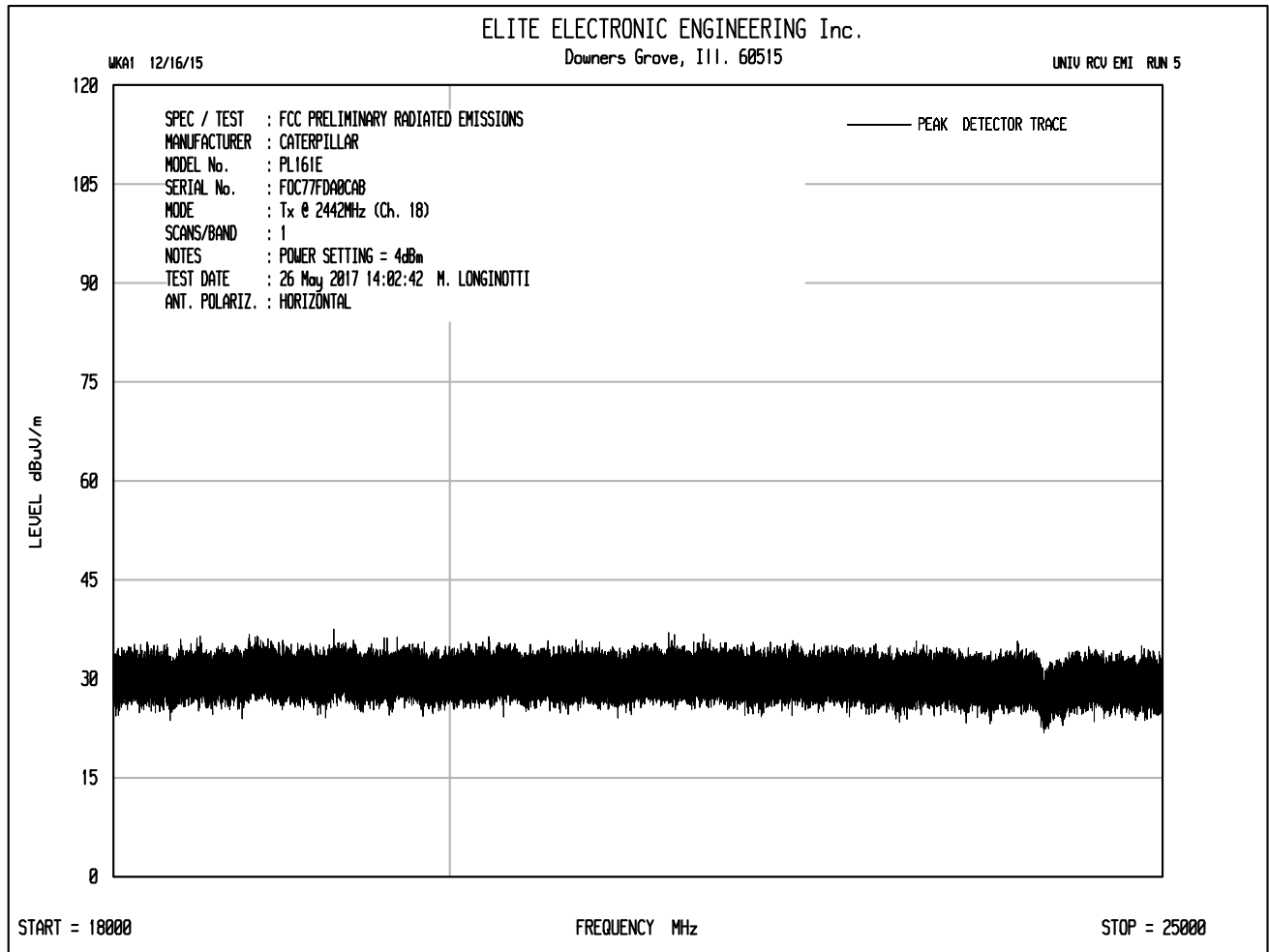


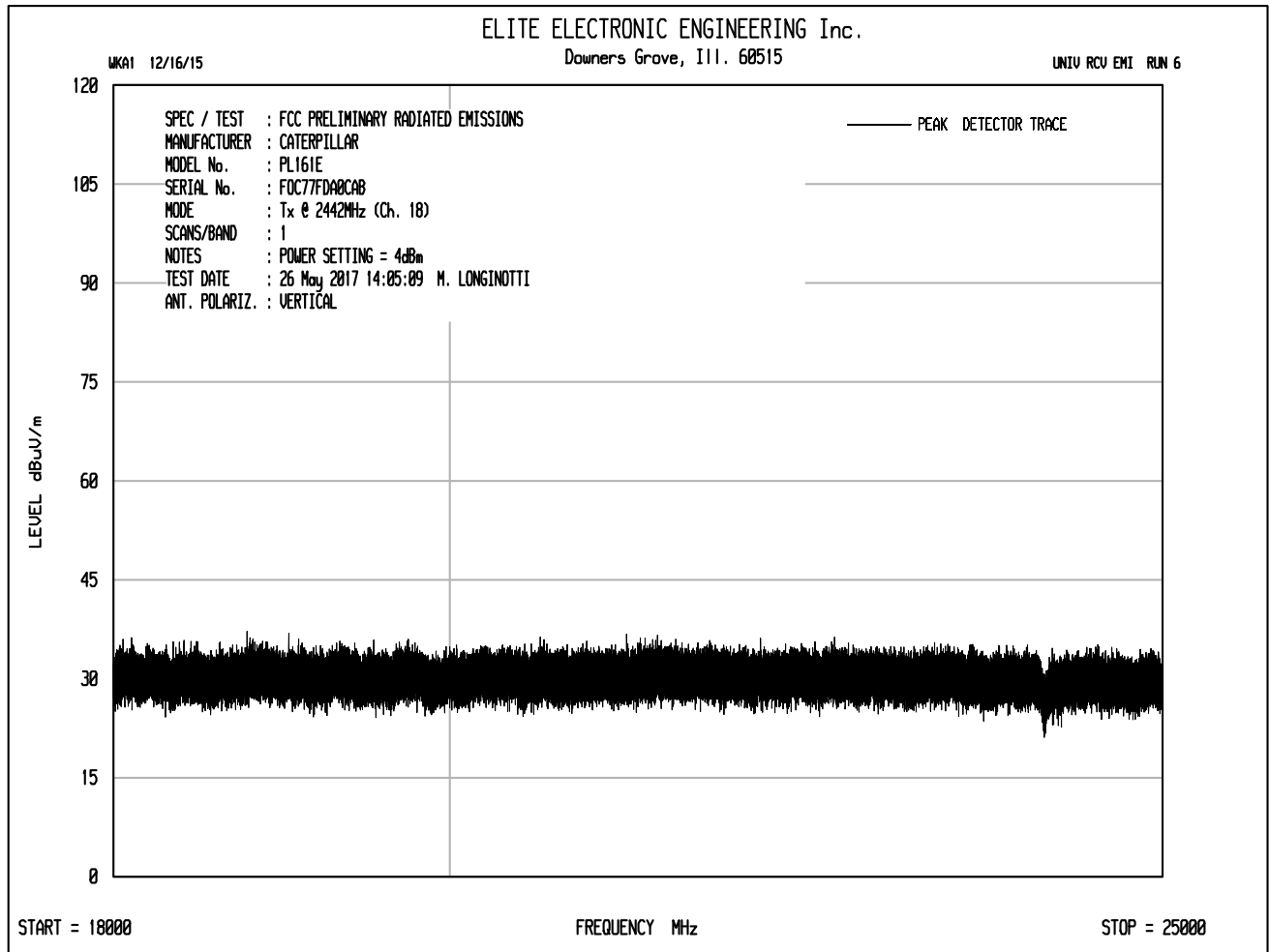


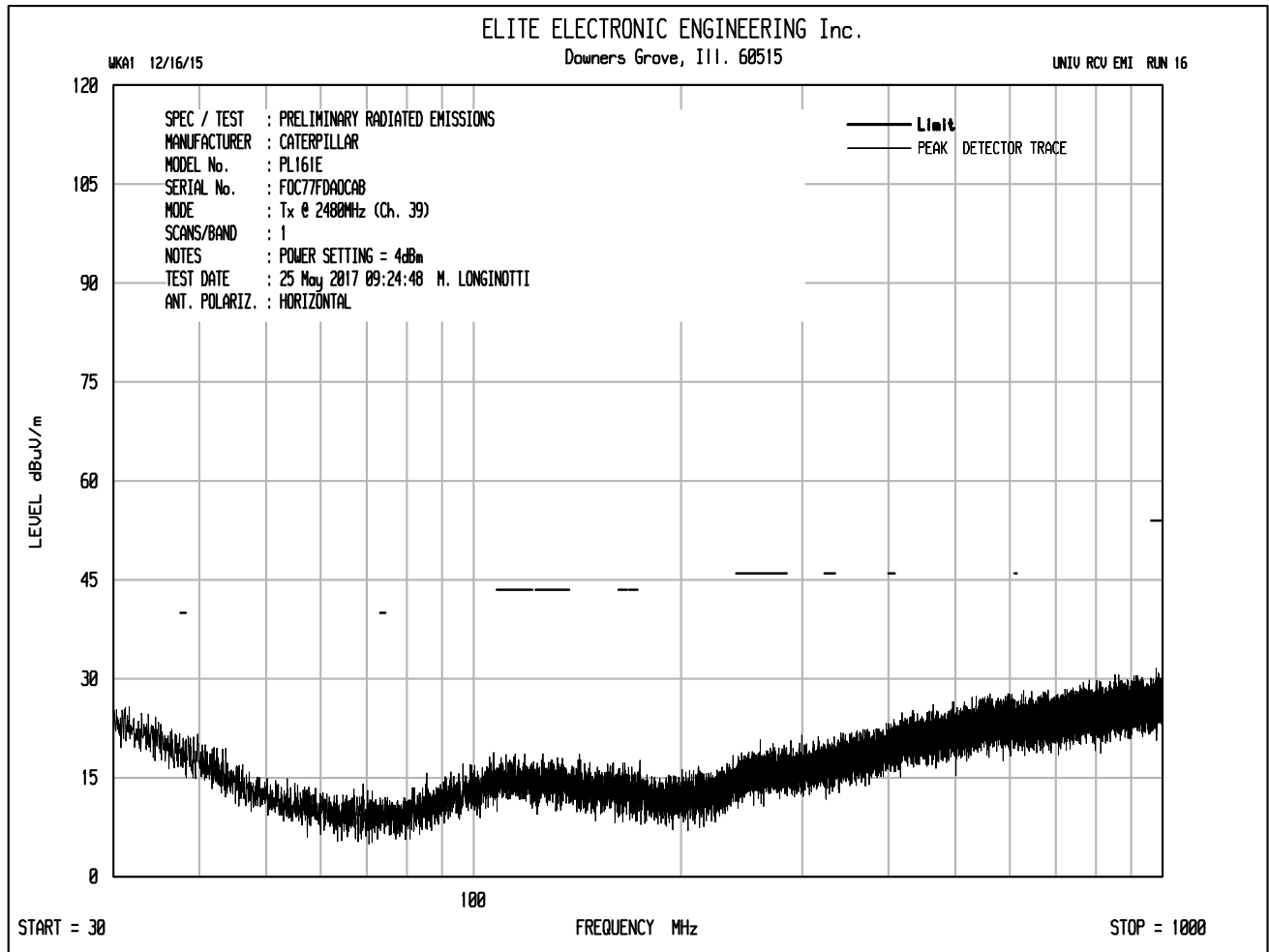


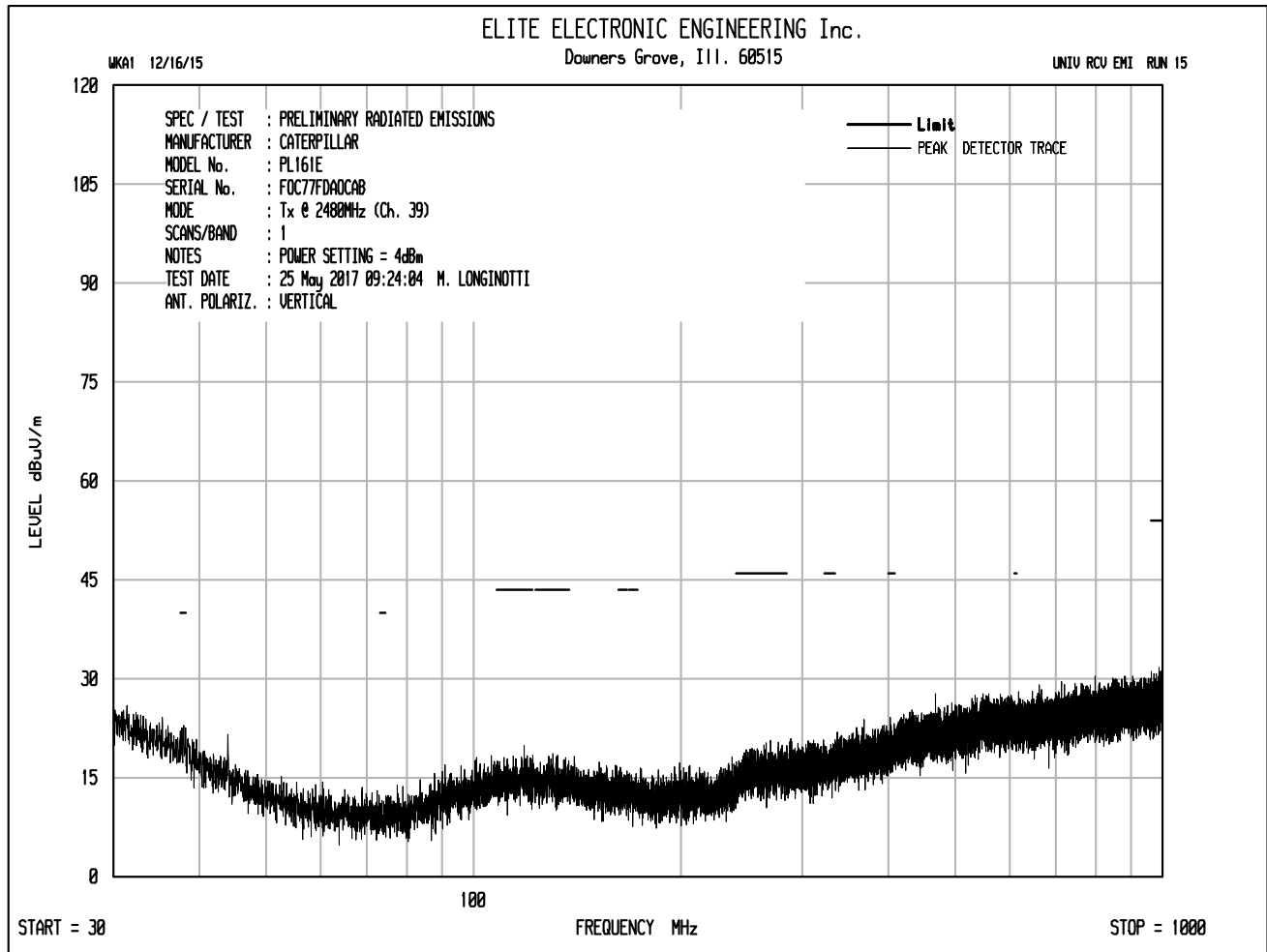


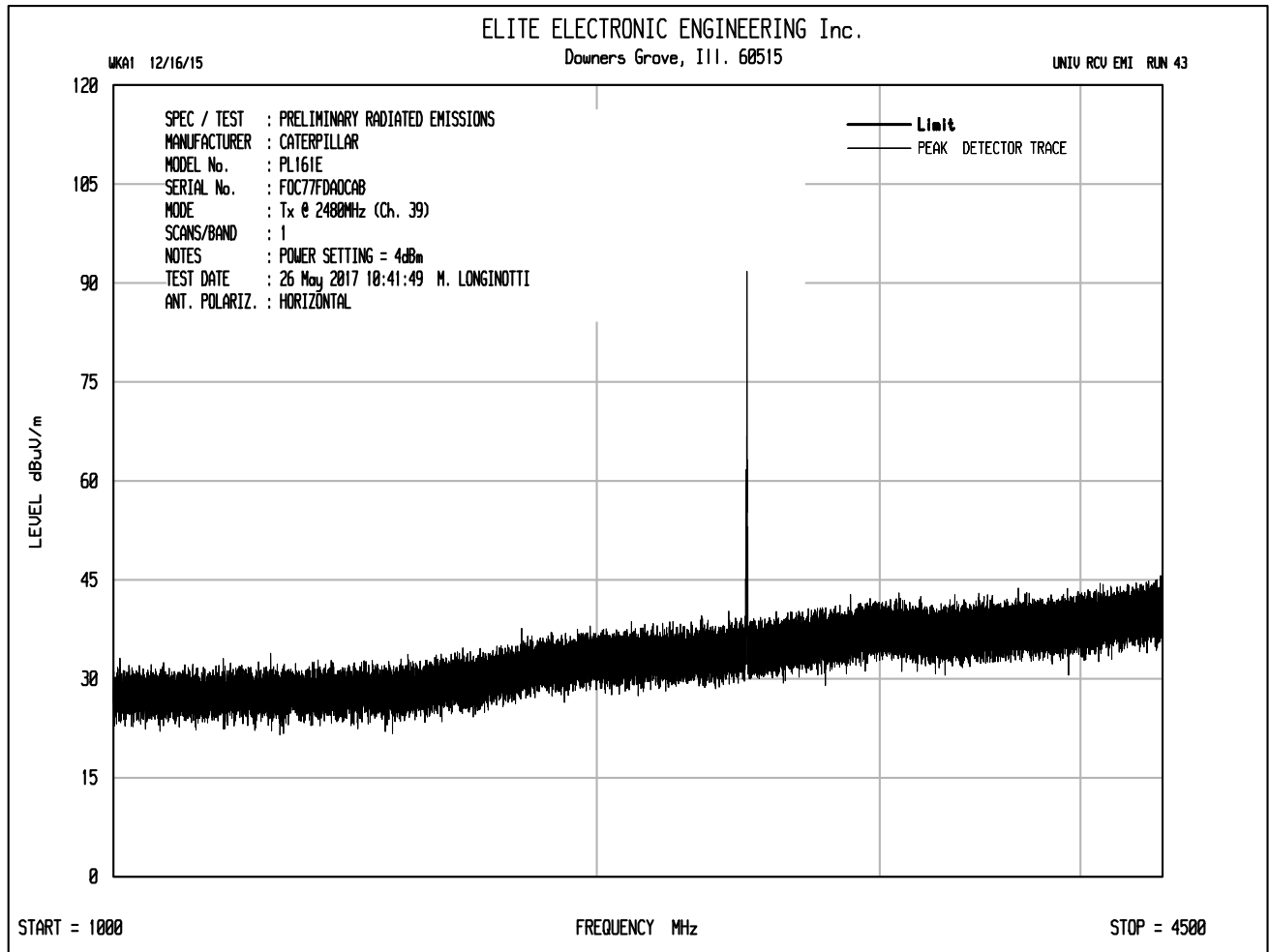


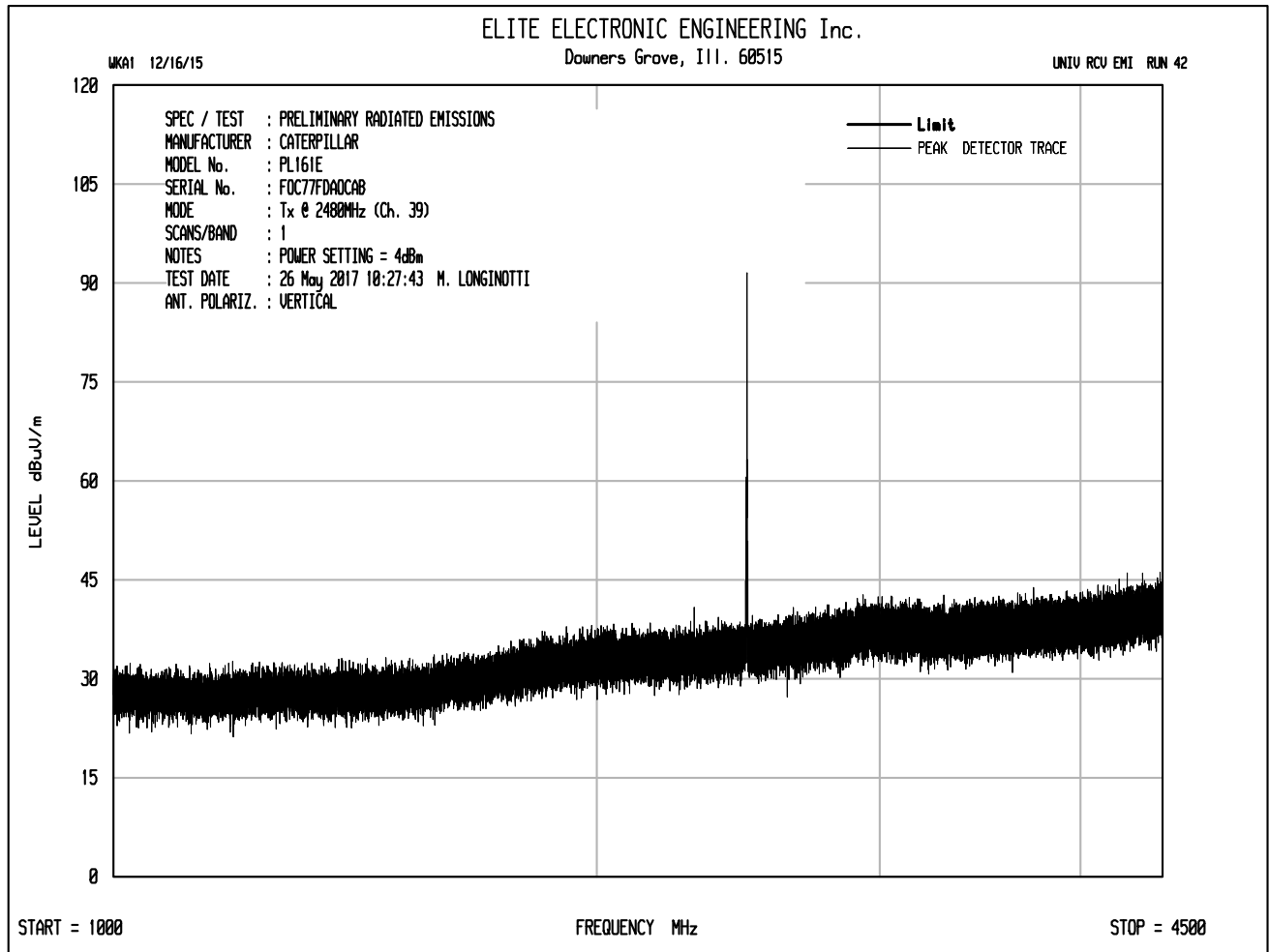


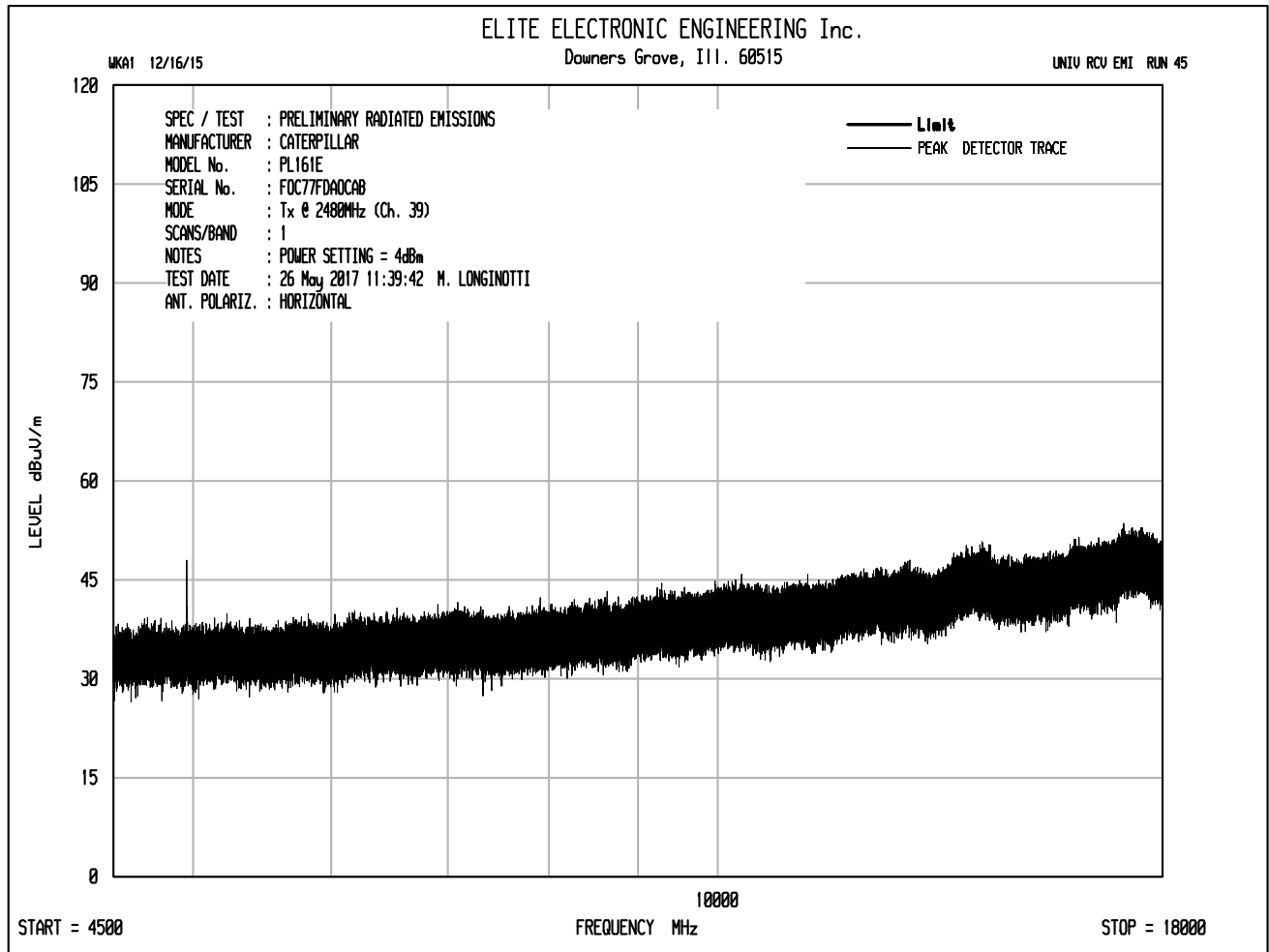


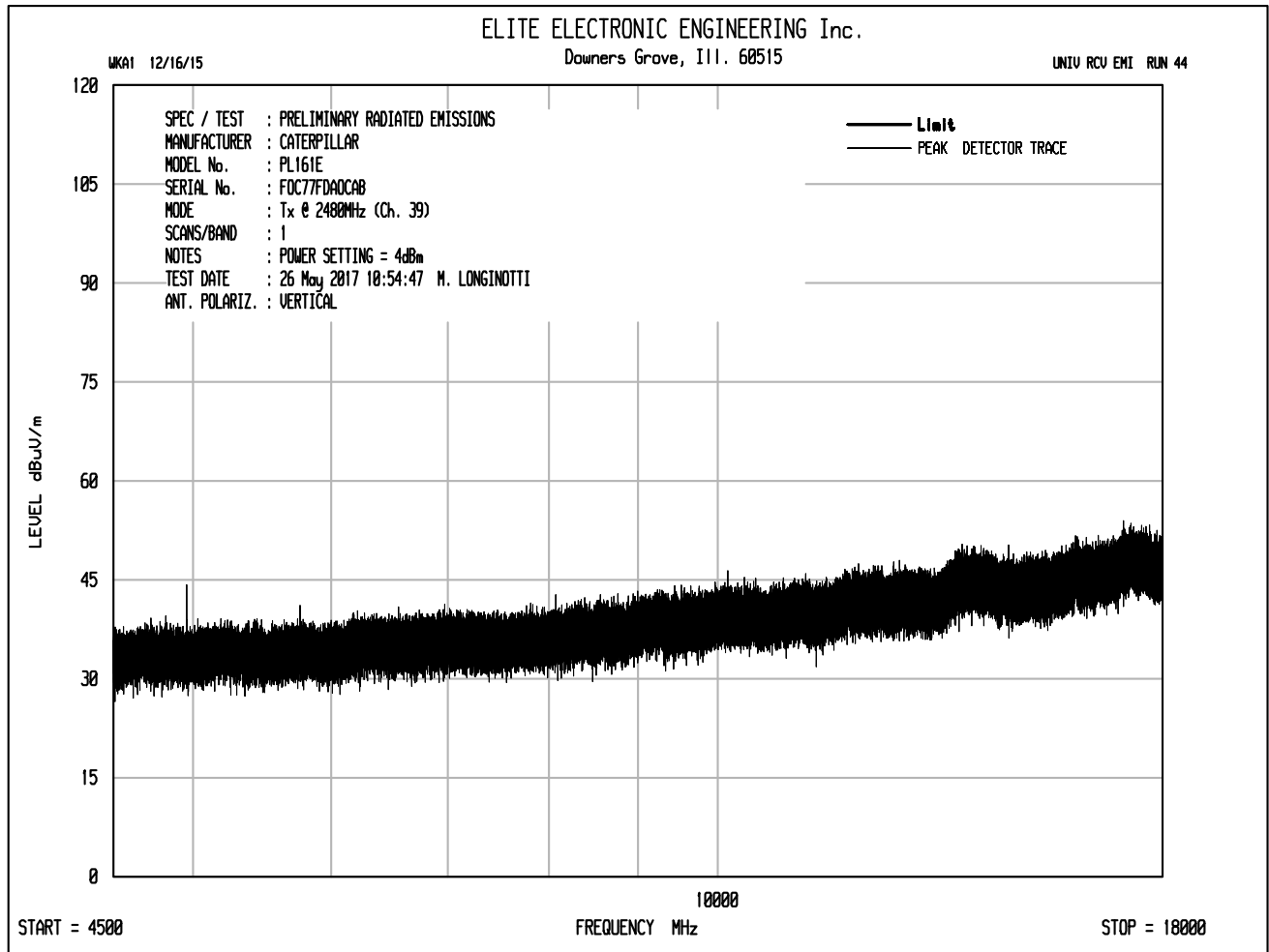


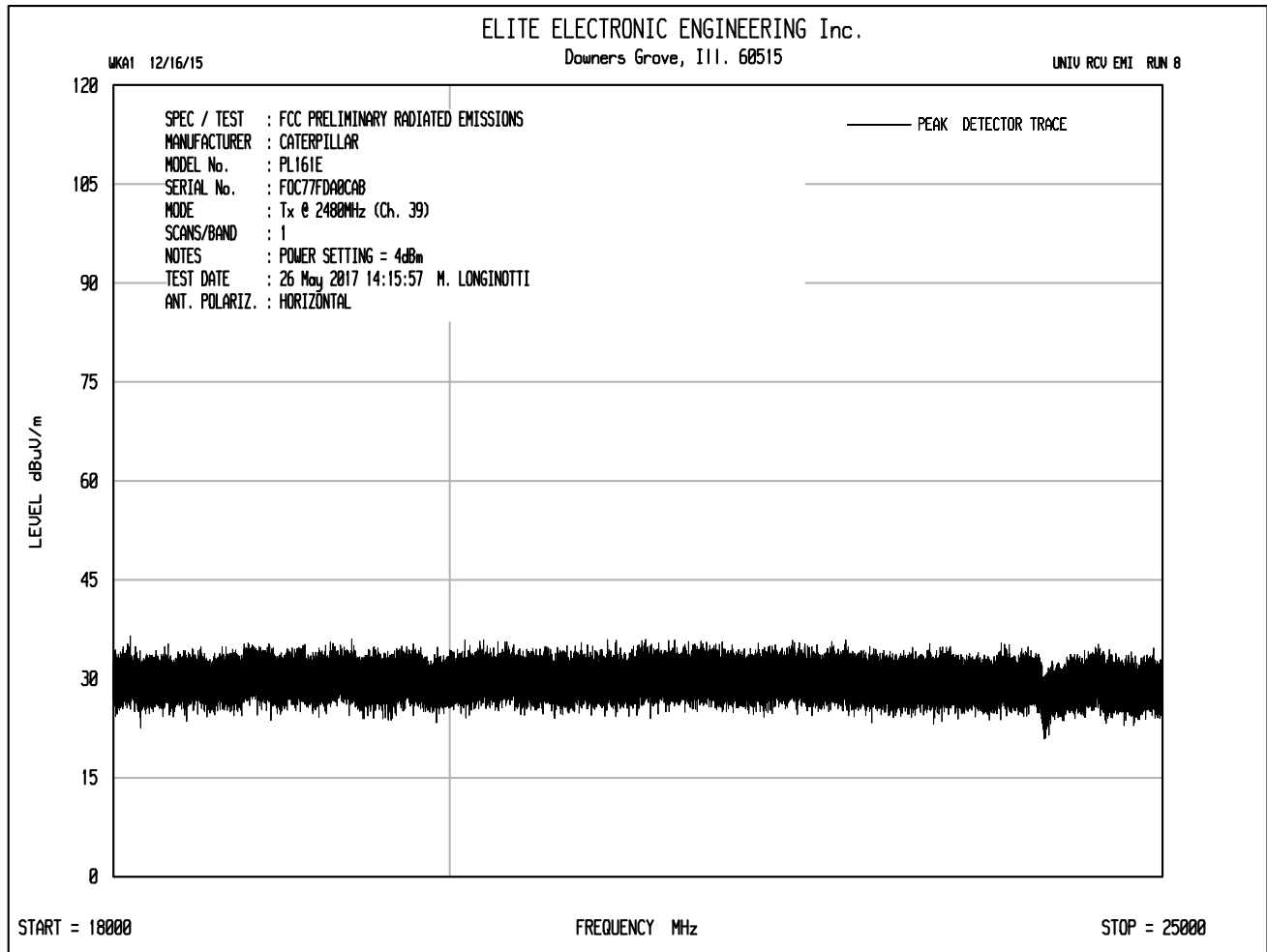


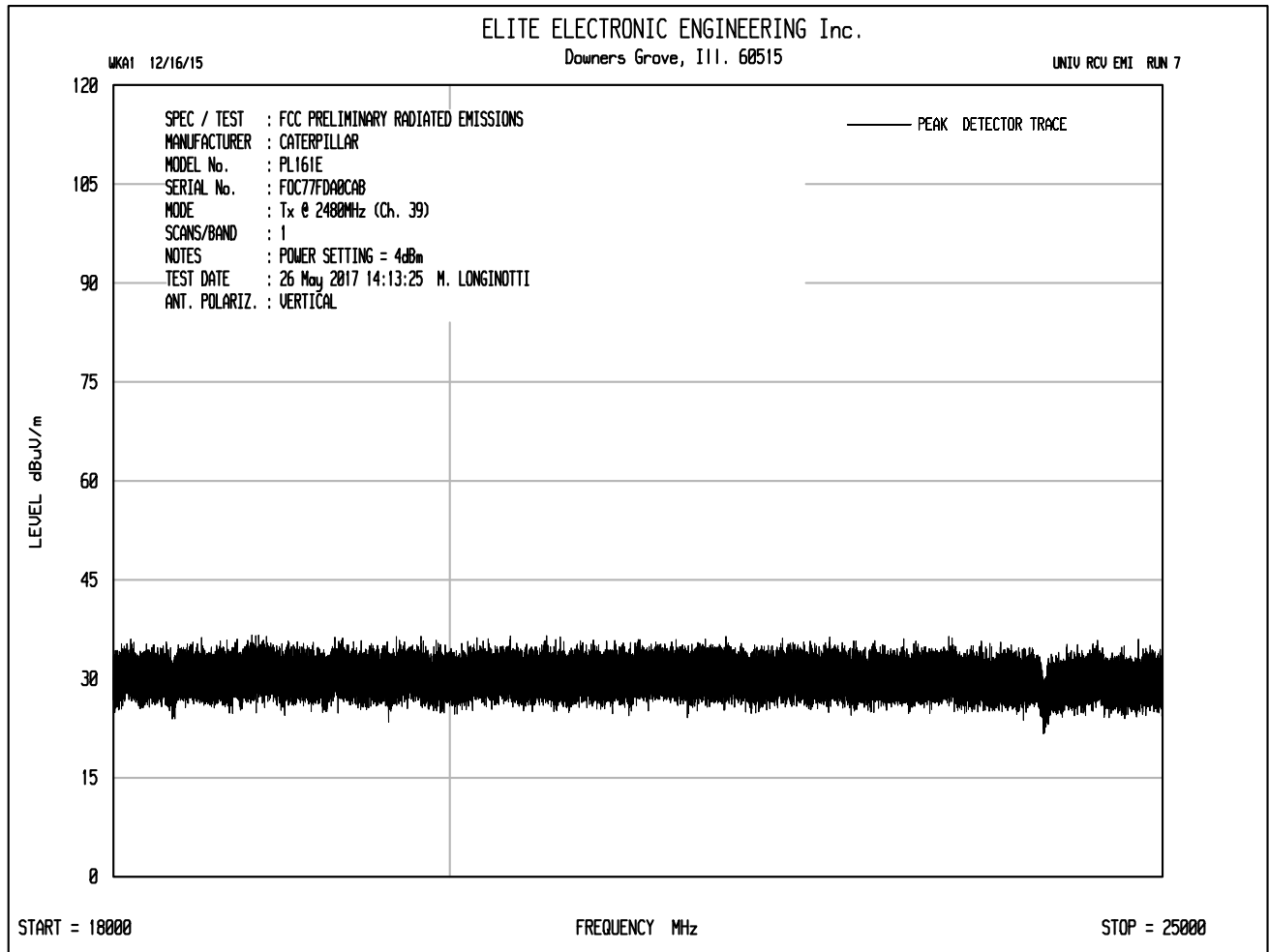














Manufacturer : Caterpillar, Inc.
 Test Item : Bluetooth Low Energy Transceiver
 Model No. : Smart Cap
 Serial No. : FOC77FDA0CAB
 Mode : Transmit at 2402MHz (Ch. 37), Power Setting = 4dBm
 Test Specification : FCC-15.247, RSS-247 Peak Radiated Emissions in Restricted Bands
 Date : May 25, 2017 through May 26, 2017
 Test Distance : 3 meters
 Notes : Peak Detector with 1MHz Resolution Bandwidth

Freq. MHz	Ant Pol	Meter Reading (dBuV)	Ambient	CBL Fac (dB)	Ant Fac (dB)	Pre Amp (dB)	Peak Total dBuV/m at 3m	Peak Total uV/m at 3 m	Peak Limit uV/m at 3 m	Margin (dB)
4804.00	H	52.0		5.7	36.8	-39.3	55.2	576.6	5000.0	-18.8
4804.00	V	51.2		5.7	36.8	-39.3	54.4	525.8	5000.0	-19.6
12010.00	H	49.0	Ambient	8.6	41.9	-39.2	60.3	1039.3	5000.0	-13.6
12010.00	V	49.9	Ambient	8.6	41.9	-39.2	61.2	1152.8	5000.0	-12.7
19216.00	H	33.4	Ambient	2.2	40.4	-28.6	47.4	235.4	5000.0	-26.5
19216.00	V	32.3	Ambient	2.2	40.4	-28.6	46.3	207.4	5000.0	-27.6
4806.00	H	51.0		5.7	36.8	-39.3	54.2	513.7	5000.0	-19.8
4806.00	V	51.0		5.7	36.8	-39.3	54.2	513.7	5000.0	-19.8

Total (dBuV/m) = Meter Reading + CBL FAC + Ant Fac + Pre Amp

Checked By:

MARK E. LONGINOTTI

Mark E. Longinotti



Manufacturer : Caterpillar, Inc.
Test Item : Bluetooth Low Energy Transceiver
Model No. : Smart Cap
Serial No. : FOC77FDA0CAB
Mode : Transmit at 2402MHz (Ch. 37), Power Setting = 4dBm
Test Specification : FCC-15.247, RSS-247 Peak Radiated Emissions in Restricted Bands
Date : May 25, 2017 through May 26, 2017
Test Distance : 3 meters
Notes : Average Detector with 1MHz Resolution Bandwidth

Freq. MHz	Ant Pol	Meter Reading (dBuV)	Ambient	CBL Fac (dB)	Ant Fac (dB)	Pre Amp (dB)	Average Total dBuV/m at 3m	Average Total uV/m at 3 m	Average Limit uV/m at 3 m	Margin (dB)
4804.00	H	41.2		5.7	36.8	-39.3	44.4	166.3	500.0	-9.6
4804.00	V	39.1		5.7	36.8	-39.3	42.3	130.6	500.0	-11.7
12010.00	H	34.0	Ambient	8.6	41.9	-39.2	45.3	184.8	500.0	-8.6
12010.00	V	34.0	Ambient	8.6	41.9	-39.2	45.3	184.8	500.0	-8.6
19216.00	H	19.2	Ambient	2.2	40.4	-28.6	33.2	45.9	500.0	-20.7
19216.00	V	19.4	Ambient	2.2	40.4	-28.6	33.4	47.0	500.0	-20.5
4806.00	H	36.8		5.7	36.8	-39.3	40.0	100.2	500.0	-14.0
4806.00	V	40.7		5.7	36.8	-39.3	43.9	156.9	500.0	-10.1

Total (dBuV/m) = Meter Reading + CBL FAC + Ant Fac + Pre Amp

Checked By:

MARK E. LONGINOTTI

Mark E. Longinotti



Manufacturer : Caterpillar, Inc.
 Test Item : Bluetooth Low Energy Transceiver
 Model No. : Smart Cap
 Serial No. : FOC77FDA0CAB
 Mode : Transmit at 2402MHz (Ch. 37), Power Setting = 4dBm
 Test Specification : FCC-15.247, RSS-247 Peak Radiated Emissions not in Restricted Bands
 Date : May 25, 2017 through May 26, 2017
 Test Distance : 3 meters
 Notes : Peak Detector with 100kHz Resolution Bandwidth

Freq. MHz	Ant Pol	Meter Reading (dBuV)	Ambient	CBL Fac (dB)	Ant Fac (dB)	Pre Amp (dB)	Peak Total dBuV/m at 3m	Peak Total uV/m at 3 m	Peak Limit uV/m at 3 m	Margin (dB)
2402.00	H	62.2		4.3	33.0	0.0	99.5	94597.3		
2402.00	V	63.0		4.3	33.0	0.0	100.3	103723.9		
7206.00	H	47.5		6.9	38.3	-39.4	53.3	460.2	10372.4	-27.1
7206.00	V	48.8		6.9	38.3	-39.4	54.6	534.5	10372.4	-25.8
9608.00	H	39.4	Ambient	8.2	39.4	-39.3	47.7	242.3	10372.4	-32.6
9608.00	V	40.0		8.2	39.4	-39.3	48.3	259.7	10372.4	-32.0
14412.00	H	37.8	Ambient	9.6	43.1	-38.3	52.2	407.0	10372.4	-28.1
14412.00	V	37.3	Ambient	9.6	43.1	-38.3	51.7	384.2	10372.4	-28.6
16814.00	H	37.9	Ambient	10.9	43.8	-37.5	55.2	573.0	10372.4	-25.2
16814.00	V	38.1	Ambient	10.9	43.8	-37.5	55.4	586.4	10372.4	-25.0
21618.00	H	22.3	Ambient	2.2	40.6	-28.7	36.4	66.4	10372.4	-43.9
21618.00	V	23.1	Ambient	2.2	40.6	-28.7	37.2	72.8	10372.4	-43.1
24020.00	H	22.9	Ambient	2.2	40.6	-30.0	35.8	61.5	10372.4	-44.5
24020.00	V	24.1	Ambient	2.2	40.6	-30.0	37.0	70.6	10372.4	-43.3

Total (dBuV/m) = Meter Reading + CBL FAC + Ant Fac + Pre Amp

Checked By:

MARK E. LONGINOTTI

Mark E. Longinotti



Manufacturer : Caterpillar, Inc.
 Test Item : Bluetooth Low Energy Transceiver
 Model No. : Smart Cap
 Serial No. : FOC77FDA0CAB
 Mode : Transmit at 2442MHz (Ch. 18), Power Setting = 4dBm
 Test Specification : FCC-15.247, RSS-247 Peak Radiated Emissions in Restricted Bands
 Date : May 25, 2017 through May 26, 2017
 Test Distance : 3 meters
 Notes : Peak Detector with 1MHz Resolution Bandwidth

Freq. MHz	Ant Pol	Meter Reading (dBuV)	Ambient	CBL Fac (dB)	Ant Fac (dB)	Pre Amp (dB)	Peak Total dBuV/m at 3m	Peak Total uV/m at 3 m	Peak Limit uV/m at 3 m	Margin (dB)
4884.00	H	51.2		5.7	36.7	-39.3	54.3	517.5	5000.0	-19.7
4884.00	V	50.6		5.7	36.7	-39.3	53.7	482.9	5000.0	-20.3
7326.00	H	49.9		6.9	38.2	-39.4	55.6	601.3	5000.0	-18.4
7326.00	V	53.0		6.9	38.2	-39.4	58.7	859.3	5000.0	-15.3
12210.00	H	48.4	Ambient	8.9	41.7	-39.1	59.9	993.6	5000.0	-14.0
12210.00	V	49.1	Ambient	8.9	41.7	-39.1	60.6	1077.0	5000.0	-13.3
19536.00	H	32.8	Ambient	2.2	40.4	-28.5	47.0	222.9	5000.0	-27.0
19536.00	V	32.9	Ambient	2.2	40.4	-28.5	47.1	225.5	5000.0	-26.9
4882.00	H	45.1		5.7	36.7	-39.3	48.2	256.5	5000.0	-25.8
4882.00	V	51.2		5.7	36.7	-39.3	54.3	517.7	5000.0	-19.7

Total (dBuV/m) = Meter Reading + CBL FAC + Ant Fac + Pre Amp

Checked By:

MARK E. LONGINOTTI

Mark E. Longinotti



Manufacturer : Caterpillar, Inc.
 Test Item : Bluetooth Low Energy Transceiver
 Model No. : Smart Cap
 Serial No. : FOC77FDA0CAB
 Mode : Transmit at 2442MHz (Ch. 18), Power Setting = 4dBm
 Test Specification : FCC-15.247, RSS-247 Peak Radiated Emissions in Restricted Bands
 Date : May 25, 2017 through May 26, 2017
 Test Distance : 3 meters
 Notes : Average Detector with 1MHz Resolution Bandwidth

Freq. MHz	Ant Pol	Meter Reading (dBuV)	Ambient	CBL Fac (dB)	Ant Fac (dB)	Pre Amp (dB)	Average Total dBuV/m at 3m	Average Total uV/m at 3 m	Average Limit uV/m at 3 m	Margin (dB)
4884.00	H	40.0		5.7	36.7	-39.3	43.1	142.5	500.0	-10.9
4884.00	V	38.6		5.7	36.7	-39.3	41.7	121.3	500.0	-12.3
7326.00	H	42.80		6.9	38.2	-39.4	48.5	265.5	500.0	-5.5
7326.00	V	43.4		6.9	38.2	-39.4	49.1	284.5	500.0	-4.9
12210.00	H	33.5	Ambient	8.9	41.7	-39.1	45.0	178.7	500.0	-8.9
12210.00	V	32.3	Ambient	8.9	41.7	-39.1	43.8	155.7	500.0	-10.1
19536.00	H	19.2	Ambient	2.2	40.4	-28.5	33.4	46.6	500.0	-20.6
19536.00	V	19.4	Ambient	2.2	40.4	-28.5	33.6	47.7	500.0	-20.4
4882.00	H	41.3		5.7	36.7	-39.3	44.4	165.6	500.0	-9.6
4882.00	V	40.8		5.7	36.7	-39.3	43.9	156.3	500.0	-10.1

Total (dBuV/m) = Meter Reading + CBL FAC + Ant Fac + Pre Amp

Checked By:

MARK E. LONGINOTTI

Mark E. Longinotti



Manufacturer : Caterpillar, Inc.
 Test Item : Bluetooth Low Energy Transceiver
 Model No. : Smart Cap
 Serial No. : FOC77FDA0CAB
 Mode : Transmit at 2442MHz (Ch. 18), Power Setting = 4dBm
 Test Specification : FCC-15.247, RSS-247 Peak Radiated Emissions not in Restricted Bands
 Date : May 25, 2017 through May 26, 2017
 Test Distance : 3 meters
 Notes : Peak Detector with 100kHz Resolution Bandwidth

Freq. MHz	Ant Pol	Meter Reading (dBuV)	Ambient	CBL Fac (dB)	Ant Fac (dB)	Pre Amp (dB)	Peak Total dBuV/m at 3m	Peak Total uV/m at 3 m	Peak Limit uV/m at 3 m	Margin (dB)
2442.00	H	62.6		4.3	33.1	0.0	100.0	100295.9		
2442.00	V	62.4		4.3	33.1	0.0	99.8	98012.9		
9768.00	H	38.6	Ambient	8.2	39.5	-39.3	47.1	225.9	10029.6	-32.9
9768.00	V	41.8		8.2	39.5	-39.3	50.3	326.5	10029.6	-29.7
14652.00	H	38.3	Ambient	9.7	42.6	-38.2	52.4	418.5	10029.6	-27.6
14652.00	V	37.7	Ambient	9.7	42.6	-38.2	51.8	390.6	10029.6	-28.2
17094.00	H	37.6	Ambient	11.0	44.7	-37.6	55.7	611.8	10029.6	-24.3
17094.00	V	37.6	Ambient	11.0	44.7	-37.6	55.7	611.8	10029.6	-24.3
21978.00	H	22.3	Ambient	2.2	40.6	-29.2	35.9	62.4	10029.6	-44.1
21978.00	V	22.9	Ambient	2.2	40.6	-29.2	36.5	66.8	10029.6	-43.5
24420.00	H	23.9	Ambient	2.2	40.6	-30.2	36.5	67.2	10029.6	-43.5
24420.00	V	24.1	Ambient	2.2	40.6	-30.2	36.7	68.8	10029.6	-43.3

Total (dBuV/m) = Meter Reading + CBL FAC + Ant Fac + Pre Amp

Checked By:

MARK E. LONGINOTTI

Mark E. Longinotti



Manufacturer : Caterpillar, Inc.
 Test Item : Bluetooth Low Energy Transceiver
 Model No. : Smart Cap
 Serial No. : FOC77FDA0CAB
 Mode : Transmit at 2480MHz (Ch. 39), Power Setting = 4dBm
 Test Specification : FCC-15.247, RSS-247 Peak Radiated Emissions in Restricted Bands
 Date : May 25, 2017 through May 26, 2017
 Test Distance : 3 meters
 Notes : Peak Detector with 1MHz Resolution Bandwidth

Freq. MHz	Ant Pol	Meter Reading (dBuV)	Ambient	CBL Fac (dB)	Ant Fac (dB)	Pre Amp (dB)	Peak Total dBuV/m at 3m	Peak Total uV/m at 3 m	Peak Limit uV/m at 3 m	Margin (dB)
4960.00	H	50.0		5.8	36.5	-39.3	52.9	444.0	5000.0	-21.0
4960.00	V	50.6		5.8	36.5	-39.3	53.5	475.8	5000.0	-20.4
7440.00	H	48.7	Ambient	6.9	38.1	-39.4	54.3	517.3	5000.0	-19.7
7440.00	V	49.3	Ambient	6.9	38.1	-39.4	54.9	554.2	5000.0	-19.1
12400.00	H	48.7	Ambient	9.4	41.5	-39.0	60.6	1072.8	5000.0	-13.4
12400.00	V	48.4	Ambient	9.4	41.5	-39.0	60.3	1036.4	5000.0	-13.7
19840.00	H	32.6	Ambient	2.2	40.4	-28.2	47.1	225.8	5000.0	-26.9
19840.00	V	32.7	Ambient	2.2	40.4	-28.2	47.2	228.4	5000.0	-26.8
22320.00	H	34.8	Ambient	2.2	40.6	-29.1	48.5	267.6	5000.0	-25.4
22320.00	V	33.6	Ambient	2.2	40.6	-29.1	47.3	233.0	5000.0	-26.6
4958.00	H	52.0		5.8	36.5	-39.3	55.0	559.2	5000.0	-19.0
4958.00	V	49.9		5.8	36.5	-39.3	52.9	439.1	5000.0	-21.1

Total (dBuV/m) = Meter Reading + CBL FAC + Ant Fac + Pre Amp

Checked By:

MARK E. LONGINOTTI

Mark E. Longinotti



Manufacturer : Caterpillar, Inc.
Test Item : Bluetooth Low Energy Transceiver
Model No. : Smart Cap
Serial No. : FOC77FDA0CAB
Mode : Transmit at 2480MHz (Ch. 39), Power Setting = 4dBm
Test Specification : FCC-15.247, RSS-247 Peak Radiated Emissions in Restricted Bands
Date : May 25, 2017 through May 26, 2017
Test Distance : 3 meters
Notes : Average Detector with 1MHz Resolution Bandwidth

Freq. MHz	Ant Pol	Meter Reading (dBuV)	Ambient	CBL Fac (dB)	Ant Fac (dB)	Pre Amp (dB)	Average Total dBuV/m at 3m	Average Total uV/m at 3 m	Average Limit uV/m at 3 m	Margin (dB)
4960.00	H	35.1		5.8	36.5	-39.3	38.0	79.9	500.0	-15.9
4960.00	V	36.3		5.8	36.5	-39.3	39.2	91.7	500.0	-14.7
7440.00	H	33.40	Ambient	6.9	38.1	-39.4	39.0	88.9	500.0	-15.0
7440.00	V	33.6	Ambient	6.9	38.1	-39.4	39.2	90.9	500.0	-14.8
12400.00	H	33.3	Ambient	9.4	41.5	-39.0	45.2	182.2	500.0	-8.8
12400.00	V	33.0	Ambient	9.4	41.5	-39.0	44.9	176.0	500.0	-9.1
19840.00	H	19.2	Ambient	2.2	40.4	-28.2	33.7	48.3	500.0	-20.3
19840.00	V	19.2	Ambient	2.2	40.4	-28.2	33.7	48.3	500.0	-20.3
22320.00	H	20.3	Ambient	2.2	40.6	-29.1	34.0	50.4	500.0	-19.9
22320.00	V	20.5	Ambient	2.2	40.6	-29.1	34.2	51.6	500.0	-19.7
4958.00	H	44.0		5.8	36.5	-39.3	47.0	222.6	500.0	-7.0
4958.00	V	40.2		5.8	36.5	-39.3	43.2	143.7	500.0	-10.8

Total (dBuV/m) = Meter Reading + CBL FAC + Ant Fac + Pre Amp

Checked By:

MARK E. LONGINOTTI

Mark E. Longinotti



Manufacturer : Caterpillar, Inc.
 Test Item : Bluetooth Low Energy Transceiver
 Model No. : Smart Cap
 Serial No. : FOC77FDA0CAB
 Mode : Transmit at 2480MHz (Ch. 39), Power Setting = 4dBm
 Test Specification : FCC-15.247, RSS-247 Peak Radiated Emissions not in Restricted Bands
 Date : May 25, 2017 through May 26, 2017
 Test Distance : 3 meters
 Notes : Peak Detector with 100kHz Resolution Bandwidth

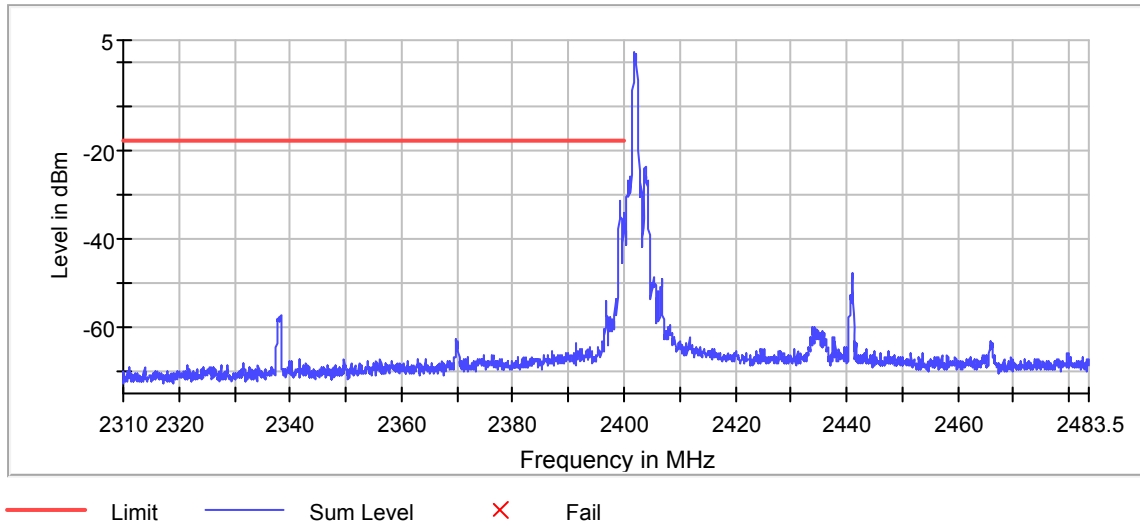
Freq. MHz	Ant Pol	Meter Reading (dBuV)	Ambient	CBL Fac (dB)	Ant Fac (dB)	Pre Amp (dB)	Peak Total dBuV/m at 3m	Peak Total uV/m at 3 m	Peak Limit uV/m at 3 m	Margin (dB)
2480.00	H	57.6		4.3	33.2	0.0	95.1	57060.6		
2480.00	V	56.9		4.3	33.2	0.0	94.4	52642.4		
9920.00	H	38.6	Ambient	8.3	39.8	-39.2	47.4	235.2	5706.1	-27.7
9920.00	V	38.7	Ambient	8.3	39.8	-39.2	47.5	237.9	5706.1	-27.6
14880.00	H	38.2	Ambient	9.8	42.2	-38.2	52.1	403.0	5706.1	-23.0
14880.00	V	38.2	Ambient	9.8	42.2	-38.2	52.1	403.0	5706.1	-23.0
17360.00	H	38.4	Ambient	11.0	44.8	-37.7	56.4	660.9	5706.1	-18.7
17360.00	V	38.2	Ambient	11.0	44.8	-37.7	56.2	645.8	5706.1	-18.9
24800.00	H	23.2	Ambient	2.2	40.6	-30.9	35.1	56.9	5706.1	-40.0
24800.00	V	23.1	Ambient	2.2	40.6	-30.9	35.0	56.3	5706.1	-40.1

Total (dBuV/m) = Meter Reading + CBL FAC + Ant Fac + Pre Amp

Checked By:

MARK E. LONGINOTTI

Mark E. Longinotti



FCC 15.247 Low Frequency Band Edge Compliance

MANUFACTURER : Caterpillar
 MODEL NUMBER : Smart Cap
 SERIAL NUMBER : FOC77FDA68F4
 TEST MODE : Transmit at 2402MHz (Ch. 37), Power Setting = 4dBm
 NOTES : The trace represents the highest power measured inside the band with a 100kHz
 : bandwidth. The red lines represents the 20dB down level from the peak in a
 : 100kHz bandwidth and the low frequency band edge.
 TEST DATE : May 8, 2017
 EQUIPMENT USED : GSFA, GSFB, RBJ2



Manufacturer : Caterpillar, Inc.
Test Item : Bluetooth Low Energy Transceiver
Model No. : Smart Cap
Serial No. : FOC77FDA0CAB
Mode : Transmit at 2480MHz (Ch. 39), Power Setting = 4dBm
Test Specification : FCC-15.247, RSS-247 Peak Radiated Emissions at High Band Edge
Date : May 26, 2017
Test Distance : 3 meters
Notes : Peak Detector with 1MHz Resolution Bandwidth

Freq. MHz	Ant Pol	Meter Reading (dBuV)	Ambient	CBL Fac (dB)	Ant Fac (dB)	Pre Amp (dB)	Peak Total dBuV/m at 3m	Peak Total uV/m at 3 m	Peak Limit uV/m at 3 m	Margin (dB)
2483.50	H	14.4		4.3	33.2	0.0	51.9	395.2	5000.0	-22.0
2483.50	V	14.4		4.3	33.2	0.0	51.9	395.2	5000.0	-22.0

Checked By:

MARK E. LONGINOTTI

Mark E. Longinotti



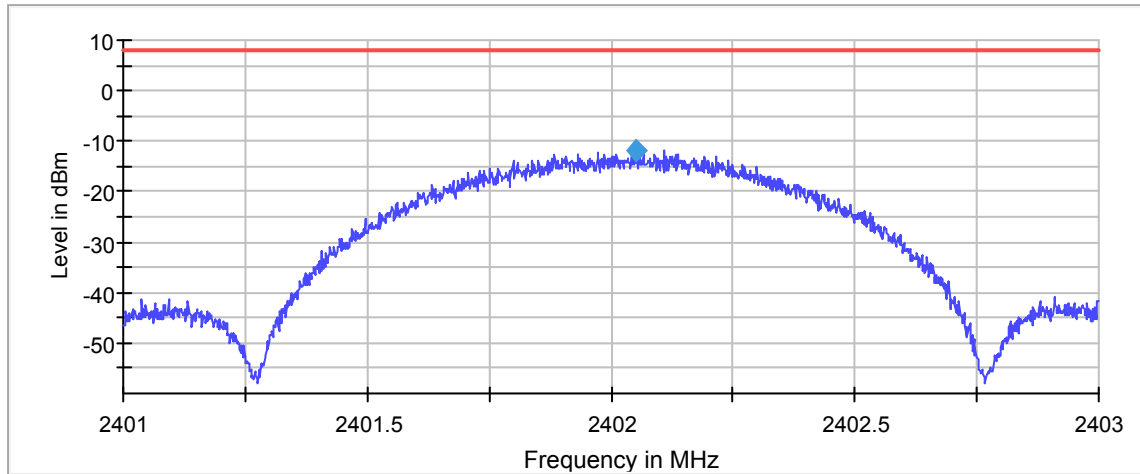
Manufacturer : Caterpillar, Inc.
Test Item : Bluetooth Low Energy Transceiver
Model No. : Smart Cap
Serial No. : FOC77FDA0CAB
Mode : Transmit at 2480MHz (Ch. 39), Power Setting = 4dBm
Test Specification : FCC-15.247, RSS-247 Average Radiated Emissions at High Band Edge
Date : May 26, 2017
Test Distance : 3 meters
Notes : Average Detector with 1MHz Resolution Bandwidth

Freq. MHz	Ant Pol	Meter Reading (dBUV)	Ambient	CBL Fac (dB)	Ant Fac (dB)	Pre Amp (dB)	Average Total dBUV/m at 3m	Average Total uV/m at 3 m	Average Limit uV/m at 3 m	Margin (dB)
2483.50	H	2.7		4.3	33.2	0.0	40.2	102.8	500.0	-13.7
2483.50	V	2.5		4.3	33.2	0.0	40.0	100.4	500.0	-13.9

Checked By:

MARK E. LONGINOTTI

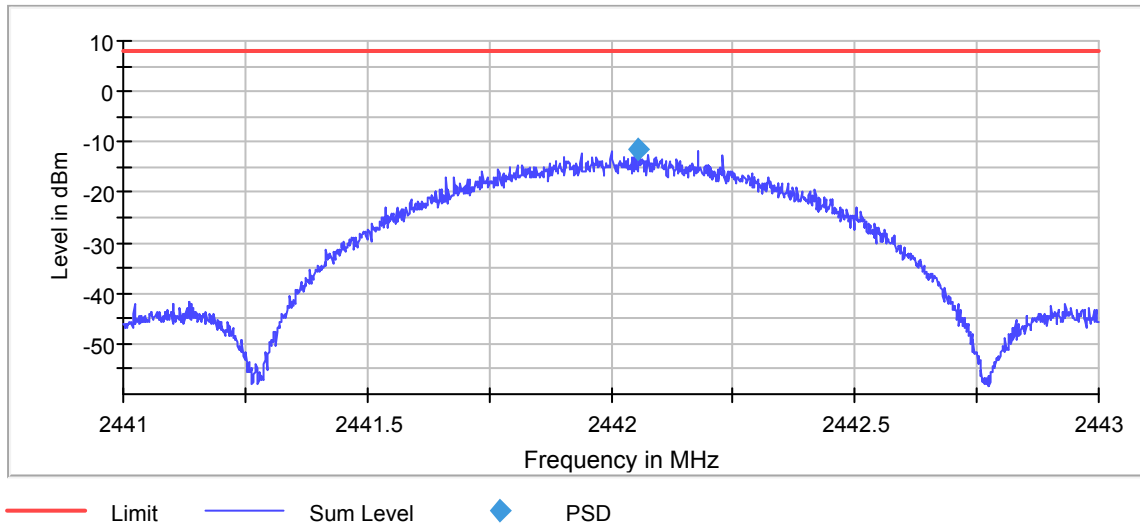
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— Limit — Sum Level ◆ PSD

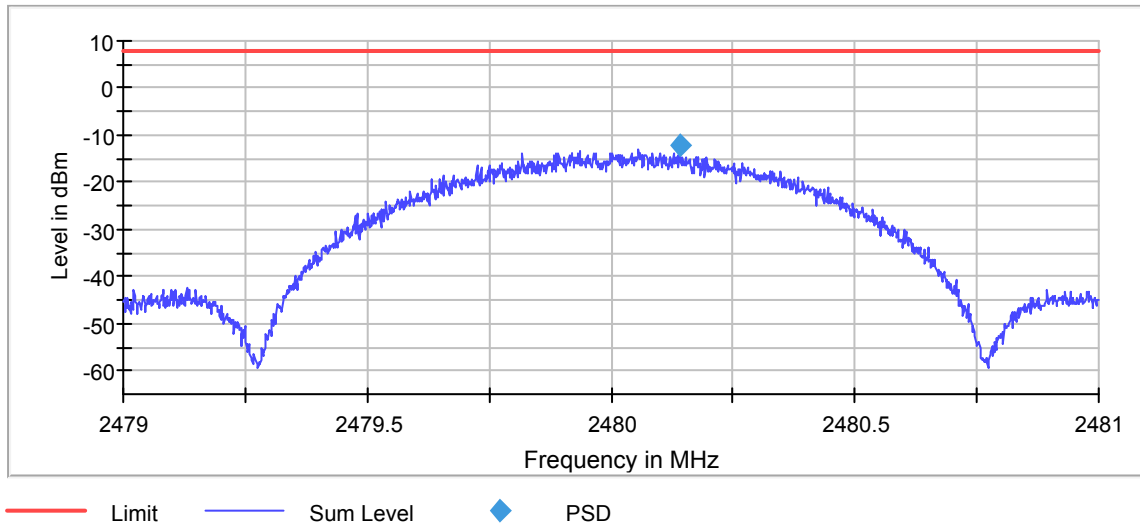
FCC 15.247 Power Spectral Density

MANUFACTURER : Caterpillar
MODEL NUMBER : Smart Cap
SERIAL NUMBER : FOC77FDA68F4
TEST MODE : Transmit at 2402MHz (Ch. 37), Power Setting = 4dBm
NOTES : Power Spectral Density = -11.94dBm in a 3kHz RBW
TEST DATE : May 8, 2017
EQUIPMENT USED : GSFA, GSFB, RBJ2



FCC 15.247 Power Spectral Density

MANUFACTURER : Caterpillar
MODEL NUMBER : Smart Cap
SERIAL NUMBER : FOC77FDA68F4
TEST MODE : Transmit at 2442MHz (Ch. 18), Power Setting = 4dBm
NOTES : Power Spectral Density = -11.55dBm in a 3kHz RBW
TEST DATE : May 8, 2017
EQUIPMENT USED : GSFA, GSFB, RBJ2



FCC 15.247 Power Spectral Density

MANUFACTURER : Caterpillar
MODEL NUMBER : Smart Cap
SERIAL NUMBER : FOC77FDA68F4
TEST MODE : Transmit at 2480MHz (Ch. 39), Power Setting = 4dBm
NOTES : Power Spectral Density = -12.07dBm in a 3kHz RBW
TEST DATE : May 8, 2017
EQUIPMENT USED : GSFA, GSFB, RBJ2